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Edge Computing & Educational Systems: Towards Advanced and Intelligent Learning—*A Conceptual Overview*

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ABSTRACT

Edge Computing is an advanced area and sub component of Information Technology and is closer with cloud computing in some contexts. Edge Computing is getting closely working with end device and end users by computational processing of sensor data. This kind of Edge Computing basically stays away from the centralized system or nodes. Edge Computing is responsible in doing activities very close to the logical edge of the network and also particular individual data sources. Edge Computing is mistakenly also treated as fog computing, though it is close but differs with attributes. Edge Computing lies on distributed IT network architecture, and uses mobile computing systems and practically produces data locally. In Edge Computing instead of forwarding data from the data centers toward decentralized systems for uses real-time processing. Therefore such kind of computing not only reduces bandwidth and also storage requirements. Edge Computing thus offers data sovereignty, autonomy, and effective data security. Implementing useful and effective Edge Computing seeks security and effective connectivity with physical maintenance. Edge Computing simply helps in transforming the traditional education system into a smart education system; apart from higher education systems it also empowers traditional Schools into Smart Schools. Emerging Information and Communication Technology especially Edge Computing and similar systems are fruitful in designing, developing, and managing digital education systems. This chapter discussed Digital Education systems, especially Edge Computing applications in higher education systems.

Keywords: Edge Computing, Educational Informatics, Digital Education, E-Learning, Intelligent Systems, Higher Education

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Introduction

Edge Computing lies on distributed information systems of architecture and in this context client data basically processed in the periphery of the network and therefore connected with modern systems like IoT (refer Fig. 1). In traditional computing virtual data basically used and data models normally restricted in centralized systems[1],[17],[29]. Though, certain issues of bandwidth, and latency including unpredictable networks are also considered as important concern in edge computing. Such computing platform basically makes eligible some of the services as well as portions are out of the central data centre and thus it keeps systems close to the source data. In Edge Computing systems after generating such type of data it normally do not transfer it to the central data system but it operates in the place itself where data is been generated. Such computing systems basically work in real time data results and also required actionable answers are normally provided to the centre for review. In reshaping IT and computing systems and entire features of Edge Computing can be considered as worthy and valuable. Real-time feedback is important in designing friendly and effective student monitoring systems, AI and ML integrated learning management systems[7],[28],[37]. Edge Computing is enhancing students and teachers towards their ultimate aim and objective using the latest technologies.

