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Multifaceted Interplay between Mobile Edge Computing based on Industry 5.0 in Transportation

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Abstract: A new technology called mobile edge computing, or MEC, is now acknowledged as a crucial 5G network enabler. The demand for computation-intensive mobile network applications—which call for greater storage, potent machines, and real-time responses—has increased significantly in recent years. Because they must support many services, including traffic monitoring or data sharing involving various aspects of vehicular traffic, transportation systems play a crucial part in this ecosystem. Furthermore, new resource-hungry applications like in-car entertainment and self-driving cars have been imagined, making the need for processing and storage resources one of the biggest problems facing transportation networks. With the advent of multi-access edge computing (MEC) technological advances, real-time, high-bandwidth, minimal latency access to radio network resources is intended to be made possible by bringing cloud computing capabilities to the edge of the wireless access network. With MEC's capacity to offer cloud computing and gateways capabilities at the network edge, IoT is recognized as a major application case for the technology. Because of its extensive mobility support and dense geographical spread, MEC will stimulate the development of a wide range of apps and services that require ultralow latencies and high quality of service. For this reason, MEC is a crucial enabler of Internet of Things services and applications that need immediate operation. At last, the globally ideal answer has been achieved. The suggested strategy is superior, as shown by the simulation results.

Keywords: *Multi-access edge computing, IoT, Cloud computing, Transportation, Automobiles*

1. Introduction

The Industry Specification Group (ISG) of the European Telecommunications Standards Institute (ETSI) introduced mobile edge computing as a way to bring better processing and storage capacities as well as knowledge to the edge of the network [1]. The ETSI industry organization renamed it Multi-Access Edge Computing (MEC) in 2017, as the advantages of MEC technology extended beyond mobile to include fixed access and WiFi. However, the name change makes it easier for ETSI to keep the MEC moniker, which is now well-known among industry participants. MEC's fundamental idea is to bring cloud computing capabilities to the boundary of cellular networks. This will reduce network congestion and enhance user experience, resource optimization, and network efficiency as a whole.

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Through the use of Radio Access Networks (RANs), MEC will significantly reduce latency and increase capacity utilization, facilitating the use of network services by content providers and application developers alike. Network Function Virtualization (NFV), Information-Centric Networking (ICN), Software Defined Networking (SDN) and Networking Slicing are some of the technologies that are recognized as the foundations for MEC realization. The Internet has changed over the past forty years, moving from peer-to-peer connections to the World Wide Web, mobile Internet, and finally the Internet of Things. By linking a vast and diverse array of smart things to the Internet, the Internet of Things (IoT) has become a major paradigm shift. The Internet of Things (IoT) allows people and things to connect with anything and everyone at anytime, anywhere, and ideally via any path, network, and service that is accessible [1]. Fifth-generation (5G) wireless networks will be extremely powerful mobile networks with large bandwidth, and low operating costs. These features will improve the quality of service and overall user experience from the perspective of the user and applications.

In this paper, the text mining structure, as shown in Figure 1.1, is utilized to explore and analyze published papers on Industry 5.0 to find frequently used key terms and topics that may be utilized to classify Industry 5.0 research using the extracted text information.

