Augmented and virtual reality for education: a case study in 5G network slicing

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Abstract

Computer networks are used in the most diverse spheres of human activity; accordingly, they are studied by various specialists with the degree of detail necessary for them. For this purpose, the educational process uses modern tools and technologies, including Augmented Reality (AR) and Virtual Reality (VR). AR/VR in education is mainly focused on providing a detailed study of certain components by deeper immersion in them, for example, in devices that are network components. In our work, we focus on the network aspects that can enable the use of AR/VR in the learning processes, taking the capabilities of 5G technology. Developed information technology allows us to realize and demonstrate the process of creating 5G network slices, their maintenance, and deactivation. An example of creating the 5G network slice oriented to the use of Augmented Reality for education is given. Developed information technology allows us to realize and demonstrate the process of creating 5G network slices, their maintenance, and deactivation. An example of creating the 5G network slice oriented to the use of Augmented Reality for education is given.

Keywords

Information Society, E-learning, Augmented Reality, Virtual Reality, Extended Reality (XR), Computer Networks, Network Slicing, 5G, Interactive Learning, Education

1. Introduction

Augmented Reality (AR) is a technology that overlays digital information, such as images, videos, or 3D models, onto the real-world environment in real time [1]. Unlike Virtual Reality (VR), which immerses users in a completely artificial environment, AR enhances the real world by adding computer-generated content to it [2]. AR technology typically relies on devices such as smartphones, tablets, smart glasses, or AR headsets to deliver the augmented experience [3].

The integration of augmented reality (AR) and virtual reality (VR) technologies into educational environments is reshaping traditional learning paradigms [4]. These immersive technologies offer unique opportunities to engage students, foster creativity, and enhance comprehension by simulating real-world scenarios or visualizing abstract concepts in ways that conventional methods cannot achieve [5]. As education increasingly shifts toward personalized and interactive approaches, AR and VR are emerging as pivotal tools in the digital transformation of learning [6].

Augmented reality enhances the physical world by overlaying digital content, such as images, text, and interactive elements, onto real-world environments [7]. This technology has proven particularly effective in disciplines like biology, where students can explore the human body in three dimensions, or geography, where they can examine topographical features as though they were physically present [8]. Such applications make complex subjects more accessible, helping learners grasp intricate details and relationships that might otherwise be difficult to visualize.

Virtual reality, on the other hand, immerses users in entirely virtual environments [9], enabling experiences that are either impossible or impractical in the real world [10]. In vocational training, for example, VR allows students to practice procedures like air-craft maintenance or medical surgeries in a risk-free environment [11]. Similarly, history classes can leverage VR to transport students to

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ancient civilizations, fostering a deeper connection with historical contexts [12]. These immersive experiences are not only engaging but also support experiential learning, a critical factor in knowledge retention and skill development [13].

One of the most compelling aspects of AR and VR in education is their ability to accommodate diverse learning styles [3]. Visual learners benefit from vivid imagery, kinesthetic learners engage through interactive elements, and auditory learners gain from synchronized soundscapes [14]. This adaptability ensures that these technologies can support inclusive education, addressing the needs of students with varying abilities and preferences [15].

Furthermore, AR and VR are transforming collaborative learning. Multi-user VR platforms al-low students from different locations to meet in virtual spaces, solve problems, and conduct experiments together as if they were in the same room [16]. This global connectivity fosters cross-cultural understanding and teamwork, skills that are increasingly vital in today's interconnected world.

The main contributions of this paper can be summarized as follows:

- information technology for 5G Network Slicing focused on using AR/VR in education has been developed and demonstrated;
- a functional decomposition method for teaching the 5G Network Slicing topic is proposed and developed;
- it is shown that the combination of 5G network technology and AR/VR can provide innovative solutions for educational purposes.

2. Literature review

2.1. The Key Characteristics of Augmented and Virtual Reality Technologies

Augmented Reality represents a transformative technological advancement that seamlessly integrates digital content with the physical environment in real time [17]. Unlike Virtual Reality, which creates fully immersive artificial environments, AR enhances real-world experiences through the strategic overlay of computer-generated elements [18]. This enhancement is facilitated through various devices, including smartphones, tablets, and specialized AR headsets [19].

The fundamental architecture of AR systems includes several main components. At its core, AR technology relies on computer vision algorithms to interpret and process environmental data captured through cameras and sensors [20].

This processing enables real-time interaction between users and digital elements within their physical space. The technology uses both marker-based and markerless approaches for environmental recognition. While marker-based systems require specific visual triggers such as QR codes, markerless systems utilize advanced sensor arrays, including GPS and accelerometers, to dynamically map and augment the environment [21].

Spatial mapping represents another crucial aspect of AR functionality. These systems generate detailed environmental maps, ensuring precise alignment between virtual objects and physical spaces [22]. This spatial awareness enables convincing integration of digital content within the user's surroundings. Furthermore, modern AR interfaces incorporate natural interaction methods, including gesture recognition and voice control systems, allowing users to manipulate virtual content through intuitive commands and movements [23].

The implementation of AR technology relies heavily on specialized Software Development Kits (SDKs). These comprehensive toolkits provide developers with essential resources for creating AR applications, including frameworks for object recognition, environmental tracking, and real-time rendering capabilities. This technological infrastructure supports diverse applications across multiple sectors, from educational simulations and healthcare visualization to retail applications and marketing initiatives.

The versatility of AR technology has led to its widespread adoption across various industries. In educational contexts, AR enables interactive learning experiences through dynamic 3D visualizations. The healthcare sector utilizes AR for surgical planning and medical training. Retail applications include virtual product try-ons and interactive shopping experiences, while marketing professionals leverage AR for immersive promotional campaigns.

Therefore, key characteristics and components of AR and VR include:

- Real-time Interaction

AR enhances the real-world environment by superimposing digital elements onto it in real time. This allows users to interact with both the physical and virtual aspects simultaneously.

- Marker-based and Markerless AR

Marker-based AR requires a specific visual marker or trigger, such as a QR code or image, to initiate the augmented experience [24]. Markerless AR, on the other hand, uses the device's sensors (like GPS, accelerometers, and cameras) to detect and augment the environment without the need for predefined markers.

- Devices

AR experiences can be delivered through various devices, including smartphones, tablets, smart glasses, and AR headsets [25]. The choice of device depends on the application and the desired level of immersion.