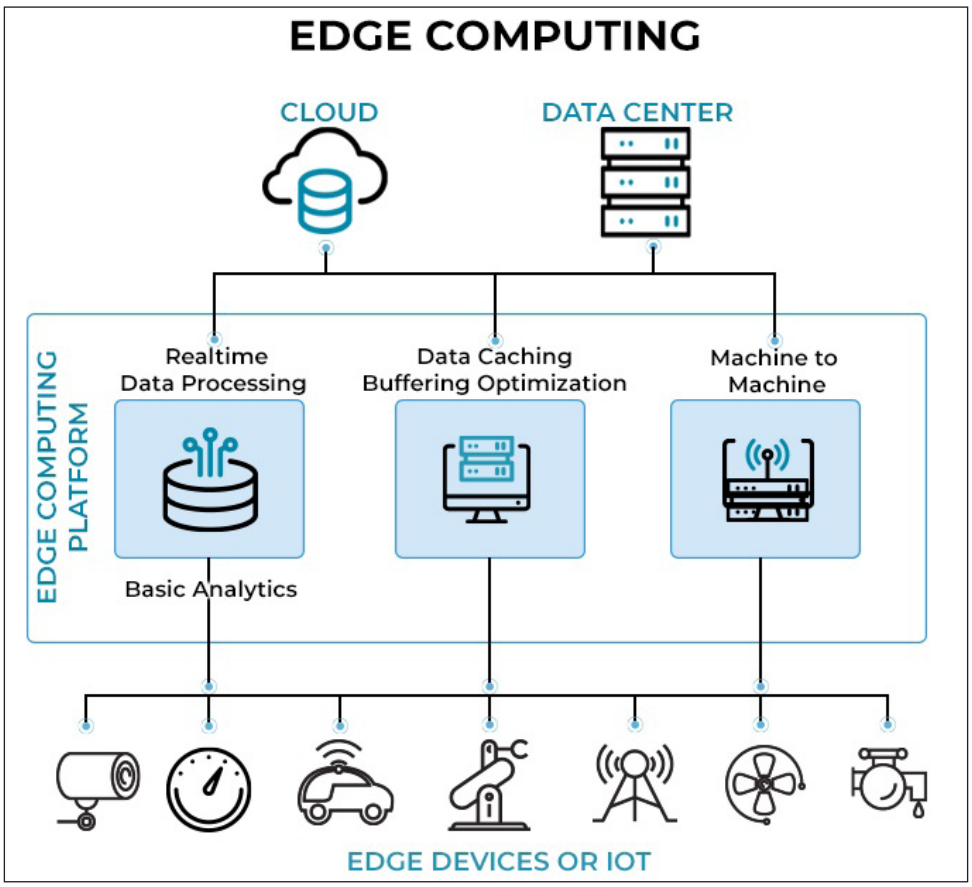

Fig. 1: Basic structure of Edge Computing in IoT Context

Objective

The chapter entitled 'Edge Computing & Educational Systems: Towards Advanced and Intelligent Learning—*A Conceptual Overview'* is a theoretical work and prepared with the following aim and objectives:—

- To learn about the basics of Edge Computing and allied systems with its features and functions in general.
- To know about the basic function of Edge Computing in regard to its applications in educational systems.
- To find out major benefits of Edge Computing in education, training and allied activities in contemporary scenario.
- To know about specific areas where Edge Computing and allied systems may be applied and integrate so far.
- To learn about the allied technologies of Edge Computing which are helpful in advancing and digitalizing educational systems.

Function and Advantages of Edge Computing in Education

Edge Computing comes with huge benefits in different sectors of society beyond education systems (refer Fig. 2), though there are huge potentialities of Edge Computing in the education segment; both in school education and higher education including research and development. And as far as major functions are concerned following may be considered as worthy in this context[18],[20].

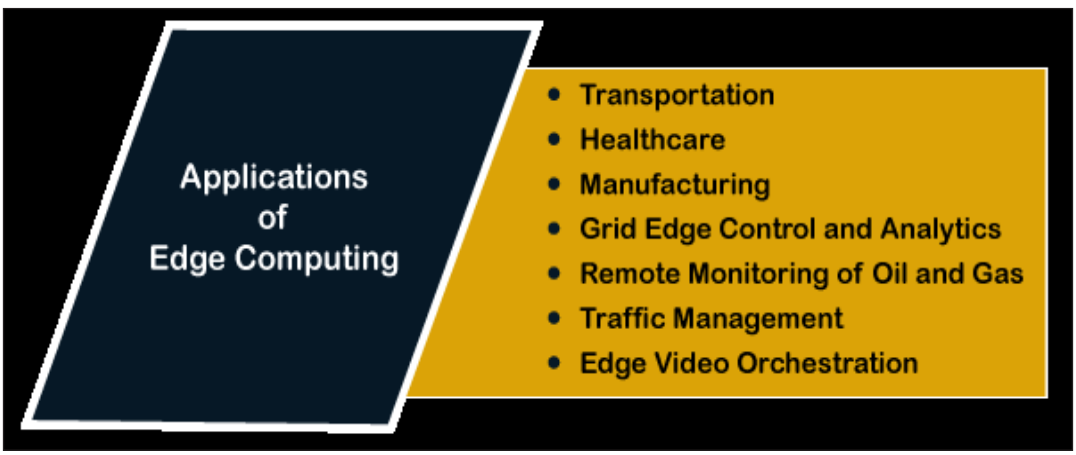

Fig. 2: Basic feature of Smart School powered by Edge Computing

Scalability

As far as Network systems of Edge Computing is concerned it offers flexibility in the network uses and management to educational institutions, especially during pick hours when students, teachers and administrators are using the network.