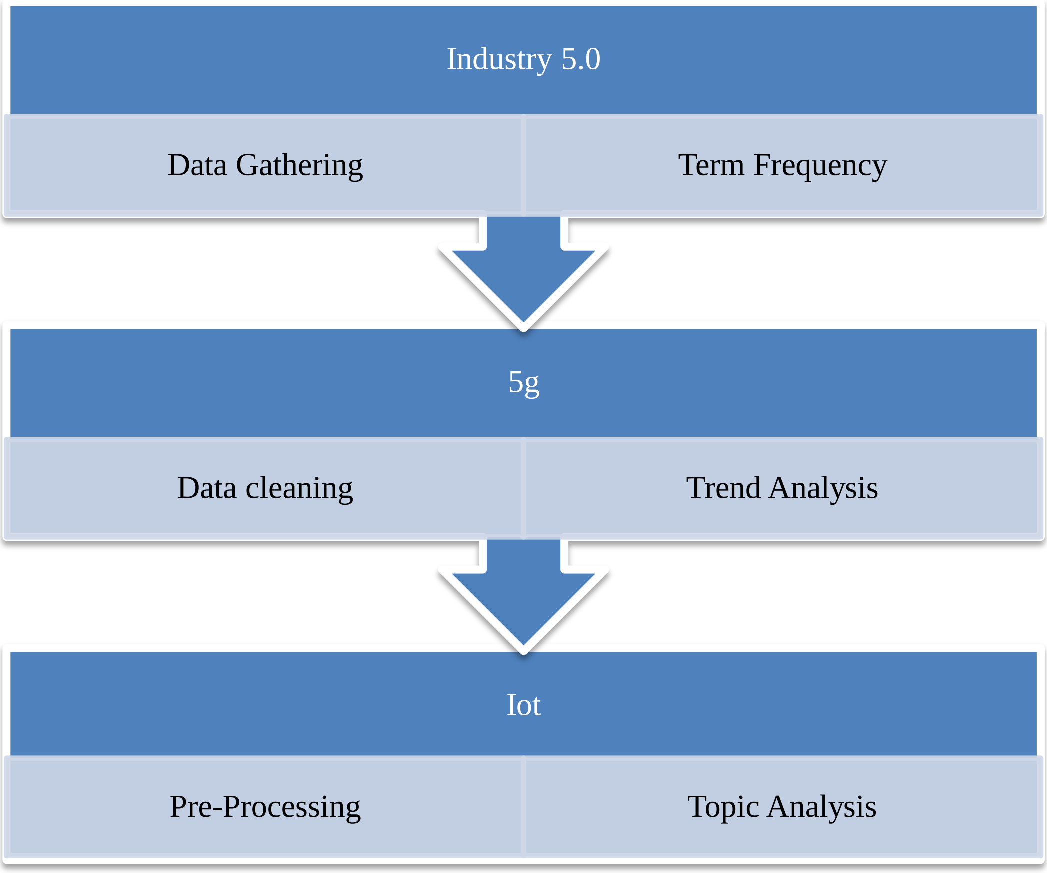

Fig. 1.1 An analytical framework for Industry 5.0 presentations

With the introduction of mobile internet access, there is a greater demand for dependable and best-in-class services and support for mobile customers. Numerous innovative applications for intelligent settings have emerged because to the abundance of cloud resources and services. However, communication-intensive apps that must meet latency requirements find it difficult to work with the current state of mobile cloud computing. The issue is exacerbated in smart cities or the Internet of Things. Low latency, location understanding, and mobility support are features that the current cloud computing architecture is unable to provide.

By bringing computation and storage nearer to end users through the use of both strategically placed and serendipitous storage and processing assets, mobile edge computing, or MEC, is starting to emerge as a very promising computation paradigm.

Such a system differs significantly from conventional cloud computing. MEC seeks to provide real-time application execution at the network edge for millions of linked mobile devices. MEC stands out for its proximity to end users, mobility assistance, and densely distributed MEC servers across several regions [2]. The goal of this special issue is to present state-of-the-art research and future developments on a range of mobile edge computing methods for cloud-based Internet of Things applications. It also aims to construct highly adaptive smart environments, meaning that behaviours can be automatically adjusted to the available resources. This special issue's primary subjects or areas of coverage are modelling, analysis, approaches, and recently released applications. This special issue covers novel commercial management systems, novel business uses of MEC the internet, and hands-on experience applying recent research advancements to practical issues in addition to the most recent research accomplishments.

As a result, the goal of this survey is to present a thorough overview of the cutting-edge technologies needed for the complimentary integration of MEC and IoT. Our responses to this poll fall into three primary categories:

- Offering a thorough analysis of how MEC technology is being used to realise various Internet of Things applications.
- Offering a comprehensive summary of relevant works as well as future research prospects in the MEC-IoT integration domains of scalability, connectivity, compute offloading, allocating resources, mobile management, safety, confidentiality, and trust administration.
- Giving a succinct overview of the most recent MEC integration techniques for IoT and associated applications.

This is how the remainder of the paper is structured: Section 2 provides an overview of the well-known Internet of Things applications that demand noteworthy MEC support, such as edge computing technologies. In terms of scalability, interaction, computational offloading, resource management, movement leadership, safety, confidentiality, and trust management, Section 3 focuses primarily on the technological aspects of MEC enabled IoT systems. The requirements and relevant works for each technical aspect are described. Section 4 separately details the related work on several MEC integration technologies and the proceeding research programmes in the corresponding fields. Section 5 describes the lessons learned and the next research directions.

2. Literature Review

Fraga-Lamas, P., et.al [3] significant amounts of energy are needed for digital infrastructures and data centers. By 2030, ICT might make up 20% of the overall electricity demand, compared to its current 5–9% share. Furthermore, materials related to the digital shift are a concern since only 20% of the world's yearly production of over 50 million tons of electronic and electrical garbage (e-waste) is properly recycled. By 2050, this volume of waste will increase to 120 million tonnes each year. Applying the concepts of the circular economy to the internet infrastructure is necessary to meet the challenge presented by the proliferation of digital technology. Although the industry's current focus is mostly on sustainable means of meeting needs in the years to come, there will be a problem with the supply of essential raw materials. Furthermore, it's important to investigate the potential the DCE offers for the digital transition.

Nauman, A., et.al [4] The suggested algorithm in this work uses a heuristic approach that takes into account the network topology, user tastes, and the current state of the devices to perform resource distribution and offloading. Taking into account the multi-user scenarios, the researchers thought about an efficient choice policy for optimal resource allocation and transferring to minimize energy consumption. Additionally, under buffer stability restrictions, the authors concentrated on minimizing the long-term weighted energy usage. In order to create an energy efficient MEC network, they suggested an optimization framework that takes into account each device's buffer's stability in order to prevent overflowing and an underflow.

Fraga-Lamas, P., et.al [5] By warning industrial workers and their medical practitioners about significant health concerns, industrial 5.0 technologies should be tailored to the different needs of the workforce. Industry 5.0 has to bring people and machines together to increase resource and operational efficiency by integrating processes with automated systems in a sustainable way in order to realize this ambition. While Industry 4.0 is primarily focused on connection and intelligent decision-making, Industry 5.0 aims to achieve a peaceful cohabitation of long-term viability resiliency, and human-centricity via semi-autonomous production that keeps humans involved. The robots of the future, known as cooperative robots, will be friends rather than just controlled instruments capable of carrying out monotonous jobs.