- Computer Vision

AR systems often rely on computer vision technology to recognize and track the real-world environment [26]. This involves the interpretation of data from cameras and sensors to understand the user's surroundings [27].

- Spatial Mapping

AR systems can create a spatial map of the physical environment, allowing digital content to be accurately placed and interact with the real world [28]. This is crucial for maintaining the alignment of virtual objects with the user's surroundings [29].

- Gesture and Voice Control

AR interfaces often incorporate gesture recognition and voice control, enabling users to interact with augmented content using natural movements or spoken commands [30].

- Applications

AR finds applications across various industries [31], including gaming, education, healthcare [32], retail [33], marketing [34], and more. Examples include AR navigation, educational simulations, virtual try-ons for online shopping, and interactive marketing campaigns [35].

- AR Software Development Kits (SDKs)

Developers use AR SDKs to create applications and experiences. These SDKs provide tools and resources for implementing features like object recognition, tracking, and rendering in AR applications [36].

2.2. The Educational Impact of Augmented and Virtual Reality Technologies

As AR technology continues to evolve and expand its applications, it has emerged as a significant driver of innovation in the digital landscape [37]. The advancement of hardware capabilities and increasingly sophisticated software solutions has enabled seamless integration between digital and physical realities, particularly in the educational sector [38].

AR and VR technologies are fundamentally transforming educational methodologies by creating immersive, interactive learning environments. These technologies enable students to engage with educational content in unprecedented ways, facilitating deeper understanding through di-rect experimentation and visualization. For instance, complex molecular structures in chemistry or intricate historical scenarios can be rendered in three-dimensional space, allowing students to examine and interact with them from multiple perspectives [39].

The implementation of AR and VR in education has demonstrated particular value in personalized learning approaches. These technologies adapt to individual learning styles and paces, creating customized educational experiences that address specific student needs. This personalization extends beyond content delivery to include assessment and feedback mechanisms, ena-bling educators to track student progress more effectively and adjust instruction accordingly.

Distance learning capabilities have been significantly enhanced through AR and VR integration. Virtual classrooms and remote learning environments now provide students worldwide with access to high-quality educational experiences, regardless of geographical constraints. These platforms facilitate collaborative learning experiences, enabling students to work together in virtual spaces while developing essential teamwork and communication skills.

The practical applications of these technologies are particularly evident in professional and technical education. In fields such as medicine, aviation, and engineering, VR simulations provide safe, controlled environments for students to practice complex procedures and develop critical skills. These virtual training scenarios offer realistic experiences without the risks associated with real-world practice, allowing students to build confidence and competency before engaging with actual equipment or patients.

Furthermore, AR and VR technologies are proving instrumental in cultural and historical education. Virtual field trips and historical recreations transport students to different time periods and locations, providing immersive experiences that enhance understanding of diverse cultures and historical events. This experiential learning approach creates lasting impressions and deeper connections with the subject matter than traditional teaching methods.

The integration of these technologies also promotes the development of digital literacy and technical skills crucial in the modern workplace. As students become proficient in navigating virtual environments, they simultaneously acquire competencies valuable for future career opportunities in technology-driven fields [40].

The educational benefits of AR and VR extend beyond traditional academic out-comes. These technologies have demonstrated significant positive effects on student motivation and engagement. The interactive and immersive nature of virtual learning environments captures student interest and maintains attention, leading to improved learning outcomes and retention rates.

As educational institutions continue to adopt these technologies, the potential for innovative teaching methods and learning experiences continues to expand. The com-bination of immersive technology with traditional pedagogical approaches creates a powerful platform for educational advancement, promising to reshape the future of learning across all educational levels and disciplines.

3. Materials and Methods

3.1. Augmented and Virtual Reality

3.1.1. Features of using AR/VR technologies

The number of users of devices that have the ability to use augmented reality is currently significant and has a tendency to constantly grow [41]. As can be seen from Figure 1, the number of active mobile AR users worldwide is expected to increase by 18% from 2023 to 2028.

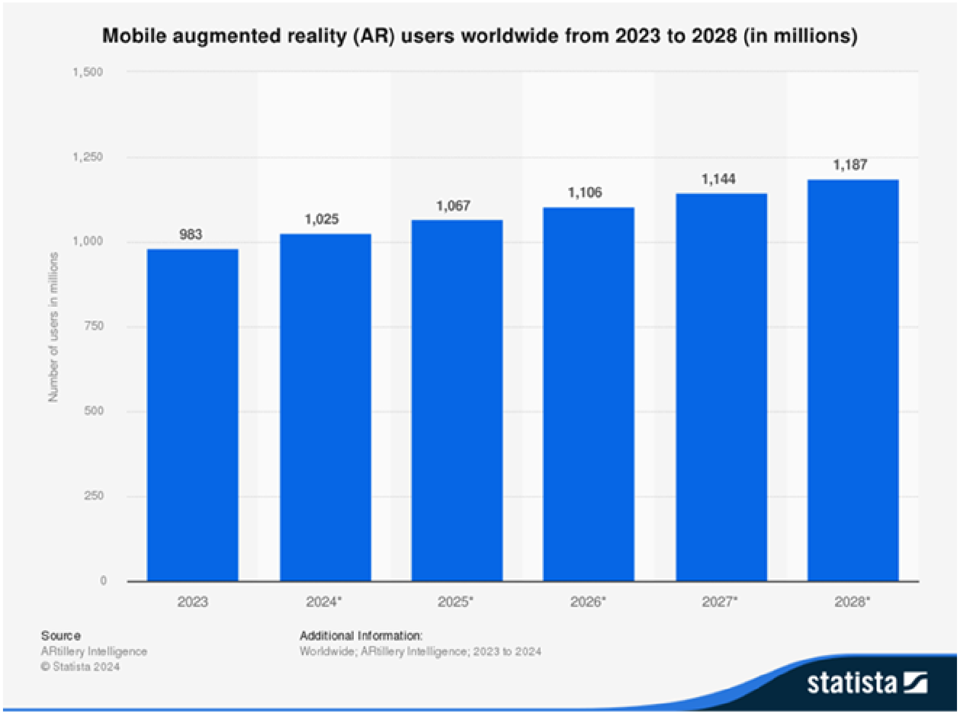

Figure 1: The number of mobile AR active users worldwide from 2023 to 2028 [41].

The above data indicate the possibility and expediency of the wide implementation of Augmented Reality in education. Some works devoted to this problem also testify to the relevance and timeliness of using AR in education.