Speediness

Edge Computing offers advanced and robust speed in terms of data delivery due to the advantages of the structure and architecture[19],[39]. As far as network performance is concerned it also gives reliable services in real time services. In regard to better connectivity, it also offers a great atmosphere to the users.

Dependable Services

As far as service dependency is concerned since it is remote service based therefore it comes with localized and remote services both. Hence in ensuring reliability and managing data management Edge Computing is worthwhile.

Security & Privacy

As data in Edge Computing keeps in local instead of central therefore in regard to security it is perfect and if any issue occurred it doesn't apply to entire systems of network and infrastructure. Therefore in regard to privacy Edge Computing is not doubt worthy and beneficial.

Flexibility

Edge Computing offers advanced data management and thus there is no need of own IT experts that can be hired based on requirements. Therefore, onsite and external can be used depending upon the requirement.

The integrated role of Edge Computing in educational systems offers better connectivity of the devices and systems. It has come to notice that today many people are using different electronic devices such as whiteboards, smartphones, tables for the purpose of education, and many devices are being used in getting data using sensors and in traditional systems there are concern of bandwidth lacking and network problems but with Edge Computing such services can be *faster, effective and sophisticated* in terms of connectivity of the devices.

Enhanced Learning is easily possible with edge supported systems, as today students are frequently use Google Classrooms, Google Teams, Microsoft Team Education and so on[4],[5],[31]. Educational toys are also being used by school children and their real-time data can be easily and effectively shared, and there apart from students educational matters concerns about student behaviors and social dynamics are easily judged and analyzed.

Enhancing immersive and interactive learning is perfectly possible with Edge Computing. It offers smooth and realistic augmented reality and virtual reality applications in schools and other educational institutions. Low latencies are possible with Edge Computing supported systems and this will be helpful in local data processing and management. Using edge based systems real, and lively experiences effectively possible. As far as future and most advanced education is concerned AI, AR and VR reality become important concern, and here edge supported systems are worthy and crucial. VR labs and other experiments are effectively possible using Edge Computing[9],[12].

As far as Enhanced real-time feedback is concerned Edge Computing and allied technologies are worthy in proper data collection using modern tools and strategies. Today research is going on regarding proper uses of Edge Computing in advanced learning to get users or students perception and feedback on a subject, thoughts, services or on a teacher and this is effectively possible with Edge Computing based services.

The AI based system will ensure existing teaching learning management systems and here indirectly Edge Computing play a leading role. The high speed network can able in designing and developing more effective learning models and styles. In online classes too, augmented reality can be considered as worthy for achieving learning goals.

Technological support in Educational System: Edge Context

In regard to the allied technological support for better and sophisticated Edge Computing practice in education and research some of the important technologies are Augmented and virtual reality, Internet of Things (IoT), Cloud Computing, Big Data Analytics, etc. As Edge Computing is focusing on processing data locally therefore it offers high performance computing services. The classroom environment may be significantly improved with Edge Computing and in this regard following technologies are important viz.—

Augmented and Virtual Reality

Edge Computing is exceptionally useful in the educational segment and here augmented and virtual reality is important for its real flourish and effective uses[16],[38]. With the combination of Edge Computing with 'AR and VR' educational systems particularly higher educational systems become important and realistic.

Internet of Things

Internet of Things (IoT) is simply the applications of the internet and similar technologies for data collection and management and as Edge Computing also concentrated on real-time and localized data management therefore combination of both 'Internet of Things' and 'Edge Computing' can be a great deal. IoT may give super services to educational objects including an online education system. The problem related with the bandwidth may be managed with this. In regard to collecting data from educational toys, IoT can be worthy and here combinations of both technologies are worthy[15],[30]. Moreover tracking cameras also important in IoT connected Edge Computing for advanced and realistic development of educational systems, particularly in school education.