Aljubayrin, S., et.al [6] The theoretical basis for a WPH-MEC system in Industry 5.0 IoT networks is presented in this section. Our goal is to maximize computational performance while minimizing IoT device energy consumption by optimizing resource allocation while taking systems and communication constraints into account. Our method ensures optimal performance within Industry 5.0 by striking a balance between energy conservation and computing efficiency. Our goal in developing this framework and including restrictions is to offer an effective response to the unique demands and difficulties faced by WPHMEC systems in Industry 5.0 scenarios.

Taj, I., et.al [7] Human-centered smart societies, which seek to raise everyone's standard of living, will unavoidably be a part of Industry 5.0. The goal is to create a society where every member of the public, including those with incurable illnesses and impairments, is actively involved and realizes their full potential. Japan Society 5.0 is an ambitious policy programmed that aims to reshape society via the use of technological tools that build the links and infrastructure between systems and innovations. A vast amount of data is gathered from real-world sensors in Society 5.0. Large amounts of data are transmitted to the internet, where advanced machine learning algorithms are used to analyse them. The outcomes are returned in a variety of ways to people in the actual world. The foundation for envisioning the community of 5.0 has been laid.

Liu, J., et.al [8] The theory of business clusters has been extensively researched, developed, and applied in real-world situations. E-commerce is a relatively new industry that emerged late but is growing quickly. Consequently, there is less use of agglomeration theory in the e-commerce industry. Several businesses, most notably the online retail sector, are displaying agglomeration as a result of the recent rapid growth of global e-commerce. To foster mutual development, several cities in my nation have created e-commerce industrial parks, grouped businesses of a particular size, and integrated capabilities. Online shopping the primary platform for industrial communities is e-commerce, which is combined with industrial clusters to accomplish the goal of upgrading and transforming business clusters.

Wang, A., et.al [9] The foundation for developing auxiliary systems for sports training is the three-dimensional posture perception technology used by athletes. This work investigates the use of the marked three-dimensional posture perception method in an exercise assistant system to perform a three-dimensional simulation of athletes' movement posture to modify the training mode and increase the training grade. The athletes use the partial estimation approach, which divides their entire posture into many partial postures and perceives each portion independently while interacting with the machine through limb movement on the overall posture formed from part of the stance, to realize the evaluation of athletes' sports stance.

Jiao, T., et.al [10] About issues related to resource distribution such as power oversight, interference repression, spectrum optimization, energy efficiency optimization, and throughput maximization in heterogeneous systems, the research techniques and theories will include convex optimization theory, dual decomposition contradiction theory, and game principle, etc. In a lot of literature studies on resource allocation, objective optimization functions like maximizing energy efficiency or minimizing execution delay are constructed. Next, constraint conditions like transmission power limitation and maximum transmission delay limitation are set, and the problem of resource allocation is solved using some traditional algorithms and theory. There will always be numerous connections between cooperation and competition in the study of distributing resources.

3. Methods and Materials

3.1 Intelligent Quality Control in Industry 5.0

The industry has been pushed in recent years towards a new range of highly advanced technical solutions with a focus on smart manufacturing systems. Smart manufacturing systems frequently incorporate smart quality management optimization abilities to reduce time and expenses for improvements in all areas of efficiency using a technology-oriented strategy, such as Industry 4.0. On the one hand, Industry 5.0 has an important link to digital sustainability, as one of its main features is the integration of modern digital technologies into manufacturing processes. On the other hand, Industry 5.0 proposes a new phase of technological advancement that builds on the earlier stages of industrialization, with a focus on humans and digital sustainability [11]. These technologies can be applied to streamline industrial procedures, save energy and trash usage, and raise general productivity. However, the European Commission noted that people continue to be a company's most valuable asset since they are more clever, creative, adaptable, and dexterous than the majority of robots or machines. In response to this shift in emphasis, the industry 5.0 concept's smart quality management was unveiled, highlighting the critical role that research and innovation play in assisting the industry in providing long-term services to humanity.

It is crucial to emphasize that Industry 5.0's development of intelligent quality management is neither a replacement for nor a chronological extension of the current Industry 4.0 concept in Figure 3.1. It is the outcome of looking forward and considering the requirements for workers' and engineers' understanding, expertise, and capacity to collaborate with robots and machines on the one hand, and manufacturing process flexibility and environmental effects on the other. Thus, Industry 5.0's astute quality control builds upon and enhances Industry 4.0. Since Industry 5.0 is a relatively new concept, the official definitions, which primarily emphasize human elements and resilient and environmentally intelligent production, still represent vague concepts generalized from practice. Early descriptions of Industry 5.0 therefore vary depending on the subject of study. As a result, we decided to define Industry 5.0 in terms of intelligent quality management and an industry environment that prioritizes people. Interestingly, the following is the meaning of Industry 5.0, taken from the mentioned references:

Industry 5.0, which is powered by cutting-edge technology and divided into areas for: process, product, and system quality improvement, is the idea of moving to a human-centric, sustainable, and resilient industry.

