



Review

Survey on Intelligence Edge Computing in 6G: Characteristics, Challenges, Potential Use Cases, and Market Drivers

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Abstract: Intelligence Edge Computing (IEC) is the key enabler of emerging 5G technologies networks and beyond. IEC is considered to be a promising backbone of future services and wireless communication systems in 5G integration. In addition, IEC enables various use cases and applications, including autonomous vehicles, augmented and virtual reality, big data analytic, and other customer-oriented services. Moreover, it is one of the 5G technologies that most enhanced market drivers in different fields such as customer service, healthcare, education methods, IoT in agriculture and energy sustainability. However, 5G technological improvements face many challenges such as traffic volume, privacy, security, digitization capabilities, and required latency. Therefore, 6G is considered to be promising technology for the future. To this end, compared to other surveys, this paper provides a comprehensive survey and an inclusive overview of Intelligence Edge Computing (IEC) technologies in 6G focusing on main up-to-date characteristics, challenges, potential use cases and market drivers. Furthermore, we summarize research efforts on IEC in 5G from 2014 to 2021, in which the integration of IEC and 5G technologies are highlighted. Finally, open research challenges and new future directions in IEC with 6G networks will be discussed.

Keywords: 6G; 5G technologies; intelligence edge computing (IEC); internet-of-things (IoT); mobile cloud computing; IEC's market drivers



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1. Introduction

The sixth-generation (6G) is applied to new communications networks which have evolved throughout the past few years and have incorporated various technologies, such as sensitive sensors, autonomous vehicles, immersive media, and Internet of Things technologies [1]. These technologies rely on millions of communication nodes and billions of endpoints. Additionally, they face many challenges such as deficiencies in wired networks and other privacy and security problems [2]. Consequently, the role of the 6G Network is to define the right set of network technologies required to deliver these applications. To be precise, its scope has been defined to meet the communication needs of societies until 2030.

The central theme of the 6G Network is the merging of digital and real worlds in all dimensions, shown in Figure 1. In addition, we expect to see much automation in the coming years. The sheer volume of things will work at the system level, and not in private networks; thereby requiring the coordination of intelligence distributed throughout the fabric of connection. Moreover, in 6G, the information between machines and robots will be provided in partial time units to safely support various operations [3]. Furthermore, the main characteristics of 6G include:

- Providing an efficient interaction among network's infrastructure and applications as well as supporting emerging technologies in the market that enable digital society in 2030 and after.
- Supporting convenient and effective binding for critical connectivity and edge computing networks which could be used by new poles with tighter limits as well as more varied limits for latency and amplitude.
- Controlling the resources effectively and rising time awareness and moving beyond the current effort of the Internet by providing high bandwidth and new case's communication service.

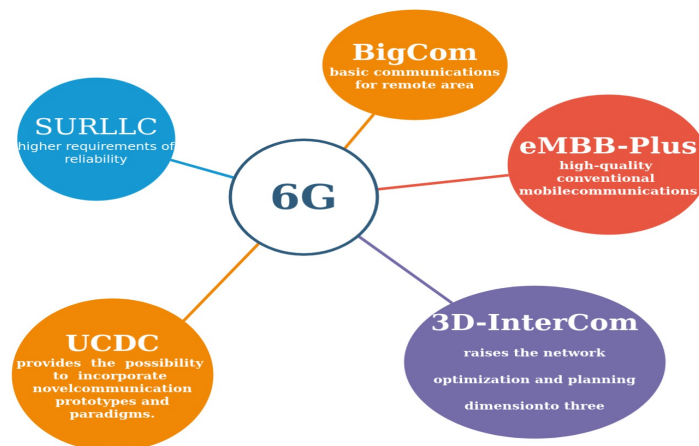


Figure 1. Vision of 6G.

However, processing, organization, and implementation of a great number of data are considered the real challenges of 6G.

Intelligence Edge Computing (IEC) is an improvement of cloud computing technology which is deployed to give easy access to the near end-users [4]. IEC is an ETSI-defined system, which is connected over a wireless network and can provide with the cloud computing resources and IT services as well as move traffic computing from center to the edge [5]. Besides, the European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) introduced IEC as a way of increasing the network's edge capability of storage and intensive processing [6]. In addition, IEC's features enable the mobility and provide with the computing and mobile communication and can exchange data anytime and anywhere (e.g., File Transfer (FT), Wide Area Network (WAN) interconnection, fax, e-mail, Internet Access (IA) and the World Wide Web). Furthermore, the wireless networks used for communications include IR, Bluetooth, W-LANs, Cellular Networks, W-Packet Data, and Satellite Communication System [7].

IEC is also considered to be mobile communication infrastructure that provides smooth and efficient communication between different mobile devices. Moreover, IEC is a design that aims to reduce bandwidth and delay by moving the required resources closer to the systems that demand them. The background to this claim is based on the promising expectation of lower capital expenditures and the potential to introduce new services, which could potentially be offered separately and could also be launched at a reduced cost. Among these new services is the potential to provide ultra-reliable and extremely low latency (URLLC) connections [6,8]. For instance, less than 5 ms or less than 10 ms, for autonomous Vehicle-to-Everything (V2X), Augmented Reality (AR) and Virtual reality (VR) applications. Subsequently, the architecture of IEC orchestration is shown in Figure 2, in which it consists of several functional blocks deployed in each IEC object. Besides, the functions of this architecture can be divided into three parts, namely border network functions, identification functions and data processing functions.

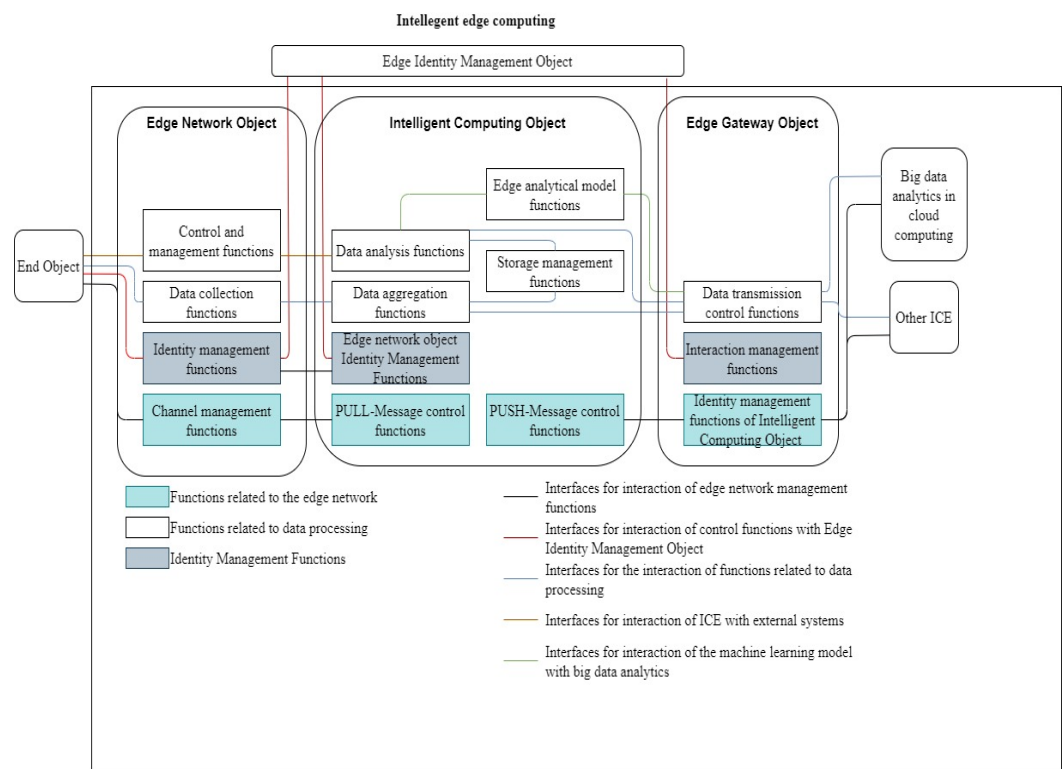


Figure 2. IEC Architecture [9].