Cloud Computing and Big Data Management

Applications of Cloud Computing in educational systems is important for last few years and as far as development of computing and ICT is concerned in between or recent past Edge Computing took place and therefore combination of Cloud Computing and Edge Computing can be important in different educational settings including physical/ face to face education and online/virtual education both. Better user experiences effectively possible with cloud and edge supported systems. Less discombobulated, effective and specifically more cost effective educational services be possible with Cloud supported system. Students-Teachers alongside administrator can get wider benefits from Cloud Computing and in proper sense many context 'Cloud and Edge' deal important. Though online, remote, and ICT based learning developed significantly in last decade but COVID-19 significantly changes educational systems from traditional to modern and intelligent one. Cloud Computing during COVID-19 played a leading role in educational systems promotion be it school education or higher education and research. As in online and digital mode lot of data basically generates during different processes therefore here the role of Big Data and Analytics also should be considered as vital and crucial for complete data management[6],[10].

Big Data Management is about managing large amount of data and complex data in different forms and settings and in respect of Higher Education, research and development lot of data these days basically generated and here proper analytics are useful. Furthermore, development of proper Edge supported Data Management is also emerging and in this context, Data Analytics can be applied effectively.

Data Security and Privacy Management

As today entire educational matters and things are online and digital including various data collected in different sources from the students and researchers therefore there are few concerns in Data Security. The aspects related to the data centre, managing infrastructure is important in teaching-learning and educational administration. Cloud Computing offers different educational benefits but at the same time, it also offers opportunities and issues related to security. Bandwidth, low latency are important feature of Cloud Computing but if it a matter of large scale integration including localization the role of Edge Computing is important. As many educational institutions these days are using third party tools and technologies including data storage therefore concern of security should not be ignored[3],[11],[35]. It is better to adopt proper professionals there to manage data and other aspects.

Edge Computing Applications in Education and allied areas

Gradually applications of Edge Computing in education, teaching and research can be seen in diverse areas of education and allied fields. Many institutions and organizations who are engaged in different sector uses on-job training and other training systems, and there applications of the emerging technology and few facets of Edge Computing can be seen significantly.

Edge Based Education: Implications in Schools and other Educational Roads

As far as emerging technologies are concerned Edge Computing has the potentialities in different segment of education including training and research in onsite and online platforms significantly. Today most of organizations and institutions related to education strongly engaged in latest IT and Computing adoption and Edge Computing and Systems is not an exception for the same[14],[21],[23]. Practically all the facets and features of Cloud Computing can be duly applied to the Edge systems supported platforms. Cloud supported educational systems are worthy mention in digital world offers variety of data format, size and platforms. All kinds of flexible benefits such as anywhere anytime learning, data management are become easy with cloud supported and Edge Computing integrated systems. In Cloud based systems data is basically processed far away whereas in Edge Computing based systems it is normally held in the systems or nearby devices or within a specific territory. Therefore such systems are important in different educational institutions including schools. As far as school education is concerned Edge Computing can be worthy in following (but not limited to)—

- Edge Computing is helpful in managing and relieving overloaded networks. Overloaded networks can be effectively managed using edge based systems. As in school hours most of the students and other stakeholders uses computer systems simultaneously therefore edge systems may be integrate to give the best results.

- In school education systems sometimes security considered as important fact though in Edge Computing all the data stored locally instead of centrally therefore chances of vulnerabilities low compared to cloud based systems[24],[25]. Simply it offers cyber protection and data assurances.
- Devices connected with IoT are getting popular worldwide and in educational systems, different stakeholders are being used IoT based systems. Staff, Teachers can use Internet of Things (IoT) enable systems for smart lesion planning & management, record management, attendance management and so on. Here as far as Edge Computing is concerned it processes better information processing, higher amount of productivity, and also efficiency.
- As far as virtual reality and augmented reality is concerned it has a tremendous impact in educational segment and in school education and management, and in this regard Edge Computing allows students and teachers towards effective, in-time, hassle-free communication. Here Edge Computing can be effective in data management and timeliness.
- Major scientist and researchers including IBM have analyzed that Edge Computing is cost effective compare to other emerging Information Technology platforms. It also helpful in expanding computing capacity with a lesser cost[6],[26]. Sending and collecting data to the cloud is involved with cost whereas edge based systems are less cost effective.
- Today big schools are with multiple campuses and each campuses integrates with different ICT infrastructure, and here 5G can be an important integration where Edge Computing can also added together for better result.