I. The Customized human-machine communication, encompassing robots, artificial intelligence, and virtual and enhanced reality.
II. digital twins of goods, processes, and complete systems, as well as CPS, are examples of manufacturing system simulation; and
III. Technology for data storage, processing, and transmission (including edge computing, cyber-security, big data analysis, and IoT).

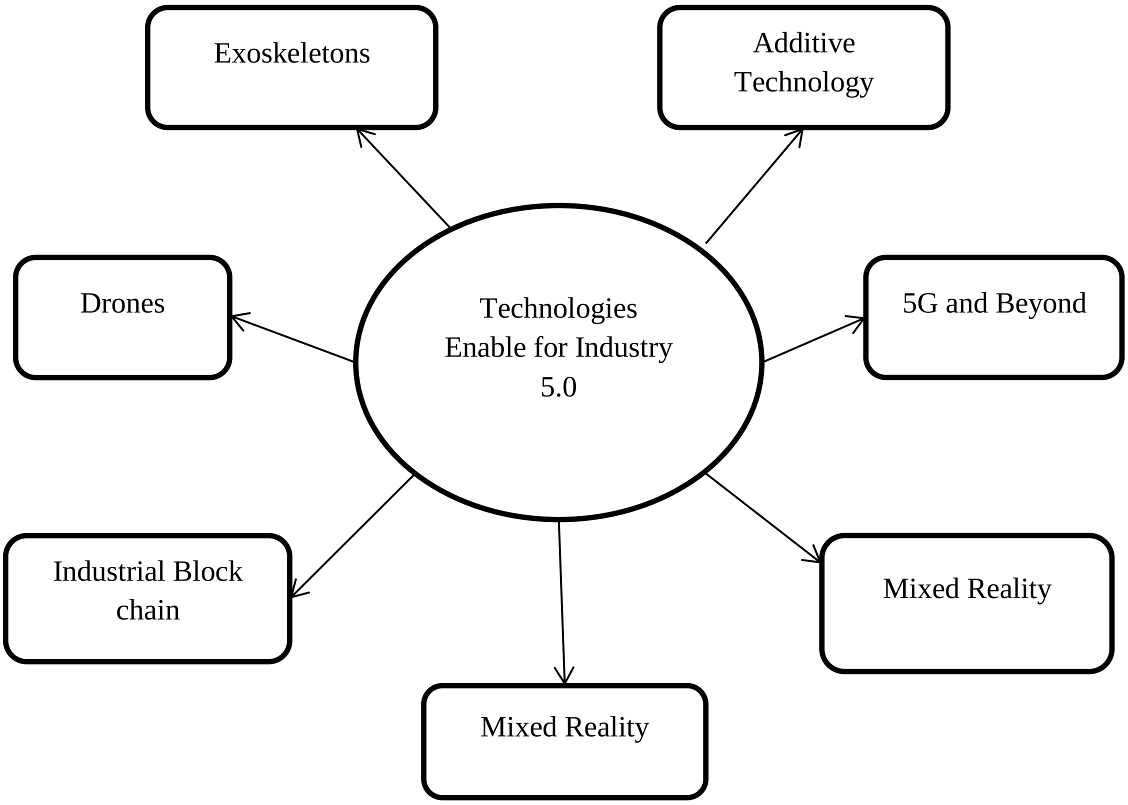

Fig. 3.1. Technology enables for Industry 5.0

3.2 Edge Computing

The handling, processing, and utilization of data from diverse industrial sources (i.e., robots and gadgets) are transformed by edge computing. In recent times, edge computing technology has become more popular in industry. The necessity for real-time decision-making, the expansion of IoT-connected industrial resources, and the use of data analysis techniques that call for less powerful processing equipment are the driving forces behind this decision. An increasing number of research papers discussing the use of edge computing in manufacturing processes also show this tendency. This development is caused by distributed computing in edge computing, which enables data processing and storage near manufacturing resources and promotes robust and ethical production.

Edge computing is constrained, nevertheless, in terms of power and computational resource usage as well as storage capacity [12]. Because of this, dealing with small-scale data sets optimizes the use of power and computing resources while lowering the amount of storage space and analysis expenses needed. Therefore, in order to utilize carefully chosen small data sets in place of big data in intelligent quality control processes without losing important big data details, both industry and academia must replace big data.

3.3 Transmission of Ride Requests via Edge Computing

End users can leverage the computation capabilities of edge devices to do computation activities with low latency because of the distributed design of edge computing and the benefit of edge devices being close to end users.

Even with a large number of computational resources provisioned in the data center, if all ride requests are directly delivered to the cloud and all matching between ride requests and public vehicles are computed in the data center, travelers would experience a high response latency for ride requests, making real-time service response impossible due to high link congestion on the network, particularly when a large number of ride requests are launched simultaneously [13]. In order to deliver real-time service response, edge computing in our system serves to decrease service response latency. Our scheme's edge devices finish rider-vehicle corresponding locally and provide low-latency local responses to ride requests. This leads to better ridesharing services and an enhanced traveller experience while also cutting down on the delay of service answers to passengers' ride requests. In our plan, the data center's job is to help edge devices with cross-region rider-vehicle matching by gathering, storing, and analysing global traffic data for the smart transportation network.