A systematic literature review on the use of augmented reality in the teaching of technical and mathematical disciplines for the development of students' spatial skills is given in [42]. A number of works are devoted to the implementation of innovative methods in the study of computer networks [43], [44]. In [45] developed an Augmented Reality Application for studying Computer Network Devices. The methodology used in this research includes the following steps: Problem Identification, Planning, Design, Testing, and Implementation. In [46], based on the Research and Development (R&D) method, AR is used to make it easier for students to understand the process of installing computer networks.

When using augmented and virtual reality technologies, several problems related to computer network bandwidth may arise due to the increased demands on data transmission:

1. High Bandwidth Requirements

AR and VR content, especially high-quality 3D models and immersive environments, often require large amounts of data to be transmitted in a short time. This high bandwidth requirement can lead to congestion and slower network speeds, affecting the quality of the AR or VR experience. In [47] compared bandwidths required by the level of AR/VR usage by CISCO and Ovum. It was assumed that by 2024, one-third of household members will be active users of VR/AR devices. This projection aligns with Cisco's compound annual growth rate (CAGR) of 38% for wearable VR/AR equipment. Considering a compression ratio of 50% of the original file size, the bandwidth requirements for SD, HD, and Retina VR games are estimated at 25 Mbps, 40 Mbps, and 300 Mbps, respectively [47].

2. Latency Issues

Low latency is crucial in AR and VR applications to ensure a seamless and realistic user experience. High latency, or delays in data transmission, can result in a lag between user actions and the corresponding changes in the virtual environment, causing discomfort and reducing the effectiveness of the technology.

For example, in [48], the authors indicate that most participants are generally satisfied with the VR system, with minimal impact on symptoms reported in the Simulator Sickness Questionnaire (SSQ). The study on display and joystick delays revealed significant effects of higher dis-play delays (30 ms) on Comfort and Immersion Quality, as well as a strong influence on SSQ symptoms, leading some participants to discontinue the tests. Conversely, joystick delays had minimal impact on performance or scale up to 200 ms, with only weak effects observed at 400 ms and strong effects at 800 ms. Delays of approximately 0.5 seconds were found to be noticeable and disruptive. While most participants tolerated the VR simulator well, a few reported moderate or severe symptoms, and two out of thirty terminated the tests prematurely. Overall, the study [48] concludes that display latency should be kept below 30–35 ms to avoid significant effects, while joystick latency can be tolerated up to 0.5 seconds with limited impact

3. Stability of Connection

AR and VR experiences require a stable and consistent network connection to avoid disruptions or artifacts in the display. Intermittent loss of connection or fluctuations in bandwidth can disrupt the smoothness and realism of the virtual experience. The article [49] emphasizes that stable, low-latency connections are crucial for AR and VR applications. Unstable connections can lead to increased latency, causing motion sickness and disrupting user immersion. The study highlights the importance of advanced communication technologies, such as 5G and beyond, in ensuring the stability and responsiveness necessary for effective AR and VR experiences.

4. Large Data Transfers

Virtual reality applications often involve the transfer of large volumes of data in real-time, such as streaming high-resolution 360-degree videos or transmitting complex 3D models. Insufficient network bandwidth may lead to buffering, reduced image quality, or interruptions in the streaming process [50]. Large data transfers in AR/VR are critical due to the high-resolution visuals, complex environments, and real-time interactivity required by these technologies. The data includes high-definition (HD) or retina-quality video streams, 3D models, and sensor data for tracking and interaction. Efficient data compression, low-latency networks, and high-bandwidth capabilities (e.g., 5G or fiber optics) are essential to ensure smooth user experiences [51]. Insufficient bandwidth or delays in data transfer can result in latency, reduced visual quality, or disruptions, which significantly affect user immersion and satisfaction. Advanced technologies and optimized protocols are necessary to handle these large data requirements effectively [52].

5. Multi-User Environments

In scenarios where multiple users are interacting with the same augmented or virtual space simultaneously, the demand on network bandwidth increases significantly. Collaborative AR or VR applications may require substantial bandwidth to synchronize the experiences of different users in real-time [53].

6. Data Compression Challenges

To reduce bandwidth requirements, data compression techniques are often employed. However, aggressive compression may compromise the quality of visual elements, leading to a trade-off between bandwidth conservation and maintaining a high-quality user experience.

7. Uploading and Downloading Content

Some AR and VR applications involve the continuous exchange of data between user devices and remote servers. Uploading and downloading content, such as user-generated virtual environments or updates, can strain network bandwidth, affecting the overall performance.

8. Mobile Network Limitations

In the case of AR applications on mobile devices, the limitations of mobile network infrastructure, such as 4G or 5G connectivity, may pose challenges. The availability and speed of the mobile network can impact the quality of the AR or VR experience.

To address these issues, it is essential to consider network optimization strategies, implement efficient data compression techniques, invest in higher bandwidth capabilities, and leverage advancements in networking technologies, such as 5G, to ensure a smooth and immersive augmented and virtual reality experience. Additionally, developers should prioritize the design of applications that can gracefully handle variations in network conditions.

3.1.2. Network Optimization Strategies for Augmented and Virtual Reality Applications

The growing adoption of augmented reality (AR) and virtual reality (VR) technologies presents significant challenges for network infrastructure due to their demanding bandwidth requirements. Let`s consider the key networking challenges and present effective optimization strategies for ensuring optimal performance in AR/VR applications.

Network Challenges in AR/VR Implementation

The implementation of AR and VR technologies faces several critical networking challenges. High bandwidth requirements for transmitting complex 3D models and immersive environments can lead to network congestion and degraded performance. Latency issues are particularly problematic, as even minor delays between user actions and visual feedback can significantly impact the user experience and potentially cause physical discomfort.

The stability of network connections presents another crucial consideration, as intermittent connectivity or bandwidth fluctuations can severely disrupt the immersive experience. This challenge becomes particularly acute in multi-user environments, where multiple participants must maintain synchronized experiences in real-time. Additionally, mobile implementations face specific constraints related to cellular network capabilities and coverage.

Optimization Strategies and Solutions

Several effective strategies have emerged to address these networking challenges. Content optimization serves as a foundational approach, focusing on efficient compression and optimization of 3D models, textures, and other virtual assets without compromising visual quality. This approach can be complemented by implementing adaptive streaming techniques that dynamically adjust content quality based on available bandwidth.