Cloud computing basically gives importance in 'out there' feature with centralized cloud platform but edge computing basically brings all the data within the jurisdiction and systems. In Edge Computing normally large amount of data are not forwarded to the central cloud system rather it bring and uses different edge and advanced devices such as routers, switches and computers, laptops and tablets. Therefore in modern schools such Edge Computing supported educational systems are impactful and growing rapidly. Every user of the school weather teachers, students, or researchers basically uses advanced Computing and ICT and, in this regard, it is important to note that AR and VR applications, cloud, IoT, Big Data are considered as additional technologies in support of sophisticated Edge Computing practices. As in cloud one breakdown or damage of the system results in entire system's breakdown but in Edge Computing such a situation not occurred, therefore in school and similar educational institutions edge is not interrupting the internet and other services[29],[32],[33]. Today many schools offer online training, session, conferences, exhibition, etc. and in all these Edge Computing can be effective for faster and robust internet and network services. Schools and similar bodies are continuing in decentralized research systems.

Edge Computing helps to transform the traditional education system into a smart education system. It helps to create the traditional School into Smart School. Information and Communication Technology is used to implement Edge Computing framework in digital education[13],[36]. Smart Schools should have smart board, digital pen or digital board marker, interactive projector, digital time table, CCTV, customize tablet or Smart phone, digital attendance, GPS base monitoring of student, digital library, virtual laboratory, online admission management, online fees collection, and a strong wireless network connectivity. Fig. 3 shows the Smart School facets and aspects.

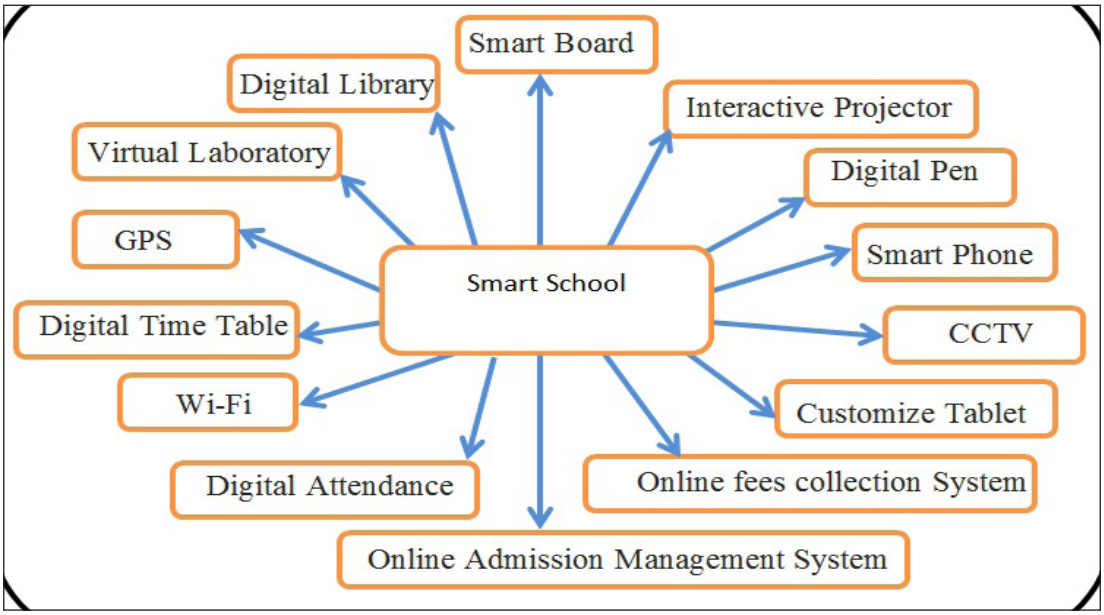

Fig. 3: Basic feature of Smart School powered by Edge Computing

Edge Computing & Educational paradigm Shifting

Edge computing helps in the futuristic learning system. Virtual reality and Augmented reality are the new technologies which could be used in digital education with the use of Technologies. The online based learning become more attractive. The learner would get a 3 dimensional view of the class room[8],[34]. The learner could virtually interact with the teacher and with the others learner. Without the physical presence in the class, the learner would be able to attend the class. With the help of Augmented Reality Technologies that the teacher can easily explain any concept to the student. Instead of only showing 2-Dimensional pictures, the teacher can present anything to the students through 3-dimensional model. 3-dimensional model helps the students to understand any concept easily.