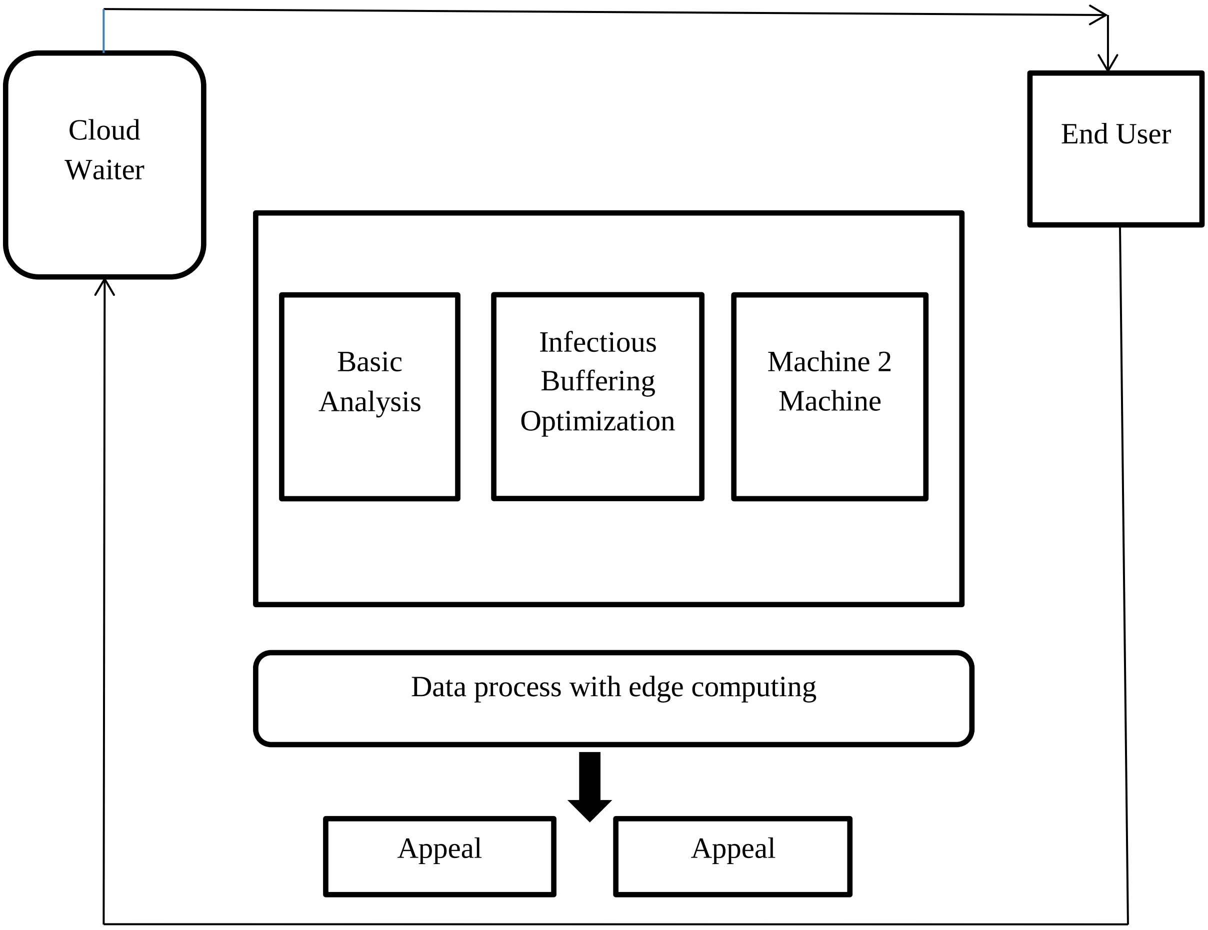

Fig. 3.2. Data transmission using edge computing

As illustrated in Figure 3.2, edge network, and cloud is taken into consideration in our suggested ECRT mechanism. When a vehicle approaches an edge device, it should send a check-in message indicating that it is able to be scheduled locally by that edge device, taking into account the mobility of vehicles. The car sends a check-out message as soon as it leaves the vicinity of this edge device. The target area is assumed to be fully covered by the edge network in our model.

When a car is near several edge devices, it sends its check-in communication to the one that is closest to it. It should be noted that a lot of research has gone into creating and enhancing vehicle networks, which can be seamlessly incorporated into our system to transmit data at high speeds. Instead, the emerging application based on vehicle network technology is the main emphasis of this article. From their mobile devices, travelers can initiate transportation requests, which can then be transmitted across cellular networks to the nearby edge equipment. Upon receiving a ride request, the edge device, sometimes referred to as ed, initiates the local car scheduling process to identify a suitable vehicle for the requested ride. Travellers and the chosen vehicle will receive the request reply back if the desired vehicle is located within this edge device's service area.

A new ride demand in our system will be fulfilled by its nearest edge devices first. The data centre or the nearby edge devices will handle the new ride demand if there isn't a car available. Therefore, even though every vehicle in our system is associated with a single edge gadget, the vehicle can also be matched to other edge devices' ride requests through edge device communication, guaranteeing the effectiveness of vehicle-rider pair corresponding in our system. It is possible to prevent situations where a vehicle is matched to multiple requests for transportation at the same moment and is served by multiple edge devices by assigning each vehicle to an individual edge device in every single increment. This way, a vehicle can only ever interact with one edge gadget for rider-vehicle corresponding.