5G is an architecture for edge computing that has been conceptualized through the enhancement of Software Defined Network (SDN) and Network Function Virtualization (NFV) [10]. Additionally, 5G technologies promote the concept of dividing networks into network resources and network functions. In 5G technology, a centralized infrastructure can be maintained while improving wireless communication at the same time [11]. This allows service providers to build a single physical network, with the potential to take into consideration high-bandwidth applications (e.g., broadcasting) and low-bandwidth (e.g., Internet of Things (IoT)) applications with time-low-latency connectivity and internal corporate networks. Increasingly development of 5G technologies enables sophisticated applications and services such as IoT, online gaming, Augmented Reality AR, Virtual Reality VR and acceleration of intelligent video [12]. The integration between IEC and 5G provides important improvements, such as enabling data processing at the network edge to reduce latency and deliver tangible business results.

1.1. IEC's Principles

Intelligence Edge Computing (IEC) enables the use of computing servers closest to the user instead of centralized devices far from the user. Therefore, it is characterized by fast data transfer and a significant reduction in response time for 5G networks [13]. This network technology is used in advanced digital systems such as (IoT) technologies, Virtual Reality VR video games, autonomous vehicles, cloud computing, and data protection. IEC includes some main principles such as portability, connection, interaction, and character [14] which are described as follows:

Portability: A mobile computing system is connected through devices/nodes that facilitate mobility. Such devices/nodes even have some limitations in capabilities and power supplies, but they have effective processing capacity and physical portability to work in a mobile environment [15].

Connection: The quality of service (QoS) of the network connection is defined on a mobile computing system. This ensures a high level of service availability with minimal delay and prevents certain hurdles without affecting the operation of connected nodes [5].

Interaction: Mobile edge computing system nodes (IECs) are interconnected through active data transactions for communication and cooperation.

Character: The operation of the mobile device or mobile node connected to the mobile network is summarized by the reference to a specific element; therefore, the mobile computing system is able to adopt specific technology to meet individual needs and also to obtain contextual information for each node [16].

1.2. Paper Motivation and Contributions

This survey focuses on reviewing the main characteristics, benefits and challenges of IEC in 5G based on previous research that took place from 2014 to 2021. Many of the previous works focused on different aspects of IEC in 5G and some of these works are quite old. The expectations of IEC in 5G are high as they provide a promising transformative platform (an enhanced effective end-user experience) and spreading in new fields such as IoT, new services and models, rapidly exceeding gigabits speeds, and enhancement in network performance with better reliability. Networks and services in 5G technology are expected to deliver enormous economic benefits because they rely on successful IEC mobile edge communication. However, due to the emerging service models which most often use a large number of terminal devices, the increased computing and data needs may overshadow the computing and storage infrastructure installed in the IEC. In addition, higher IEC installation and storage capacities can be decreased by cost pressure in the telecoms industry [17]. Based on the effectiveness and benefits of IEC in 5G, the contributions offered by our review could be summarized as follows:

1. We conducted an overview of IEC in 6G including characteristics, benefits, challenges, new and open cases and applications and recent market drivers.
2. We summarized integration of IEC in 5G networks related works from 2014 to 2021 including surveys, state of the art and future research.
3. Furthermore, we discussed the key factors for network 6G including momentum, architecture and market.
4. Finally, open research challenges and issues and new future direction in IEC with 6G network will be provided.

1.3. Paper Organization

The rest of this paper is summarized as follows: Section 2 includes the related works and surveys of IEC, specifically, an overview of characteristics, challenges, open cases and applications and market drivers. Section 3 includes the main characteristics and benefits while Section 4 includes the main challenges. In Section 5, the potential use cases and applications are provided, whereas Section 6 includes the market drivers of IEC in 5G. Furthermore, Section 7 introduces IEC in 6G and the research challenges and future direction issues are presented. Finally, Section 8 concludes this paper.

2. Related Work

This section gives an overview of related topics and previous surveys related to IEC's challenges, characteristics, benefits, potential use cases and applications, and market drivers. Previous works and surveys have covered reviews, state of arts, software and applications, vehicular and heterogeneous networks, IoT, content awareness and IEC in 5G [17]. According to the main objective of this study, the related works included overviews [18–20] surveys of IEC [21–24], characteristics and benefits [25,26], challenges of IEC [19,22], potential use cases and applications [5,7,11], and market drivers [27].

Previous studies in intelligence edge computing in Table 1 investigated published work from 2014 to 2020 in 5G and its integration with multi-access edge computing. These works were summarized by the topic, year and main contributions. Our research demonstrates intelligence edge computing in both 5G and 6G networking. Furthermore, our work includes market drivers and open cases in 6G networks. Vertical markets include entertainment such as tele-presence, holo-portation, and multi-sense technologies. For

instance, conducting teleconference video-call in daily meetings where several people carry out their presence to the same location. In addition to healthcare uses, such as tele-surgery, tele-monitoring, and haptics technologies, automotive applications and technologies which have a huge use in different industries including broadcasting, communication, computing, instrumentation, security, programming, and networks.

Table 1. Reviews of IEC.

Topic	Reference	Methods	Contributions
Intensive review of MEC, its characteristics and challenges	[18,19,22]	Surveys and Reviews	Overview of MEC technology and its potential use cases and applications. Determining IEC framework and performance and comprehensive overview of the state of arts, challenges, and further research directions for MEC.
MEC Software and Applications	[28]	White Paper	Newly guidance for developers how to run and build the needed architect in edge cloud.
MEC Vehicular Networks	[29]	Position Paper	MEC features in-premises and need for SDN and NFV in addition, mobility solutions and mitigation interface.
MEC Game Theory	[30]	Survey	Applying game theory on MEC and Challenges over MEC services.
Heterogeneous Networks MEC	[31]	A Novel Architecture	Architecture of MEC-empowered HetNets and offloading task in MEC-empowered UAV-assisted HetNets.
MEC to support Enhanced (IoT)	[32]	Propose an architectural solution	Propose an ETSI-compliant MEC architecture solution that allows existing and future IoT platforms to be seamlessly integrated.
MEC in 5G-connected cars	[33]	Automotive use cases	IPresenting automotive use cases relevant to MEC, providing insights into technologies identified and investigated by the ETSI MEC Group (ISG).
Characteristics of MEC	[25,26]	Survey, Empirical study	Introducing MEC infrastructure to understand the characteristic and future deployment.
SDN Management of MEC	[8]	Novel architecture Analysis	Introducing layback architecture to facilitate access to resources. Calculating function blocks with resource sharing between operators increases the revenue rate measurement by more than 25% compared to CRAN.
5G Context-Awareness in MEC	[34]	Comprehensive system evaluation	A new, decentralized validation architecture is proposed based on Markov model. The numerical simulations showed that this approach is able to strike balance between MEC reliability and network operating cost.
MEC Device-Enhanced	[17]	A survey	Surveying device-enhanced MEC and classifying: sub-classifying MEC IEchanisms offloading and caching.
Survey on MEC for IoT Realization	[27]	A survey	An overview of leveraging MEC technology to achieve IoT applications and synergies between them. Technical aspects of enabling MEC in the Internet of Things.
MEC's Market Drivers	[27,35–37]	Comprehensive system evaluation	MEC features in-premises and need for SDN and NFV in addition, mobility solutions and mitigation interface.
Surveys on MEC	[21–24]	Different Surveys	MEC features in-premises and need for SDN and NFV in addition, mobility solutions and mitigation interface.