Edge computing has proven particularly effective in reducing latency by distributing processing capabilities closer to end-users. This approach, combined with the strategic implementation of

Content Delivery Networks (CDNs), can significantly improve response times and content delivery efficiency. The deployment of 5G technology further enhances these capabilities by providing increased bandwidth and reduced latency, particularly beneficial for mobile AR applications.

Advanced Caching and Distribution Methods

Advanced caching mechanisms play a crucial role in optimization by storing frequently accessed content locally on user devices. This approach significantly reduces the need for repeated downloads and minimizes latency. Progressive loading techniques further enhance performance by prioritizing essential content delivery while loading additional elements in the background.

The implementation of peer-to-peer networking presents an innovative solution for content distribution, enabling direct sharing between devices within the same virtual environment. This approach reduces server load and improves overall system efficiency, particularly in collaborative scenarios.

Technical Infrastructure Considerations

Network Quality of Service (QoS) settings play a vital role in ensuring optimal performance by prioritizing AR/VR traffic. The adoption of efficient network protocols, such as WebRTC, enhances real-time communication capabilities. Hardware acceleration capabilities can be leveraged to optimize processing tasks related to content rendering, particularly beneficial for resource-intensive applications.

Monitoring and Maintenance

Continuous network monitoring and optimization remain essential for maintaining optimal performance. Regular analysis of usage patterns and network metrics enables proactive identification and resolution of potential bottlenecks. This ongoing assessment allows for timely adjustments to network configurations and optimization strategies.

Integration of these various optimization methods requires careful consideration of specific application requirements and available infrastructure capabilities. Success in implementing AR/VR applications depends significantly on selecting and combining appropriate optimization strategies while maintaining flexibility to adapt to evolving network conditions and user requirements.

As AR and VR technologies continue to advance, the importance of efficient network optimization strategies will only increase. Organizations implementing these technologies must maintain a balanced approach that considers both current requirements and future scalability needs while ensuring consistent, high-quality user experiences.

3.2. 5G network technology

The use of augmented reality services places increased demands on the networks serving them. These networks must provide support for different services, guarantee the QoS, deal with the increasing number of users and devices, and optimize the network resources. New trends and applications, such as vehicular networks, wireless sensors, ubiquitous networks, heterogeneous wireless networks, cloud networking, and high-speed networks, are presented in [54], [55], and mobile ad-hoc Networks with IoT environment in [56]. The result of developing network technologies with improved capabilities is the fifth-generation networks 5G, which are constantly being improved [57], [58].

Traditionally, 5G services are divided into the following three categories:

- enhanced mobile broadband (eMBB);
- Ultra Reliable and Low Latency Communications (URLLC);
- massive Machine Type Communication (мMTC).

Table 1
Summary of five service categories of 5G [59]

Categories	Services
Immersive 5G Service	Massive Contents streaming
	Virtual Augmented Reality
	Telepresence
Intelligent 5G Service	Crowded Area Service
	User-centric Computing
	Edge/FOG Computing
Omnipresent 5G Service	Smart Personal Devices/Health
	Smart Building/Grid
	Smart City/Smart Factory Systems
Autonomous 5G service	Smart Transportation/Teleoperation
	Drone-based 3D connectivity
	Robot-based Service
Public 5G Servies	Private security and Public Safety
	Disaster Monitoring
	Emergency Service

The eMBB category improves 4G mobile broadband, providing high-speed Internet access even in poor environmental conditions. In turn, URLLC is intended for communications in which speed is not as important as low delay. For example, an autonomous vehicle in a critical situation may need a millisecond delay to make a decision. The mMTC is characterized by the connection of a large number of different devices, most often industrial, with low energy consumption, for which the main requirement is the stability and reliability of the connection. These are, in particular, sensors, measuring devices, and infrastructure objects of a smart city.

Another way of classifying 5G services is also known. Table 1 [59] presents the division of 5G services into five categories, where, among other categories, the immersion category is introduced. Virtual/augmented reality, telepresence, and mass streaming content services that require huge amounts of traffic volume are included in this category.

5G development scenarios relate to all everyday life aspects, including education. In combination with augmented reality (AR), 5G networks make it possible to offer and develop new innovative solutions for educational purposes [60]. A 5G network operator can split traffic, divide the network into subnets, or aggregate the bandwidth of multiple networks. This allows operators of 5G networks to select the characteristics necessary to support certain applications. Network Slicing can be used as a tool for this purpose [61]. Based on shared wireless infrastructure, universal computing, and storage resources, service providers can provide only as much throughput for specialized services as is necessary to customers' needs [62].

The concept of Network Slicing in 5G networks [63] is the best answer for operators on how to build a network that meets the increased requirements of users and manage it. The way to create such networks is to transform the network of a given infrastructure into a set of virtual sub-nets [55]. Each virtual network is designed to fulfill a specific business purpose and contains all the necessary network resources. The network functions you need can be flexibly built, quickly deployed, and automatically managed throughout their lifecycle.

3.2.1. Optimizing Quality of Service Parameters for AR/VR Applications Through 5G Network Slicing

Network slicing technology in 5G networks represents a transformative approach to meeting escalating user requirements through the creation of virtualized subnet architectures. This technology enables operators to partition physical infrastructure into virtual networks, each precisely tailored to specific business objectives while maintaining independent resource allocation and management capabilities.

The optimization of Quality of Service (QoS) parameters for AR/VR applications begins with comprehensive requirements analysis. This process involves a detailed examination of application-specific needs, particularly focusing on critical parameters such as latency tolerance, throughput requirements, and connection stability specifications. These requirements must be systematically categorized within the framework of 5G use cases, including enhanced mobile broadband (eMBB), multi billion device communications (mMTC), and ultra reliable low latency communications (URLLC) [64].

The specification of QoS parameters requires precise definition of performance metrics for each network slice. This includes establishing maximum acceptable latency thresholds, mini-mum throughput requirements, and reliability standards. These specifications form the foundation of Service Level Agreements (SLAs), which define both guaranteed performance levels and acceptable operating ranges for each AR/VR ap-plication slice.

The integration of edge computing capabilities plays a crucial role in optimizing network performance by reducing latency through localized data processing. This approach, combined with dynamic resource management mechanisms, enables real-time adaptation to varying network loads and application demands. The implementation of the SLICEX API facilitates dynamic net-work communication, allowing real-time adjustments to QoS parameters in response to changing application requirements.