Travellers will not have to wait long and there is a higher chance of successfully matching requests for transportation with vehicles if the vehicles are close to the location from where the requests are made. This is how most ride requests are matched in reality. In order to reduce cloud computing load and ride request delay while providing travelers with real-time offerings, our edge computer-based ride request transmission method can therefore perform the majority of ride matching in the edge equipment. Because cars transmit check-in notifications to the edge device as soon as they enter its region, the edge device is always up to date on the information about the vehicles in its vicinity. Using this information, the edge device is able to match the majority of travellers locally with available vehicles. Even if a neighbouring edge device can be necessary for an edge gadget, while other edge devices might not require access to this knowledge, edge devices will provide the most recent information about vehicles to their neighbors in the immediate vicinity. As a result, we can prevent information inconsistency in our ECPV system locally, and since a large percentage of connecting vehicle-rider pairs will occur locally at edge nodes, it might not be required to address it throughout the whole transportation network.

3.4 International edge computing procedure

The suggested work's primary goal is to offer an edge node that is optimised for data transmission. This optimisation is carried out in conjunction with edge computing domestically.

- Pre-processing, detecting, and measurement of documents;
- Sorting;
- Results obtained;
- enhanced edge component;

4. Implementation and Experimental Results

The suggested scheme's superiority over alternative schemes is demonstrated by the simulation experiments that validate its performance and provide information on the experimental environment and results. First, in a 400 m × 400 m simulated region, car nodes and mobile edge computing server nodes are assigned at randomly. The research's parameters, including the quantity of cars, edge computing servers, connectivity resources, and processing power, are predetermined. The suggested strategy's simulation experiment is run on the MATLAB environment. Table 1 displays the pertinent experiment variables.

Table 1. The Experimental parameters for simulation

Limitation	**Standards**
Total bit rate	4 × 206 Hz
Quantity of automobiles	6
The quantity of mobile edge computers	2
Mobile edge servers' CPU rate	6 ×2015 cycles/s
CPU rate of automobiles	9 ×2015 cycles/s
Task data magnitude	2,4 MB
The power use of the unit processing	2/7.2
The amount of energy used by cars to send and receive information	2.63*9 bit
Acceptable task lateness	500, 700, 800 ms
Acquired power	0.6 w
Power of sounds	6 w
The ability to interfere	5 W
number of people	100
The maximum quantity of repetitions	200
Generational disparity	1.76

4.1. Algorithm Performance Evaluation Analysis

The Key evaluation indicators to gauge the effectiveness of the strategy include the algorithm's integration speed [14], the correlation between average cost and data volume, the average delay and task count, and the relationship between total task cost and task count. The allocation of resources strategy centred on mobile edge computing in the IoV context suggested in this paper, along with the methodology, are listed below for the four assessment indicators mentioned above.