2.1. IEC's State of Art

Successive and rapid developments of IEC in 5G have changed many concepts of people' lives. Therefore, these technologies have become indispensable to anyone because these developments provide new and advanced services and technologies that keep pace with their growing needs; thus the shift from the second generation "2G" technology, for example, to the third generation technology. G3's goal was to add Internet services to personal phones, then switch to G3.5 technology, which at the time caused a huge leap for its goal of expanding Internet services and linking them to smartphones and their applications.

The 5G network technology constitutes a tremendous revolution in the world of communications. It provides a high speed in data transmission compared to the current fourth-generation technology, which allows faster access to contents with the possibility

of transferring billions of data without obstacles [14]. Internet of Things (IoT) and smart environments depend on the high speed and low latency of 5G technology and move their uses to a new era [38]. Industry drivers [8] and the radio communication Sector has identified three important categories, including eBBm, mMTC and URLLC.

Some studies predicted that by 2020, 50 billion objects would be connected to the Internet [39]. Some IoT applications have very short response times, some have private data, and some may generate large amounts of data that can be a heavy burden on networks. In addition, Cloud computing is not efficient enough to support these applications. As more devices connect, sensitive applications face severe latency problems. Furthermore, Cloud computing fails to meet mobility and location awareness support needs. With the explosion of data, devices and interactions, cloud architecture alone cannot manage the influx of information [40,41]. To overcome these problems, a new model called Cloud calculations was proposed since 2012.

(1) *Edge Computing*: Edge computing significantly reduces the amount of data that needs to be transmitted, resulting in traffic and distance that needs to be traveled [42,43]. Edge computing also means enabling technology to transfer computing to the edge of the network, where downstream data is performed in cloud services and upstream data is operated in IoT services. In computing edge storage and information processing are guided to the edge of the network and near the source of information, i.e., instead of sending information generated by IoT devices in the traditional way to data centers or remote servers for storage and processing; this information are placed on local servers and stored through a local gateway. This approach increases the speed of data analysis and reduces network pressure.

The logic of edge computing is that the computing should be done in the vicinity of data sources. In addition, edge computing can be replaced by fog computing [16]. From Weisong Shi's point of view [44], edge computing can be replaced by fog calculation, but edge calculation is more object-oriented, while fog computing is more structure-oriented.

Edge computing offers many advantages over traditional architectures, such as optimizing resource use in a cloud computing system. Performing computing at the edge of the network reduces network traffic. Edge computing also improves security by encrypting information close to the network kernel while optimizing data, rather than the kernel, for performance. Control is very important for the edge.

(2) *Edge computing and security*: Edge computing provides the creation of small virtualization infrastructures at the edge of the network, using base stations, radio network controllers, or other aggregation sites. Edge computing is a paradigm similar to fog computing but with different architectures and business models (infrastructure belongs to a single operator and does not include user devices). In addition, edge computing explicitly defines telecommunications infrastructure for providing mobile edge services, such as radio network information, location, and bandwidth management [45].

IEC has similar security concerns to the cloud. However, distributed resources associated with the installation of peripheral networks usually have fewer restrictions and physical access control than traditional data centers, so the risk of diversion is negligible. Besides, IEC reduces the need for more human resources (with different capabilities and security skills) and reduces the risk of errors, weaknesses or missing settings.

Range API increases the level of attack and the potential impact of the attack. In fact, such services allow access to sensitive information about the physical and virtual environment, including the location and network traffic of other users. Integrating intelligence edge computing with the entire network operational support system also enables successful penetration and increased commitment to control large infrastructure and regional or national communications services [46].

Finally, IEC is expected to run orchestral services, in short, to combine several applications. For example, the Virtualization Function is often designed for orchestration tools which can dynamically select and upload images from hidden images. In this case,

the external software may run inside the security environment with all the associated security risks [46].

2.2. Development Framework

The framework for the future development of 5G and beyond is described in recommendation ITU-R M-R 0-2083.M-R in detail and this means that IMT systems are contributing as follows:

Wireless Infrastructure: Broadband connectivity became as important as getting electricity. IEC in 5G technologies plays a significant role in enabling service to deliver and exchange information. In addition, different users would be enjoying a wide variety of applications and services, starting of entertainment media services to professional applications.

New ICT Market: The prospective improvement of IEC systems works to enhance emergence of integration ICT industry that enable economies around the world. Among the potential areas are accumulation, analysis of big data, provision of customized services for networking for enterprises, aggregation, companies and groups of social networks on wireless networks.

Bridging the digital Gap: 5G technologies are still helping to bridge some scarcity caused by the growing digital gaps. According to its ease for deploying mobile and wireless communication, IEC's systems can support this goal, while at the same time, saving energy and maximizing efficiency.

New communication Methods: IEC allows any type of content to be exchanged at anytime and anywhere from any device. Users will generate and share more content without being restricted by time and location.

New forms of Education: IEC in 5G changes teaching methods by providing easy access to digital libraries. Internet sources Martial or storage of knowledge in the cloud, in addition to, promoting applications such as e-learning, distance learning, and teleconferencing [47].

Enhancing Energy effectiveness: IEC has a significant role across a range of economic and energy sectors, including supporting machine-to-machine (M2M) communications and providing solutions for smart energy grid, logistics, smart transportation, and teleconferencing.

Social Changes: Broadband networks facilitate the rapid formation and public exchange of a political or social issue through a social networking service. Creating the opinions of many connected people due to the ability to exchange information at any time and any place is considered to be the main reason for social change.

Culture and Art: 5G technologies play a significant role in supporting arts and artists in participating and performances such as group activities, creating a virtual singing group, catching eyes, co-authoring, or writing songs. In addition, 5G technologies enhance the connection throughout virtual platforms for people to exhibit culture.

3. IEC'S Characteristics and Benefits

Distinctive characteristics of IEC are its proximity to end-users, mobility support, and densities of geographic deployment of IEC servers. IEC enhances 5G networks because it reduces the latency and enhances the use of bandwidth. The main characteristics of IEC based on ETSI white paper [48] includes proximity, ultra-low latency, high bandwidth, and virtualization.

On-premises: IEC can operate in stand-alone environments (for example, IEC can operate in isolation from the rest of the network) and has access to local resources.

Proximity: Typically, IEC servers are placed near device end-users, thus IEC can capture data from electrical device users for other purposes as analysis of data and/or processing of big data.