3.2.2. Network Traffic Management and Optimization

Effective traffic management strategies are essential for maintaining optimal network performance. This includes implementing sophisticated traffic prioritization schemes, optimizing network routing protocols, and employing advanced data flow management techniques. These strategies ensure efficient bandwidth utilization while maintaining service quality across all network slices.

Continuous monitoring and performance assessment are crucial components of successful network slice management. This involves implementing comprehensive monitoring systems to track network performance metrics and analyze operational data. Real-world testing protocols verify that actual performance aligns with specified QoS parameters, while feedback mechanisms gather user experience data to inform ongoing optimization efforts.

The implementation of QoS optimization in 5G network slicing requires a sophisticated approach that balances technical capabilities with practical application requirements. Success de-pends on maintaining flexibility in response to evolving AR/VR application needs while ensuring consistent service quality across all network slices.

As AR and VR technologies continue to advance, the role of network slicing in supporting these applications becomes increasingly critical. Organizations must maintain adaptable optimization strategies that can evolve alongside technological capabilities and user requirements, ensuring sustained performance and service quality in this dynamic environment.

To estimate the part of augmented reality work in the total set of Use Cases when 5G Network Slicing was used, we analyzed the 5G Network Slicing dataset [65]. Figure 2 shows that the network slices were created for cases: Industry 4.0, Healthcare, AR/VR/Gaming, Smartphone, Smart Transportation, Smart City & Home, Public Safety, and IoT devices.

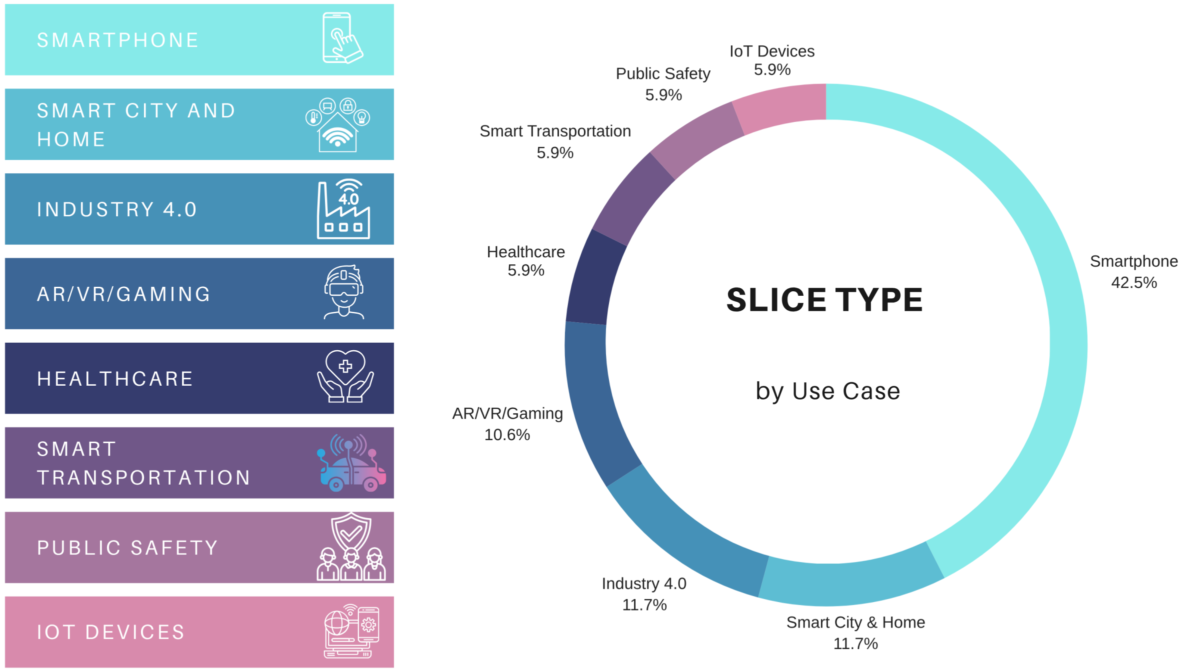

Figure 2: Slice type by Use Case.

As we can see, augmented reality, although compatible with virtual reality and games, occupies a significant part (10.6%) of total traffic and is in fourth place after Smartphones, Industry 4.0, Smart City & Home. Given the growing relevance of Augmented Reality, 5G technology, and Network Slicing, we have developed an information technology that will allow us to demonstrate to students 5G network slicing, including the case when creating an "Augmented Reality for Education" slice.

3.3. Approach to creating information technology for configuring logical subnetworks based on a shared 5G network infrastructure

3.3.1 Conceptual model

The conceptual model of information technology for configuring logical subnet-works based on a common 5G network infrastructure is represented in Figure 3. It consists of the following components:

- user interaction block;
- database, which acts as a repository of information for its further processing and use;
- visualization block, which transforms information into a visual form understandable to the user;
- IT-system.

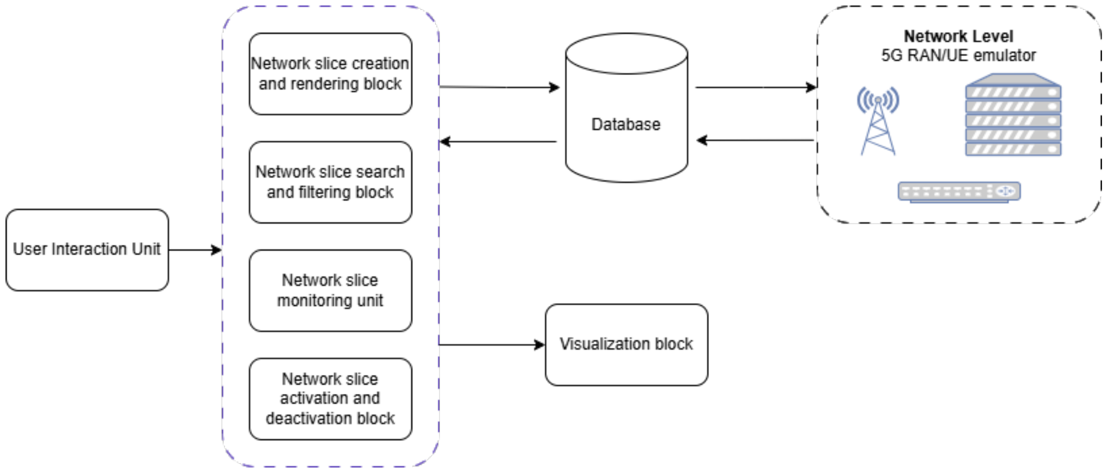

Figure 3: The conceptual model of information technology for configuring logical subnetworks based on a common 5G network infrastructure.