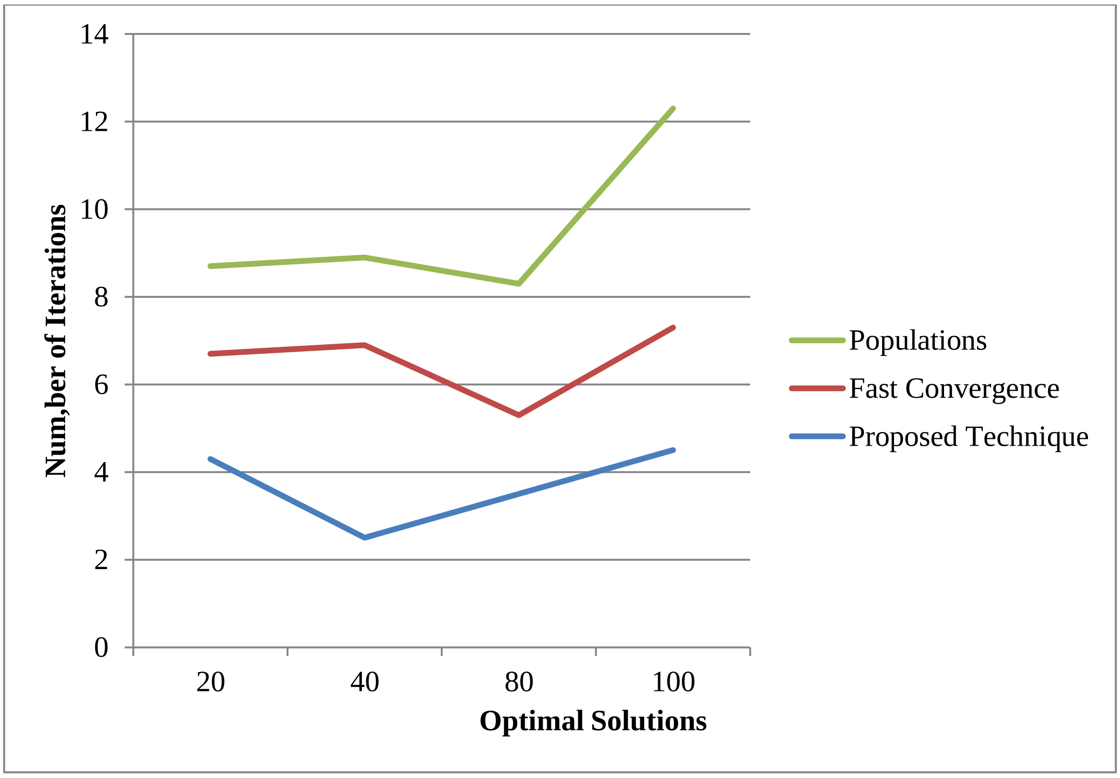

Fig. 4.1. Confluences of several techniques

First, the highest possible number of repeats up to 200 is established, and various algorithms' rates of convergence are contrasted and examined. Figure 4.1 displays the results of various algorithms' calculations. Figure 4.1 shows that, in comparison to the other three strategies, the suggested strategy has the fastest rate of converging and tends to converge at 20 repetitions. The Halton sequence is included during the initial population generation phase, resulting in an initial population that is less distinct. This enhances the method's speed in locating the best global solution.

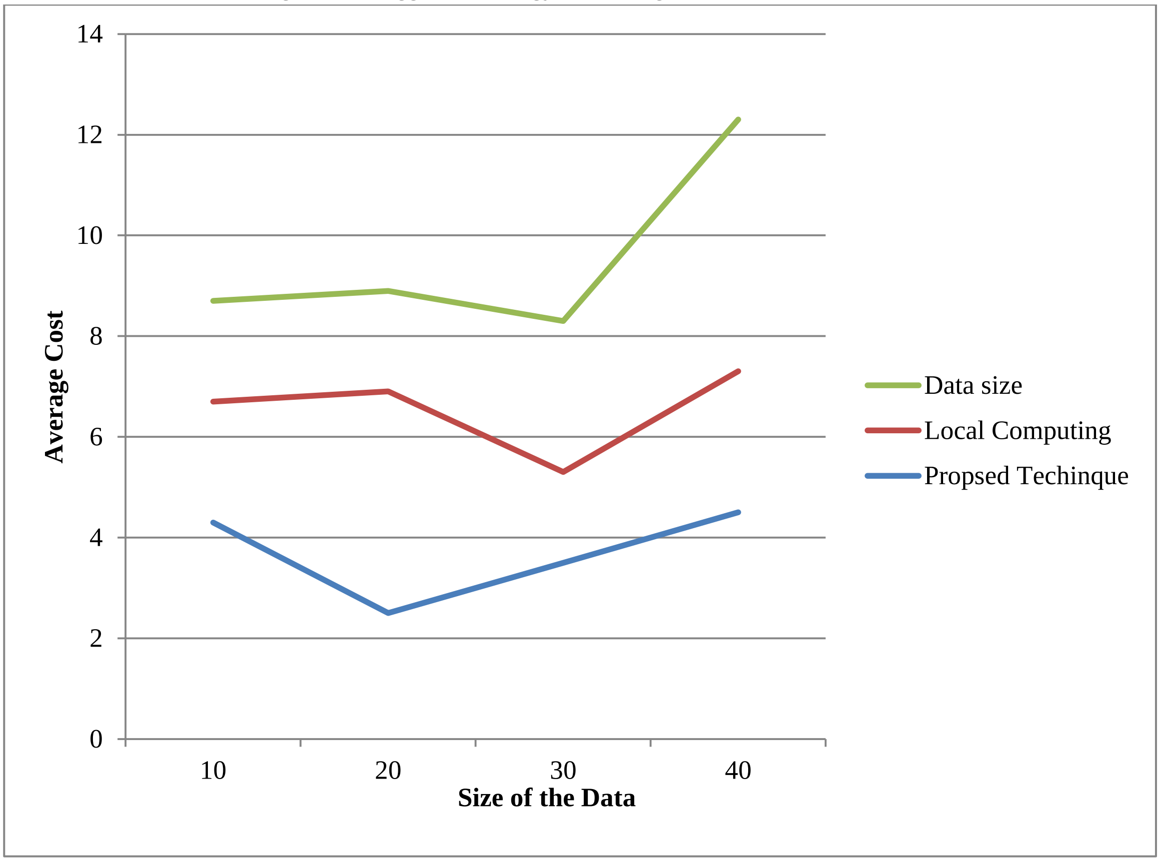

Fig. 4.2. The Connection between the Number of Task Data and Overall Average Cost Of Different Approaches