Ultra-low latency: IEC server has limited computing power, it is usually sufficient to handle emerging compute-intensive applications in real time. IEC has the potential to shorten communication latency and propagation, making IEC a promising enabler for latency-critical 5G applications. IEC also opens up opportunities to alleviate the burden on

forward and back linking and to accelerate content and service response by appropriately caching popular and relevant content locally at the network edge.

Awareness of locations: based on the closeness of proximity, IEC can make use of signal information from end users to predict locations. This becomes somehow significant for location-based IEC services.

Contextual information of Network: Featuring proximity, IEC can take advantage of real-time knowledge of radio network conditions and local contextual information to improve network and service quality. For example, contextual and real-time information can be used to improve user experience across personal services [6].

Virtualization: Virtual Multiple Access Computing (vMEC) technologies are the next generation 5G networks, which is a flexible software network that supports various Internet devices and Internet of Things (IoT). vMEC is based on Network Function Virtualization (NFV) and Software Defined Network (SDN). With the development of diversified networking applications, vMEC brings intelligence to the edge of IEC, reduces latency and increases available capacity. In addition, the proposed use of vIEC for container-based virtualization technology (CVT) as a gateway with IoT devices for flow control mechanism in scheduling and analysis methods which effectively increases the quality of service (QoS) of the application [49].

The ultimate goal of IEC is to provide improved, low latency infrastructure with deployment speed that can be scaled horizontally or vertically based on requirements. Based on the concept of IEC, services and content can be transported to the closest end-users and obtain more quality of service while reducing connection congestion and improving gateway interconnection costs. Cloud Edge has five unique mobile computing capabilities that set it apart in the market today:

- *Network performance:* Cloud Edge has the ability to transfer 10× more performance throughput than competing alternatives: more than 200 Gbps on a single Intel Xeon server. Furthermore, linear scaling, independent aircraft, data monitoring and user management allow projects to support local communities to network resources quickly and efficiently scale on the edge of the network [50–52].
- *Flexibility:* Due to the actual use case and other related business, intelligence edge computing has flexibility to deploy a centralized or distributed solution. This flexibility is critical to economies of scale—the ability that Cloud Edge provides. For example, a CSP looking to provide multiple cloud services with low latency will benefit significantly by focusing control plane functionality (according to network proximity) but deploying user-level instances in a distributed manner either in the CSP or the customer edge.
- *Divergent experiences:* Cloud Edge enables CSP to deliver premium services to its customers on a per-flow basis. This is achieved with a single, integrated and highly optimized platform consisting of basic mobile network and LAN functions such as vProbe, CG-NAT, deep packet inspection (DPI), optimization and load balancing.
- *Virtualization and analytics:* cloud computing service providers look to complement the various service offerings in the related businesses. Intelligence edge computing has the ability to provide a real-time network and insight into customer behavior. For instance, IECs define operational efficiencies, anticipate future demand and deliver service innovation which is considered to be a core value-addition. Cloud Edge supports audit paths including security data audits and provides these capabilities, along with real-time analytics.
- *Automation:* In the inevitable decoupling of mobile networks, intelligence edge computing has the ability to automate the process of integrating enterprises, end-user services, applications and dynamically expanding network infrastructure, especially with IEC applications. Applications and tools of cloud edge automation enable cloud computing services to provide the ability to quickly adjust traffic rises and falls automatically which leads to reduce the operational costs and reduce the time needed to generate revenue.

4. IEC's Challenges

According to the special use of IEC in commercial deployment, there are some important factors that must be taken into consideration. Primarily, challenges include:

- *Network openness*: major challenges are related to mobile networks edge openness, where mobile operators work to control over the entire industry chain, and business risks from each other among equipment suppliers.
- *Multiple services and processes*: Several types of third-party providers such as application developers, content providers, OTT operators, and network equipment vendors work with service type creation and IEC server cluster management. All participants have to face the challenge of new business models and the value chain.
- *Durability and Resiliency*: When integrating smart networks into a mobile base station, the robustness of the IEC server must be ensured and that the integration between them does not affect the availability of the mobile network.
- *Privacy and Security*: Integration of intelligence edge computing and other communication systems raise many challenges about the security and privacy of users and organizations. For instance, security threats of cyber-attacks with more of consideration about privacy protection when analyzing data of different users or parties.

Furthermore, according to survey studies about IEC, here is a list of some open issues and challenges. These challenges are categorized as open issues that need further research and investigation.

The standard protocol: IEC is a modern technology that advances through the implementation phases and requires standardization arising from the collaboration of industry and researchers across an agreed platform [7].

Effective deployment: The latency can be reduced to a minimum with optimized use of bandwidth through efficient deployment of IEC. However, it may look hard to optimize spectrum use with reliance on complex system components.

Mobility User and transparency: Providing uninterrupted services to an “always on the go” customer is another challenge in the IEC environment with a transparent migration process and platform heterogeneity.

Heterogeneity and scalability: Since high-end devices use different access technologies including 4G, 5G, Wi-Fi and Wi-Max, so the heterogeneity aspect of the smooth performance of IEC operations must be met. This also entails providing scalability to different platforms with varying numbers of users [53,54].

Availability and security: Resource availability often depends on server capacity and wireless access to ensure consistent service. Besides availability, the security of data and applications from any hacker must be provided with physical measures.

Interworking between fog clouds: there are three different aspects to consider in any end-to-end system when it comes to communication challenges for gates and/or fog nodes. Communication difference, which is the communications between the gateway/haze nodes and the cloud service (public or private) and the connections between the gateway/haze node and the edge/objects/sensor networks or the connections between the gateways/fog nodes themselves, so that they can share data without the need for a cloud connection.

Data management: The required data management capabilities include (but are not limited to) [18]:

1. *Data normalization*, which is the assimilation, alignment, and enrichment of data from various sources (objects, devices, and sensors) into a common data model with well-understood connotations.
2. *Filter and query data*, so apps and analytics can efficiently access and use related data.
3. *Integration with Edge Analytics* Because the whole reason this data is captured is the ability to analyze it, create new actionable insights, make decisions, and put these decisions into action. Converting data into different representations and formats for integration with the (IoT) ecosystem.

4. *Compiling abstract data and / or metadata*, as preparation for local analyzes or pushing them to cloud services [18].

In addition, many new challenges must be studied in order to create an advanced ecosystem where all players in the network (i.e., IoT users, service/infrastructure providers, and mobile operators) can benefit from advanced services. These challenges are summarized as follows [18].

Distributed Resource Management: Resource allocation is an important challenge to the success of IEC due to limited resources, the increasing number of applications, and the massive increase in mobile traffic [55,56]. Multi-purpose resource allocation optimization is different in different situations due to the diverse nature of applications, heterogeneous IEC servers, different user requirements/characteristics, and channel connectivity characteristics. With a large number of users, the wireless channel will be in trouble and competition among users for scarce computing resources will become extremely intense [57]. Although the centralized approach can deliver competitive performance, it suffers from low computational complexity and huge reporting expenses. Therefore, the central approach is not suitable for distributed IEC systems [12,58]. Additionally, there may not be a dedicated backhaul for information exchange and account offloading, and even if there is, the wireless connection can be congested due to the high burden of sharing large data [59].