The IT system, in turn, consists of a block for creating and editing network slices, a block for searching and filtering network slices, a block for monitoring network slices, a block for activat-ing and deactivating network slices, and a Radio Access Network/User Equipment (RAN/UE) emulator.

3.3.2 Information Technology Architecture

The information technology architecture (Figure 4) is two-layered oriented. It includes the Operations Support System level (OSS) [66] and the Network's level.

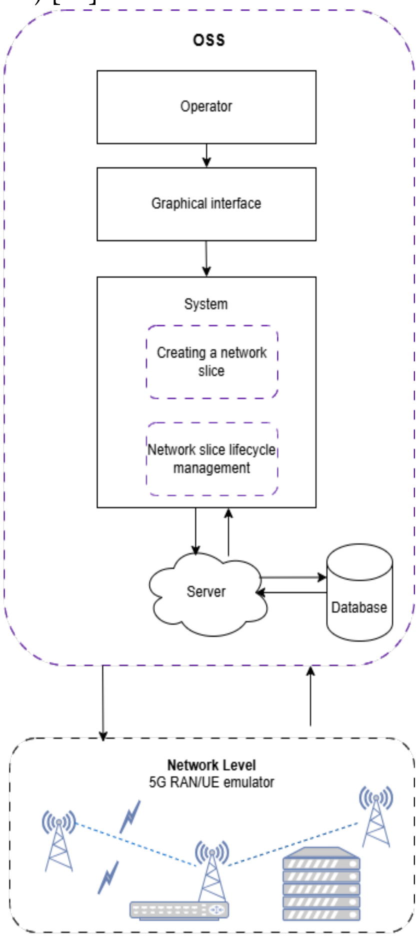

Figure 4: Information Technology Architecture.

OSS is intended for telecommunications service providers. It’s used to configure network components, provide services, and support network processes. The Operations Support System includes such components as:

- a graphical interface that is necessary for interacting with the system and presenting information;
- a system for configuring a network slice and managing its life cycle;
- a remote server on which the collected information is located;
- a database that contains structured groups of data about network slices for further work with them.

In turn, the network layer is a 5G RAN/UE emulator with access to a database containing data on network characteristics and services.

3.3.3 Logical subnet configuration algorithm

The flowchart diagram that depicts the approach to logical subnet configuration is represented in Figure 5.

The configuration process begins with creating a network slice. The created slice is checked by the Network's level for its compliance with QoS requirements. Based on the results of the check, the slice can be approved or rejected. If the network slice has passed the Network's level check, it can be edited if necessary. The next stage is the activation of the slice. The active slice is subject to constant monitoring until the operator decides to deactivate it. Deactivation ends the algorithm.

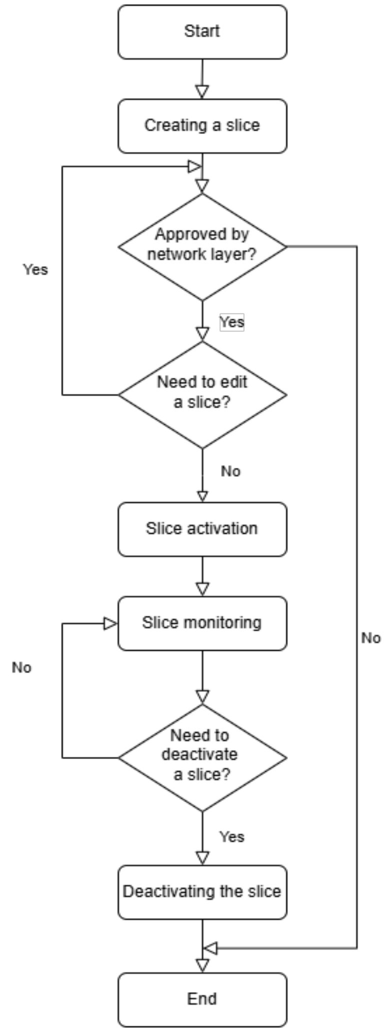

Figure 5: Logical subnet configuration algorithm flowchart.

The above diagram clearly illustrates the life cycle of logical subnets for a specific purpose.

4. Result and discussion

Let`s consider the developed information technology for setting up virtualized and independent networks created on top of a common physical infrastructure 5G, and illustrate it in the scenario of cutting the network for the use of augmented reality in education.

The system has a graphical web portal interface. The web portal provides users (customers, mobile network operators, resource providers) with an easy way to enter Quality of Service (QoS) requirements in the form of user intents. User intents are higher-level requirements for a slice, such as:

- slice information (slice ID/slice name);
- QoS requirements (data rate, throughput, latency, security requirements);
- coverage area;
- one of three service categories:

  1) eMBB (Enhanced Mobile Broadband);
  2) URLLC (Ultra-Reliable Low Latency Communication);
  3) mMTC (Massive Machine Type Communication).

A network slice refers to the physical and virtual resources required to operate network segments. A network slicing provider owns the physical infrastructure on which a lot of slices can be built.

The user interface for configuring logical subnets based on the shared 5G network infrastructure includes:

- Authorization page.
- Dashboard page.
- Page for configuring logical subnets.
- Page for editing logical subnets.
- Search page for logical subnets.
- Logical subnets details page.
- Logical subnet monitoring page.

The process of configuring logical subnets based on the common infrastructure of the 5G network, their maintenance, and elimination can be presented as follows.

Creating a slice. The Slice Creation process begins with the configuration of the slice instance (step 1 in Figure 6) and defines the requirements for the characteristics and service to be deployed.

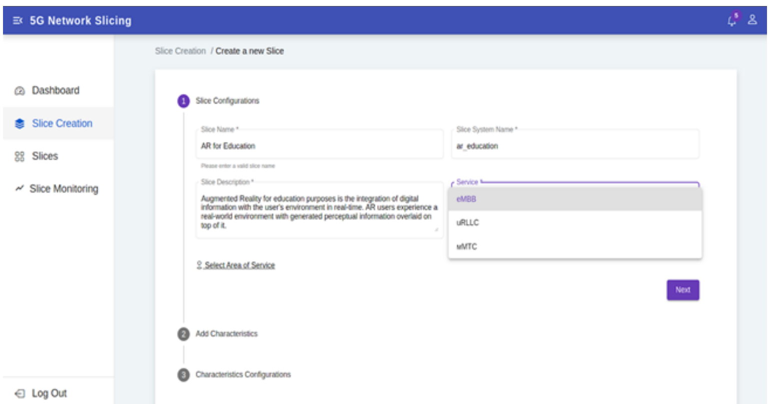

Figure 6: Entering information about the slice and service.