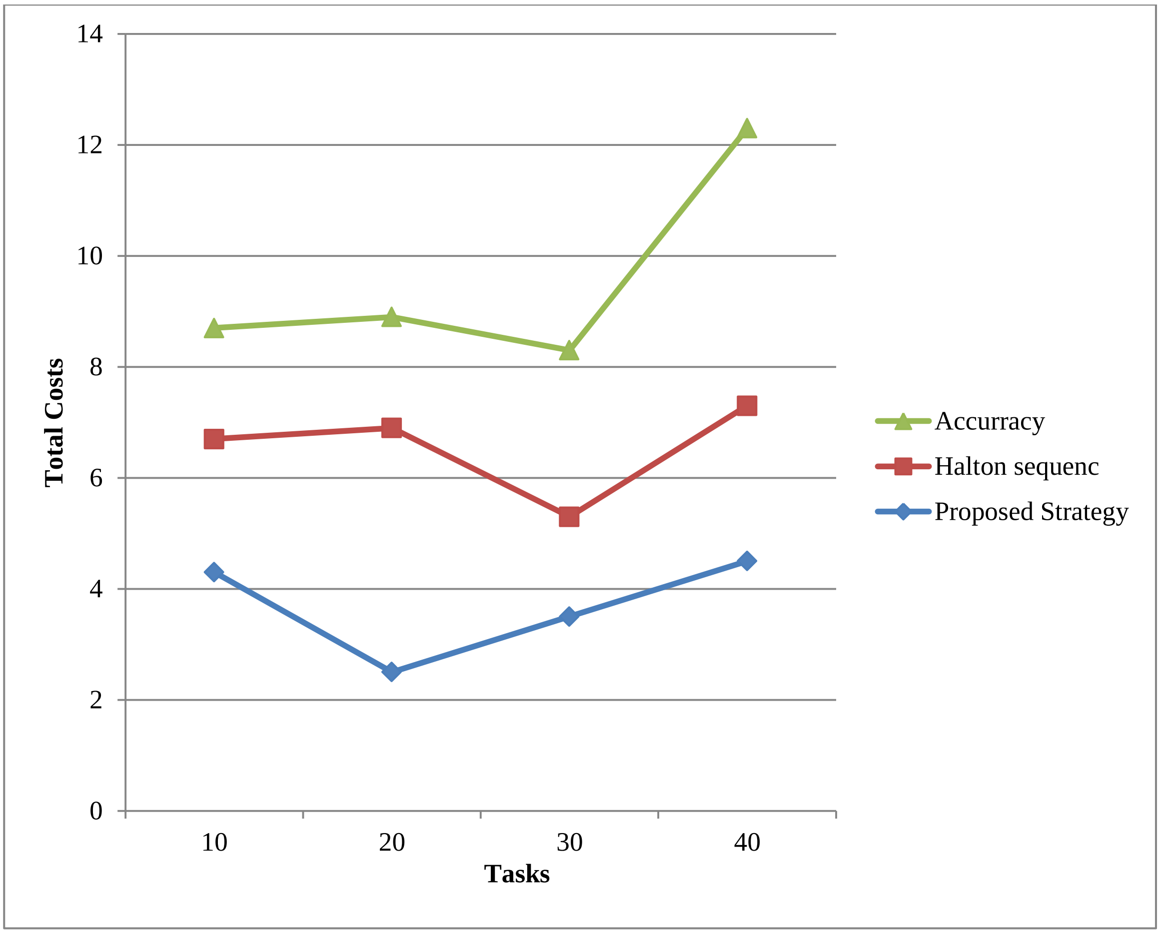

Fig. 4.3. The Correlation between the Overall Quantity of Tasks and the Total Expense of Tasks for Various Techniques

Figures 4.3 display the performance outcomes of comparison of several methods. Figures 4.2 demonstrate that [15, 16], when compared to the other three ways, the strategy suggested in this study has the lowest average overhead when the job data size is identical. Additionally, the median overhead of a work grows at the slowest rate as its volume of data steadily rises. When the job data size is 80, the median overhead of the suggested technique is 0.38, substantially less than the 2.74, 0.67, and 0.68 of the other three approaches.

Assuming an identical quantity of tasks, the suggested approach likewise has the lowest average delay and total cost. Additionally, the growth rate of total overhead and average delay is lowest when the number of tasks grows. The mean delay of the suggested method is 0.32 s, and the overall cost is 0.34 when 45 tasks are involved. According to the experimental findings, a genetic algorithm's capacity for global search can be enhanced and individual differences can be minimized by using the Halton sequence. Moreover, interactively and adaptively adjusting the crossover rate and mutation frequency can solve that problem of the local optimum solution and increase algorithm accuracy.

5. Conclusion

MEC has grown in significance in the current technological environment. The requirement for computing and storage resources has grown as a result of the significant growth in data generated by IoT networks. Installing MEC in the network makes it possible to address the aforementioned demands for computation-intensive and delay-sensitive applications. The hierarchical design from cloud-based networks to edge computers was examined in this paper. Subsequently, the difficulties in delegating work and allocating resources to carry out tasks in MEC-assisted transportation systems in an optimal manner are examined, supported by the most recent research on the subject.

Moreover, our study included a thorough examination of current advancements in using MEC to facilitate automotive applications. This involved a thorough examination of the subsequent domains: The use of MEC to improve VN collision avoidance systems; the use of MEC in platooning situations; MEC support for teleoperated driving; and MEC-powered improved VN video streaming applications.

Furthermore, we also took into account how cars themselves might improve MEC abilities. This included research on the possibility of using automobiles as mobile edge nodes to increase the range and functionality of MEC infrastructure. Our thorough research on these subjects not only advanced our knowledge of MEC's potential for use in automobiles, but it also gave us important new perspectives on how to best apply and optimize these advances in the setting of contemporary transportation networks.

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