Reliability and portability: Condensation is the cornerstone of the 5G network and is expected to reap enormous benefits. However, how to manage mobility and ensure reliability is a huge challenge in these environments. First, with several smaller servers covered, user mobility can cause frequent deliveries, resulting in service downtime issues and affecting overall network performance [60]. After that, users (such as vehicles) may move to new locations during the account of the period. In such a case, users may not be able to receive the mathematical result because they have already exited the service coverage for their servers. Therefore, efficient computation dump forms are essential for application completion. Moreover, the dynamic change in the number of offloading users leads to random uplink interference and variable computing resources over time [61]. Finally, providing reliable IEC services in mobile environments is really challenging due to the time-varying dynamics of wireless communication and user mobility.

Network integration and application portability: IEC servers can be deployed in various locations within the RAN based on specific technologies, and technical and business requirements. Thus, another important challenge is the seamless integration of IEC into the existing backbone network architecture and interfaces [48]. The presence of the IEC and the enabled applications should not affect the basic network and peripheral hardware standards. According to [38], a key component of IEC integration is the ability of IEC to interact with 5G networks in directing traffic and receiving relevant control information. Moreover, the application migration entails what are called applicability requirements. This eliminates the need for application developers to design multiple versions of different IEC systems.

Coexistence of IEC and Cloud Central: Cloud Distributed centers, with abundant computing resources, can handle big data applications at near-zero time and support a large number of users. However, distributed IEC is highly desirable because the computation at the edge of the network cannot only satisfy user requirements but also reduce end-to-end delays caused by traffic congestion and transmission delay. In comparison to the HetNet architecture, it is very beneficial to implement IEC in a hierarchical manner, i.e., user layers, terminal computing and cloud computing [62]. In this way, the IEC vendor also injects computing resources into small eNBs so that the advantages of HetNets can be exploited to diversify wireless transmission and spread the computing requirements [50,63]. We note that a distributed IEC may not have sufficient computing resources to handle all account requests and full reliance on the cloud poses challenges in providing critical latency services. Therefore, it is self-evident to distribute critical large data/latency accounts to distributed IEC servers while moving account-intensive and delay-tolerant tasks to the DC

cloud [64]. The coexistence of a distributed IEC and a cloud core is an important issue and more research is needed for their interactions.

Coexistence of human-to-human traffic and IEC traffic: Integrating both traditional human-to-human (H2H) traffic (for example, voice, data, and video) and IEC traffic in the 5G network is a challenging task due to the massive paired IoT connections With the various quality of service requirements and the unique characteristics of the IEC movement [11]. For example, the Internet of Things system consists of human-type devices (HTDs) and machine-type devices (MTDs) that may run different types of applications, for example, MTD with sensors and smart homes, and HTD with video games. While MTDs have a mixed set of QoS requirements, such as latency, reliability, and energy efficiency, HTDs typically require a high-speed rate with a limited energy budget [65]. Likewise, the IEC system must be designed in a way that meets the QoS requirements of H2H traffic while preserving the unique characteristics of M2M traffic (for example, real-time response and context awareness).

5. Potential Use Cases and Applications

Enterprises of different types, sizes, and domains have increasingly needed to deliver QoE, high bandwidth and low latency including data backup, disaster recovery, email use, office virtualization environments, software development and testing, big data analytics, and web applications used by customers. For instance, the healthcare sector is using cloud-based services to develop better suited patients' personal needs treatments. Financial sector providers use cloud-based services to operate necessary capabilities that detect and prevent fraudulent operations in real time. Video game makers based on IEC and 5G technologies provide online games service to their customers around the globe. Here are some open cases and applications using IEC and 5G services [66–68].

5.1. Customer-Oriented Services

Customer Services: IEC has provided a wider range of customer services than ever before, as companies and organizations in the commercial sectors use intelligence computing in order to expand and improve their core services as well as create an opportunity to achieve more revenue with the latest services [69]. IEC works to provide these companies with enhanced situation awareness and ability to access data and statistical analyzes in addition to reporting incidents and sending alerts and notifications when necessary. Because of its ability to provide unified communication capability between employees, IEC has become a very attractive solution.

Cloud Gaming: Cloud games are a new type of game that broadcasts directly to game on devices (the game itself is processed and hosted in data centers) so that it relies heavily on latency [70,71]. The idea of cloud gaming companies is to work on sophisticated servers that are as close to the players as possible in order to reduce latency and provide a responsive and immersive gaming experience. For example, developing a new cloud gaming technology called Orion. It is designed to enhance the video game streaming experience. Combining Orion with AWS Wavelength and Verizon's 5G network helps deliver a friction-free, ultra-low latency streaming experience that enables millions of gamers to play high-quality games at their maximum settings [72].

Augmented and Virtual Reality: both AR and VR greatly benefit from intelligence computing (IEC) because they require very low latency and high bandwidth. AR and VR are considered as the main trends currently dominating entertainment [73,74]. For instance, Pokémon Go became the vast majority of mainstream gaming. In addition, virtual reality headsets have gained the popularity of AR and VR technologies skyrocket, and IEC technologies are being considered in order to take AR and VR to the next level [75]. Multiple-access edge computing allows rapid real-time data transfer between the device and the edge of the network. Its proximity provides the decisive factors for low latency, scalability, and high speed to play a non-portable VR/AR experience.

Commercial Operations: Besides customer services, multiple access computing is currently used in many business processes which in turn enhance the daily operations of companies and organizations all over the world [76,77]. For instance, IEC plays a vital role in security, distribution for asset management and data routing. In addition, depending on intelligence computing architectures provides network operators with advanced surveillance and video analytics that aggregate data much closer to the source, where this data is processed, analyzed, and then stored.

Data Analytic: Intelligence Edge Computing helps to prioritize data that should be analyzed, stored, or remain on the edge for further processing, in addition to determine which data should return for analysis to data centers [78]. It is acting as a relay station while providing additional computing power for mission-critical analytics that should remain close to the end-users [20]. Due to the huge generated data by one vehicle using IEC, there is a need to run this data with powerful analytics software to generate actionable information of value to the business [49]. For instance, a single autonomous vehicle can generate about 30 terabytes of data in a single day.

5.2. Operator and Third-Party Services

Typically, operators of mobile networks offer and supply IEC service. However, a third party could supply these services. For example, third-party cloud service providers are entities that provide services and resources for hosting IEC applications, while they are not traditional network operators. There are many examples of third-party providers such as location and facility management companies, neutral vendors, tower owners, and vehicle fleet management companies. Some of these service introduced by third parties as follows:

- *Autonomous vehicles:* The autonomous platoon of truck convoys was one of the first use cases of autonomous vehicles [79–82]. So a group of trucks moves closer to each other in a group, which saves fuel costs and reduces congestion. With advanced computing, it is possible to remove the need for drivers in all trucks except for the front-end trucks, because the trucks will be able to communicate with each other with extremely low latency. In addition, automated vehicles are powerful enough to manage all kinds of on-board computing tasks and well-connected enough to interact with more than one network or device [83]. These robotic vehicles will be in constant contact with the world while making split-second decisions based on information from smart sensors.
- *Industrial IoT:* Actually, IoT devices and processes that included into this category are often referred to as the Industrial Internet of Things (IIoT). Safety is one of the fundamental issues that needs attention in the sector of Industry [84–86]. By using intelligence edge computing technologies and hardware it enables, safety levels could be improved and also provide analysts with real-time information about equipment, machines, tools and vehicles so that workers can work in a safe environment [87].
- *Big Data Analytic:* This case, by using a pool of cloud-based service for external vendors depending on the collection of massive information (such as video, sensor data, etc.) from different devices, where these data are being analyzed before being sent to the central servers. These applications could be run in a single location (i.e., on a single host), distributed over a specific region such as campus or for the entire network. To support the restrictions imposed on a party that is requesting third-party service, it is necessary to run in all required sites (IEC hosts) applications.
- *Tracking of locations:* the main use of such cases enable real-time, network-metric tracking of active terminal equipment (regardless of GPS) using “best-in-class” geolocation algorithms [1]. In addition, deployment in the IEC system provides an efficient and scalable solution with local processing. It also enables these services to businesses and consumers (for example, on primary adherence), or in retail venues, locations and in different coverage areas where GPS services are not capable [88].