At the stage of configuration of the slice instance, the basic data about the slice are specified, such as:

- the name of the slice that will be displayed in the user interface (AR for Education);
- system name of the section (ar_education);
- slice description;
- the service that will serve the future network slice (eMBB);
- the zone in which you want to deploy the network slice.

Figure 7 illustrates the deployment of the service in the area of the Lviv Polytechnic National University of Ukraine.

The second step of creating a slice is adding characteristics (Add Characteristic). When opening this step at the stage of creating a new section (Figure 8), a dialog box appears with a list of available characteristics. From the list of available characteristics coming from the Network layer, the network characteristics that define the service requirements for the network slice can be added to the "Selected characteristics" table.

Figure 7: Selection of the zone to deploy the network section.

Different services have different network performance requirements. Some services require low latency and high speed, others high bandwidth and acceptable latency, or high security with acceptable data rate and latency. For the AR for Education network slice, this is Latency, Network Speed, Downlink Throughput, Uplink Throughput, and the number of devices or users that can be simultaneously connected to the network.

In the third step, you can configure the parameters of the added characteristics (Characteristics Configuration). Each characteristic selected in the previous step has a certain set of variability values, defined by the Network layer. The operator can leave the selected default value or define their own from the list of proposed values.

After the successful completion of the parameter setting procedure, the "Create Slice" button becomes active, allowing the Operator to save an instance of the slice with all settings. A request for data processing is sent to the Network layer, and the slice itself will be added to the table on the "Slices" page with a status of waiting for a decision (Waiting for Network approval).

On the "Slices" page in the table, you can view all the network slices that were created by the system and their statuses, or a specific network slice by using the search function and entering text in the "Search for slice" field. The following status values are possible:

- Waiting for Network approval - a response from the Network layer is expected;
- Rejected by Network - rejected by the Network layer.
- Ready to use - the slice has been checked at the Network level and is ready for activation.
- Active - the slice is successfully activated.
- Deactivated - the slice is deactivated by the Network Operator.

Activation. After the slice has passed the verification at the Network level, the status of the slice changes to 'Ready to use' or 'Rejected by Network' depending on the response received. If the status of the slice is 'Ready to use' (Figure 8), then the system provides the Operator with a certain list of actions that are possible with this slice, in particular:

- View details - view the details of the section.
- Edit - edit the slice.
- Activate - activate the slice.

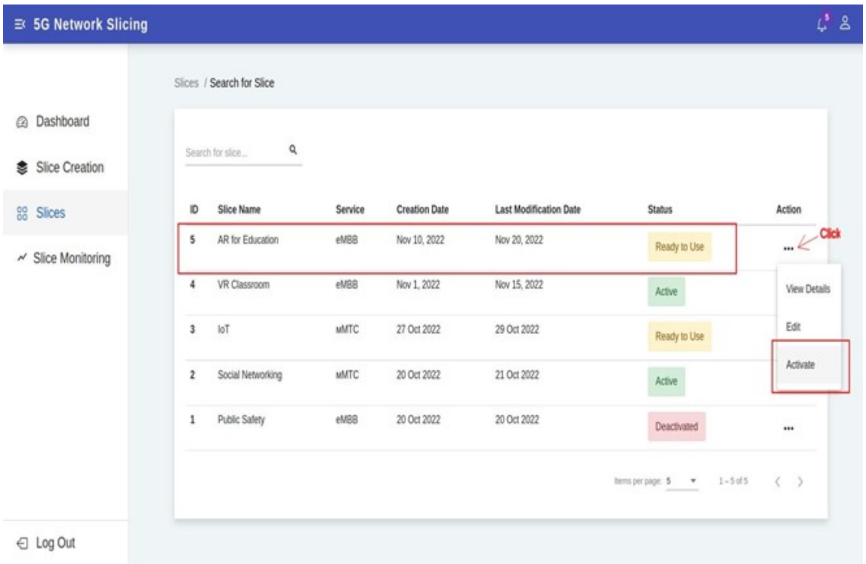

Figure 8: Approving the slice by the system.

Activating a slice makes it available for use. At the same time, its status changes to "Active" in the table, and the system sends a notification that the slice has been successfully activated. The cut, the creation of which we carried out with the help of our developed system, is ready for use.

Monitoring. To keep the slice in the right state, the activated characteristics of the slice are constantly monitored using monitoring tools. For this, feedback is provided to the Network layer, which dynamically, with the specified time interval, sends data for monitoring network indicators. Figure 9 shows the results of monitoring parameters Latency and Upper Throughput for slice AR for Education.

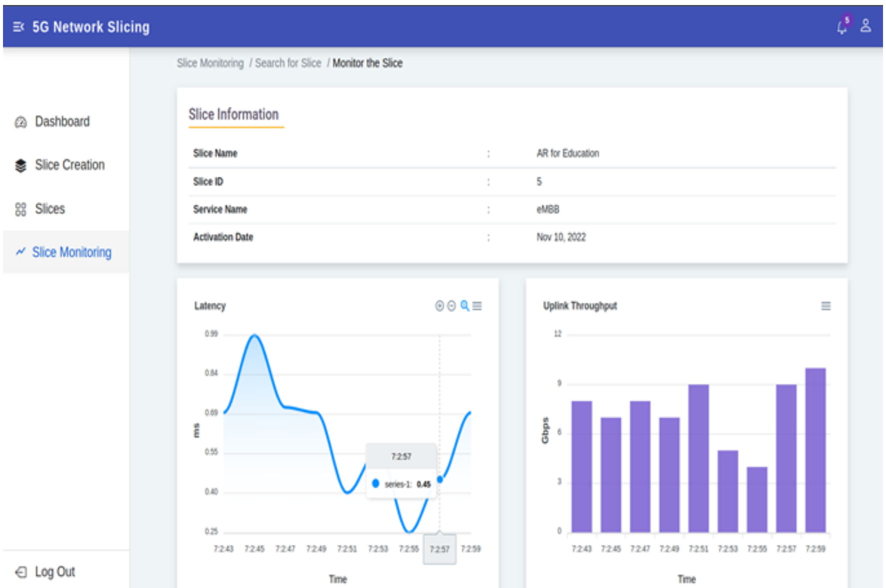

Figure 9: AR for the Education network slice monitoring page.