5.3. Network Performance and QoE Improvement

Local content caching: By leveraging content caching technology—for example music, video streams, and web pages—at the edge, improvements to content presentation can be distributed massively [89]. Latency could be significantly reduced [17]. Content providers work to distribute CDNs more broadly to the edge, thus ensuring flexibility and customization on the network depending on user traffic requirements.

Telecom Industry in a 5G: different business models have been used in Telecom to improve operations and enable service providers to keep in business such as connectivity, partnership and digital service models [49]. With the emergence of OTT providers, telecom operators have been greatly affected. SMS is dominated by OTT Messaging Service, and VoIP is a major contributor to international calling [45]. The revenue lost by the telecom industry due to OTT services is only increasing. Now with the advent of 5G, the telecom industry will need to make some serious changes to its current business models [58].

5G Networks: IoT edge hardware and the Intelligence Edge Computing framework are expected to enhance already existing 5G networks [78]. When it comes to 4G technologies, speed, efficiency, and bandwidth limitations exist as a long-term solution, especially with the start of autonomous vehicles. On the other hand, 5G can offer companies the means to expand computing and networking capabilities [72]. The numerous 5G towers will definitely make the aforementioned future autonomous vehicles possible.

Smart Networks: IEC is a key technology in the widespread adoption of smart grids and helps allow enterprises to better manage their energy consumption [22]. Sensors and IoT devices connect to sophisticated platforms in factories and offices to monitor energy use and analyze energy consumption in real time [90]. With real-time visibility, enterprises and energy companies can strike new deals, for example, where high-power machines are turned on at off-peak times of electricity demand [84]. This can increase the amount of green energy (such as wind energy) the enterprise consumes.

Market Research: Many kinds of research have been conducted to improve 5G infrastructure due to the importance of IEC development [91]. (ETSI) Industry Specification Group (ISG) introduced IEC to active more open-standard environments. This work has allowed vendors and service providers to integrate applications efficiently and effortlessly. During the last few years, much previous research investigated standards and specifications of IEC [90]. These publications help to understand IEC infrastructure, challenges, benefits, security, operations and requirements of IEC. Additionally, the ETSI ISG has proposed different solutions to several major problems in IEC deployment in different environments.

6. IEC's Market Drivers

The main drivers of advanced computing include existing 4G and 5G networks and Internet of Things (IoT). IEC market drivers are included in components of IEC's software and hardware, applications such as video surveillance, locations. Data services and data analytics. Infrastructures of networks will need to expand effectively to deliver more significant amounts of data. IEC depends on the flexibility and agility of end-user cloud-based to meet these requirements. IEC's networks are also evolving to encompass residential, commercial, mobile, and virtual converged networks.

6.1. Smart Environments

The best uses of (IoT) in the areas of home automation and consumer electronics are the main drivers of the market [92]. There are many applications of smart environments that have been created on the basis of the concept of the IoT in many consumer markets. These technologies vary according to their use, from simple temperature sensors to other more sophisticated automation systems such as smart metering, heating, smart lighting, home entertainment systems and cleaning services. Using these technologies needs a huge data transformation. Hence, IEC can be leveraged in specialized and reliable local services to facilitate the processing and storage of large IoT traffic that is generated in these smart environments. Smart gateways by using IEC enable IoT applications to run easily

and transfer information to the center and reduce the communication latency [93,94]. In addition, since these smart environments are deployed with IoT applications, IEC servers offer additional services including easy instantiation, privacy preservation, easy transfer, and update when necessary [95]. Furthermore, IoT has advanced use in city scales such as highways, hospitals, transport and tourism. The massive IoT data traffic generated in smart environments can be optimally processed at the edge of the network providing low latency and location awareness [90,96]. For instance, video cameras in the streets can transfer data (video) to the IEC server in the real-time or healthcare applications that need to collect data from different entities including hospitals, government, pharmacies, and insurance companies [44].

6.2. Autonomous Vehicles

Based on the 5G infrastructure, IEC is considered as the basic infrastructure of V2X (Vehicle to Everything) concept covering Vehicle to Vehicle (V2V), Vehicle to Device (V2D), Vehicle to Infrastructure, Vehicle to Home or Vehicle to Network [55]. Depending on the concept of (IoT) Automotive, V2X requires an important communication infrastructure where reliability and significant low latency are critical requirements [97]. To work efficiently under this category, many improvements have to be made including traffic mentoring [35,98], sensing in vehicles continuously [99,100], infotainment application support [10] and security [101]. These features are not fully adopted yet, but in the near future, 5G is expected to offer such flexibility, software and take advantage of emerging network-related technologies [102]. In addition, to enable IoT automatization, there is a need to improve RAN technologies where IEC has a major role here. IEC replacement within RAN gives a sufficient control for vehicles and radio network services [103]. Moreover, integration of IEC can overcome different technical challenges such as scalability, massive data handling, deployment strategies and issues of security and privacy. Drones or Unmanned Aerial Vehicles (UAVs) are another example of autonomous vehicles where they have the ability of sensing their environment without human involvement by using some cases such as smart agriculture, safety systems, and monitoring of the environment [104].

6.3. Healthcare

Health facilities, based on IEC solutions, became an important area to adopt 5G technologies [37,105,106]. For instance, some of the medical services as tele-surgeries require extremely low latency, uninterrupted communication links and collaboration between surgeons located in different locations. As another example, monitoring patients remotely in places away from medical facilities enables doctors to interact with them effectively. Based on these situations and potential usage scenarios, IEC's role in the health and social aid industries becomes more apparent. Previous research investigated the cooperation between IEC and IoT in the healthcare areas [107,108]. IEC and 5G technologies also enable critical medical services including examining large numbers of patients in a short time and with less effort. Therefore, doctors dispense with a long time to analyze these tests without eliminating the presence of a doctor. Besides, IEC enters the medical paths of doctors in the future and it could be an auxiliary tool for the doctors. In addition, IEC technologies have the ability to predict diseases through an application that analyzes data, predicts infections and diseases that enable doctors to take the critical decision and diagnose the diseases [109,110].

6.4. Gaming, AR and VR

The integration of 5G wireless systems and mobile computing is recognized as a driving force for the development of immersive content for virtual and augmented reality content. Based on the data aggregated by IoT, the human is more able to interact with technologies through augmented reality, virtual reality or mixed of them [111]. AR is technology based on dropping virtual objects and information into the real user environment to provide additional information whereas, VR is based on projecting real objects in a

virtual environment. Users can deal with AR information and objects through several devices, including portable ones, such as smartphones, wearable devices such as glasses and lenses [6]. All of these devices use a tracking system that provides accurate forecasting. As defined by the European Telecommunications Standards Institute (ETSI), IEC is considered to be sufficient method for low latency in AR and VR applications and services, especially when dealing with physical reality [90]. Additionally, IEC platforms have the ability to provide high capacity and low latency wireless coverage for big places such as smart cities with an enormous density of people enjoying AR and VR experiences.

6.5. Smart Energy

With the use of many smart applications and artificial intelligence in the development of smart cities, cloud computing has become crowded with data. Through this method, a new paradigm for saving energy is used in cloud computing where energy level in various cloud computing can be monitored while energy use and distribution could be predicted [36]. The Smart system has the ability to analyze and evaluate the data continuously both power flow and power transmission infrastructure. Due to this, the smart grid provides two-way flows of electrical energy and enables two-way real-time and automatic information flow. On the one hand, smart power grids can accept many different energy sources and switch dynamically between them unlike traditional power grids, which are less flexible. Although smart grids have been around for some time now, technological advances have taken them to the next level. Smart grids can use modern technologies such as artificial intelligence and the IoT—a system made of computers and Internet-connected devices that can dynamically share and act on data—to collect information, increase operating efficiency and automate processes. Generally speaking, smart grids span large geographic experience bandwidth bottlenecks and connection delays due to poor network connectivity and the overwhelming number of devices generating data. However, the architecture of cloud-based is not sufficient depending on heavily central processing [112]. IEC's features enable near-user processing and performing. Moreover, the potential attack points of the network increase as the ubiquitous sensor penetration grows. In addition, IEC provides the opportunity to enforce a security mechanism closer to peripheral devices [44].

7. IEC in 6G and Open Research Challenges in IEC with 6G Network

Telecommunication network technologies are experiencing a period of rapid change and high opportunity. In particular, the impact of 6G Network's capabilities on distributing and managing network functions will dramatically increase network resilience. These combined developments will transform a paradigm shift in how future networks are envisioned, designed, and perform for the next decades, shown in Figure 3.

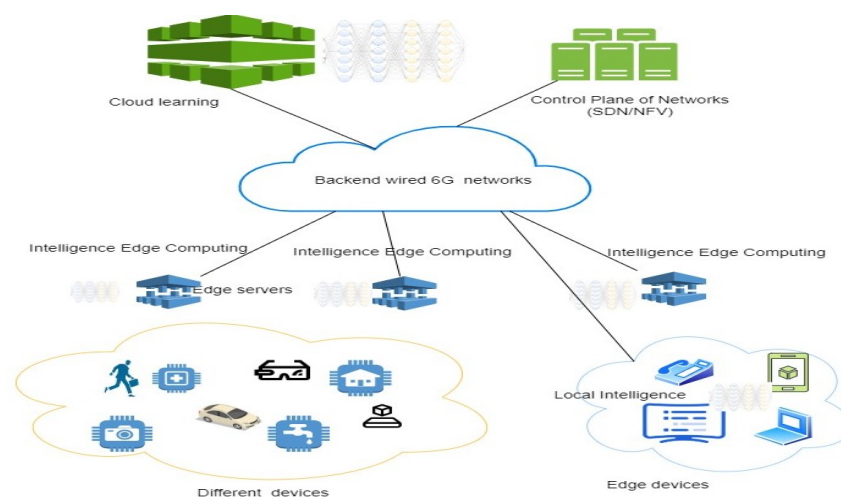


Figure 3. IEC and 6G Integration.

7.1. Emerging Technology and Business

The next generation of intelligent edge computing after AR and VR in 6G will include more sufficient technologies and services such as holographic media and multi-sense service. New media will be more effective based on its realism and attractiveness in rendering objects. Holographic media provides magnificent remote presence and merging some of the lifetime applications such as remote surgery which means this media is not limited to the realm of entertainment or teleconferencing.

Holographic Communications: applications of holographic became more sufficient day after day starting by light display technologies to develop HMDs. Holographic technologies are on their way to become a reality where they have the ability to transfer holographic data remotely. Holographic-Type Communications (HTC) will have the ability to project participants remotely to be attendants in virtual space. Furthermore, a combination of HTC and tactical networking applications will allow users to interact with hologram.

Multi-Sense Networks: used networking applications including optical, acoustic and tactical are not the only target for IEC in 6G Network but also the other lower senses such as smell and taste. The lower senses focuses on the near chemical interaction in opposite to vision and hearing that involve far distance perception of remote sources. Some progress has been made to simulate the sensory sensation such as digital lollipops, but these technologies face many challenges. For instance, the ability of digital multi-sensors in some of the advertisement applications could be improved by adding smell sense.

Time Engineered Applications: time-engineered applications will have a significant role in 6G Networks based on the human need to remember some events or rescheduling and handling some voice or video communications that have problem in connection. Most of the machines are built to achieve special tasks such as automotive machines, sensors and autonomous systems where they are not supposed to determine the time loops which unable to overcome delay or slowness. Sensors, actuators, and tiny entities of networks are supposed to perform within milliseconds.

Effective Infrastructure: referring to necessary infrastructure that is supposed to continue to smooth the use of network and improvement of services in 6G Network in the future. One of the primary goals of 6G Network is identifying new capabilities to face challenges of security, rescuing of any subjects anytime and emergency situations. In particular, the 6G Network will have the ability to identify how subjects are associated with devices by using time centric sensors [113].

7.2. 6G Network Momentum

Emphasizing the importance of digital society and the role of the Internet have been increasingly discussed since 2014 [2]. Putting the human in the center of technology development and enhancing the service for more use of these technologies is one of the goals of 6G Network including penetration of technologies in all aspects of human life, media, and holographic and increasing networks capabilities. Indeed, our life is increasingly impacted by new technologies and networking services.

Troubled or Active Market: drivers of market penetration in networking technologies include Bandwidth capabilities, lower latency and high reliability. On the other hand, high cost of introducing possible network solutions and the ability to replace the hardware with sophisticated software such as software-defined networking (SDN) have become a critical issue in 6G Network.

Current Communication Challenges: the purpose of the 6G Network initiative is to define the current network's abilities and opportunities and to reduce next generation challenges by introducing possible solutions for use of and emerging technologies in 2030. The initiative is based on new technologies, new media, new infrastructure and new services. However, there are some consideration must take into consideration including:

- *Connectivity:* there is a lack of research to find proper connection among applications and networks such as network reliability, security of delivered data, level of awareness, and capacity.

- *Holographic and multi-sense media:* streaming of holographic media has a very large scale of transferring data per second. It is not a limited problem for end-user or bandwidth problem but more about the ability of the network to enable connection without any jitter which may decrease the behavior of interactive applications.
- *Accuracy of services time:* Most of the market segments aim to be operationally and mechanically independent, both of which are time-bound functions. Factory automation aims to eliminate wasted time, improve quality, and be cost-effective, relying heavily on every sensor, actuator, electronic physical system, and robot to perform with the pinpoint accuracy of a few milliseconds.
- *Coexistence of Heterogeneous of Network Infrastructure:* Networks in general, and not just on the edge, are becoming increasingly more affluent in terms of technology, ownership, and end-user engagement. It is very likely that there is not only one network, but several public Internet networks. As a result, 6G Networks will need more consideration in terms of internet environments (Table 2).