Deactivation. If the slice status is “Active”, then the system provides the Operator with a certain list of actions (Figure 10) that can be performed with this slice, in particular:

View details - view the details of the section.

Deactivate - deactivate the slice.

After selecting "Deactivate", the system will display a dialog box with a request for confirmation of actions to deactivate the network section. Only after the operator confirms his intentions to really deactivate the slice by pressing the "Yes" button, the system sends a request to the Network layer with a request to deactivate the slice. After the network level approves the received request, the operator receives a message about the successful deactivation of the network section.

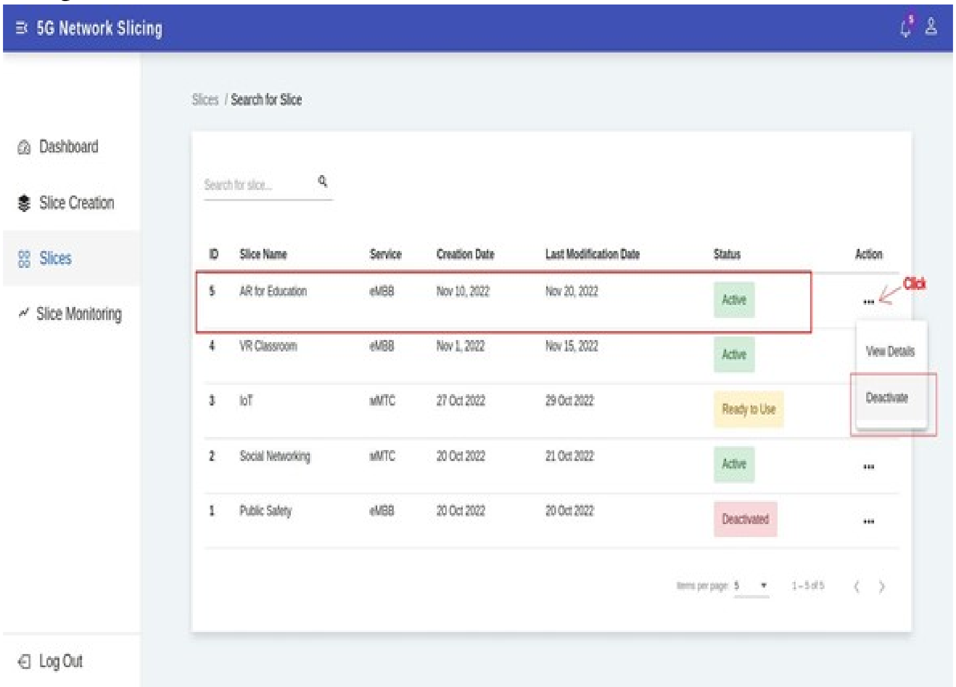

Figure 10: The process of deactivating the AR for Education slice.

The status of the network slice automatically changes to “Deactivated”, as shown in Figure 11.

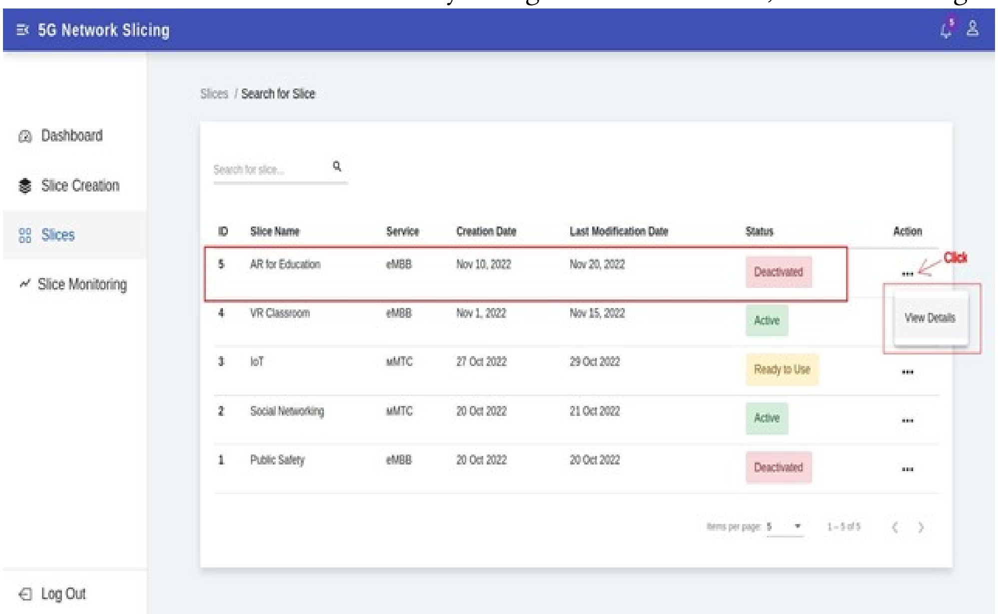

Figure 11: Changing the status on the Slices page after deactivating the AR for Education Slice.

The developed technology based on the concept of 5G Network Slicing clearly demonstrates the work process of creating a logical subnet for the use of AR technology in modern education.

5. Conclusions

The use of augmented and virtual reality in education goes beyond mere novelty; it represents a paradigm shift in how knowledge is delivered and consumed. By making learning more engag-ing, interactive, and inclusive, these technologies hold the potential to democratize education, bridge learning gaps, and prepare students for the demands of the 21st century.

The analysis of edge network devices showed that today many of them support applications with augmented reality, and statistical data indicate a tendency towards their intensive increase. Analysis of the network slices in the 5G network shows that the network traffic part focused on augmented and virtual reality is also significant. So, nowadays we have resources to implement the elements of augmented reality in the computer network learning process more intensively.

In addition to existing approaches involving, for example, the study of network devices using AR, we focused on the study of Network Slicing technology in 5G networks.

The information technology developed by us allows to demonstrate the process of creating network slices, their maintenance, and deactivation. An example of creating a network slice ori-ented to using augmented reality for education is given.

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Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT and Grammarly in order to: Grammar and spelling check. After using these tools/services, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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