Table 2. Vertical Markets in 6G Network [3].

Entertainment	Healthcare	Automotive	Education	Industry
Tele-Presence	Tele-Surgery	Coordinated	Coordinated	Autonomous
Holo-portation	Tele-monitor	Situation Response	In-place Presence	Automation
Multi-Sense	Tactile	Time Awareness	Holographic Media	Time Awareness
Holographic Media	Haptics	Tactile	Haptic	Tactile

1. *Entertainment:* tele-presence in entertainment refers to the adoption of new technologies such as robotics to experience feeling of being present even the person is in another location. For instance, conducting teleconference video-call in daily meetings where several people carry out their presence to the same location. Furthermore, holo-portation depends on augmented and virtual reality tele-presence in 3D where objects and people interact in 3D teleportation in real time. Additionally, multi-sense, holographic media and gaming have changed the face of entertainment by involving overlaying the physical environment with virtual elements. Holographic 3D-capture technology and its applications for holo-portation and media are completely transforming how we exist as social beings.
2. *Healthcare:* Tele-surgery is about delivering a real-time healthcare service effectively and accuracy to a remote location depending on wireless channel. The use of telemedicine in pre-operative evaluation and diagnosis, post-operative evaluation and follow-up visits became increasingly significant. Patients reported benefits of using telemedicine such as avoiding unnecessary trips to hospitals, saving time and reducing the number of lost work days.
3. *Automotive:* refers to self-propelled vehicles or machines. Automotive applications and technologies have a huge use in different industries including broadcasting, communication, computing, instrumentation, security, programming and networks. Situation response and time-awareness include devices that integrate with the vehicle, such as navigation systems and remote information systems, as well as those carried by drivers, such as cell phones, PDAs, etc., and they also include more advanced automation technologies, such as adaptive cruise control and lane-centering systems. Recently, automotive in vehicles has increased dramatically, with electronic control units (ECUs) communicating over increasingly complex and heterogeneous networks and presenting challenges in scalability, verification, and security.
4. *Education:* in place presence or holographic in education refers to ability to use holographic representations in three-dimensional and life-size such as holographic video-conferencing. The HVC technology-enabled presenters to appear as 3D, life-size entities and to interact with the audience in real time. Monitors and holographic images were calibrated so that presenters were able to point to and achieve eye-contact with members of the audience. The adoption of HVC within higher education is at an

early stage; however, there are significant efforts to ingrate these technologies in the near future.

5. *Industry*: automation and time awareness in industrial sector refer to the use of control systems, such as computers or robots, and information technologies to deal with the various processes and mechanisms in an industries to replace the human being. It is the second step after mechanization in the manufacturing scale. Industrial automation is categorized into four types including fixed, programmable, flexible and integrated automation systems. The main goals of adopting automotive technologies are speeding up productivity, better use of resource, improve human safety and reducing mistakes.

7.3. 6G Network Market

Many expectations of emerging technologies and network of 6G and beyond, based on the 6G Network and its infrastructure. Positioning of 2030 Networks will depend on different edge computing technologies and advanced communications. Integration between 6G Network and edge computing mobile and wireless is expected to be more effective and practical. Many verticals will depend on the 6G Network infrastructure to enter the market. 6G Network promotes the horizontal ICT sector by enabling new services which will foster the creation of cutting-edge applications in a variety of industries.

One of the most important factors in entering new markets is the flexibility achieved through the allocation of the resources used and the ability to program and customize them. Such customization and computing will fulfill the need for bandwidth, latency and localization. Furthermore, the ability of compounding service that depends on both time or data transfer and tactile internet will enable new communication services to enter new markets. Some of the emerging market examples are education, healthcare, energy, entertainment and industry.

Taking into account the rapid evolution of wireless networks and the core of the network, it is believed that AI in general and machine learning in particular will play a significant role in next-generation networks (i.e., networks of the fifth and subsequent generations). Recently, machine learning has been used in a variety of applications, such as virtual personal assistants, video surveillance on social networks, filtering spam and malware by email, search engines, etc. In the future, machine learning (ML)-based approaches, including reinforcement learning, supervised/unsupervised learning, deep learning, transfer learning as well as federated learning for AI in MEC have become hot topics. For research in the field of using AI for communication networks, the following global tasks can be distinguished at present:

1. Unambiguous identification of traffic in the communication network, without introducing additional delays in the flow, in order to meet the requirements of communication networks with ultra-low delays.
2. System online monitoring of a communication network from data flow, including virtual, to multi-parameter models of a network segment with many devices and systems.
3. Short-term and long-term forecasting of the load both on network elements and on entire segments.
4. Short-term and long-term prediction of the behavior of data streams at the data transfer level and service flows at the control level.
5. Long-term forecasting of the load on the network and computing infrastructure, taking into account trends in traffic profiles, types of services, in order to determine and automatically generate proposals for reducing or expanding the network, as well as its threshold characteristics.
6. Efficient allocation of 5G radio coverage with a prediction of cell load.
7. Enhancing signal quality with predictive physical layer codecs.
8. Short-term and long-term forecasting of user needs for certain services.
9. Predicting the user's movement geographically, as well as the formation of a model of his preferences in the content.

10. Recognition and prediction of malicious attacks on the system with the formation of a proactive response to a possible attack.
11. Application of AI technologies to consistently distribute services over the network on edge computing and fog computing frameworks.
12. AI-based MEC system for integrating heterogeneous IoT technologies with 5G cellular system.
13. Security-aware data offloading and resource allocation for edge computing systems

8. Conclusions and Discussion

We comprehensively surveyed and investigated Intelligence Edge Computing (IEC) characteristics and benefits, challenges, potential use cases and market driver. Every part of this paper started with an overview then was followed by intensive investigations of IEC factors in 5G networks. 5G applications empowered by IEC technology are being enabled by extending some intelligence to the edge of the network. To summarize the main contributions of this paper, some conclusions are as follows:

- Integration of IEC in 5G technologies enables sufficient and massive support for different services including IoT, smart environments, augmented and virtual reality, and sustainability of energy systems, vehicles connection, network performance, video games, economic services, education technology, ICT markets, and communication.
- IEC's main characteristics and benefits include proximity of end-users, ultra-low latency, location awareness, integrated virtualization, super network performance, flexibility, real-time analytics, and automation.
- IEC's current and up-to-date challenges include privacy and security, latency, distributed resource management, data traffic and bandwidth, heterogeneity, and scalability in addition to some issues related to network openness, multiple services and processes, data management, durability and resilience.
- IEC's potential use cases and applications that have been investigated in this paper include three main categories as customer-oriented services, operator and third-party services, and network performance and QoE improvement. To enhance these categorizations, it is essential to integrate IEC in 5G technologies.
- IEC's Market Drivers vary based on the different use and accessibility of 5G technologies in various sectors. We investigated five main sectors including smart environments, autonomous vehicles, healthcare, gaming in AR and VR and smart energy.
- Intelligence Edge Computing will have a significant role in 6G Network. Some of the examples and methods of using IEC in business have been discussed in addition to the architecture, momentum and market drivers of IEC in 6G Network.

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