Edge Computing facilitates the digital education by providing an efficient platform to the student. It helps interactive learning. The learner may create groups according to their needs and Study by discussing among themselves. Edge computing implementation in digital education also encourages Peer learning. The learner can learn a concept from each other. Even they can form the Peer groups to learn and discuss themselves. Edge Computing also provides personalized learning. It could customize the study material according to the need of the learner. it helps in student centric learning.

Artificial Intelligence (AI) base learning is another important aspect of digital education. Different type of machine learning and deep learning algorithms have analyzed the learner performance and give suggestions to improve the performance of the learner. It could try to predict the future score of the student by analyzing past records. It helps to find the difficulties which may face by the learners. AI based Teaching and learning also help the teacher to understand the students better.

Different digital tools have played vital role in Edge Computing. Digital tools are very important to transforms the traditional schools into Smart School. It is very difficult for the student to practice the laboratory based work at home. Edge computing helps to create virtual Laboratories[7],[27]. The student can practice is the science experiment virtually. It is possible to virtually create Laboratories for chemistry, physics, geography, biology, engineering, medical science, and so on. The student can practice the experiment as much as they need. There is no restriction of time and space. It is possible to reduce the risk by practicing the experiment virtually. It is also able to simulate the classroom virtually.

It is very important to implement the Edge Computing framework in healthcare and education. Edge Computing helps to run the system more efficiently. It is actually reduce the Network latency time by processing the data closer to the origin of the data. It does not always access the cloud server since the processing is done locally. If any essential information is required that does not available locally then only it sends the request for the information to the cloud server[9]. Edge Computing reduces the network overhead. It tries to maintain the network congestion free. So it has reduces the latency time, data processing cost and make the system faster. It also reduces the network dependency of the system. It is very risky if the whole system is completely dependent on internet. If any connection related problem encounters, then the whole system may collapse. As in Edge Computing the data is processed locally and separately so for any kind of fault that only affects that particular portion, the whole system will not affect by it. The data can be processed without the help of the Internet which increased data accessibility.

Edge Computing hence the privacy and the security of the system. As the data processed nearer to the origin and the main dataset stored in the centralized server, the edge node does not have the full data set which make the system secure. If any hacking occurs at the age node then the hacker will not get the whole system[14],[35]. Internet of Things (IoT) devices has played an important role in Edge Computing. Different type of sensors and actuators has been controlled by these IoT devices. Scalability is another benefit of Edge Computing. It is possible to add or remove any edge node according to the need. The end point hardware and the edge devices are less costly, so it is easy to add more edges with the expansion of the organization. It also provides a flexible system for the user. Though the initial setup cost of Edge computing system is very high but still in long run it is cost effective. There is no need to store all the data to the cloud server so it will reduce the storage cost. As the data process locally, there is no need to store and fetch all the data to centralize server. This is actually saves the bandwidth utilization which directly saves the bandwidth cost. This makes the whole system more efficient, robust and reduces risk factor.

Edge Computing plays a vital role in digital education. It has changed traditional schools into smart schools. Edge Computing Technologies have used in all the elements in the Smart School. It helps to create the smart classrooms and a better management system. The student gets more benefits for the use of Edge Computing. They can learn any topic from anywhere at any time. The student can interact with the teacher more easily. Teacher can explain any concept mode easily with the use of Technology. By the use of Augmented reality Technologies the teacher can show any 3-Dimensional model which is more realistic. This will help to build a clear concept to the student. Edge Computing helps to build better teacher student relationship. By the use of Edge Computing Technologies the parents can continuously monitor their children. The student will be able to access the classes of any teacher. There will be no geographical restriction. Virtual reality technology also simulates the real time classroom scenario virtually. The student will get the 3- dimensional view of the classroom. Edge computing also helps to sharing the resources between different educational institutions. They can share any physical resource

or any educational resource or any faculty. Edge computing technologies help in all round development of a student[6],[31].

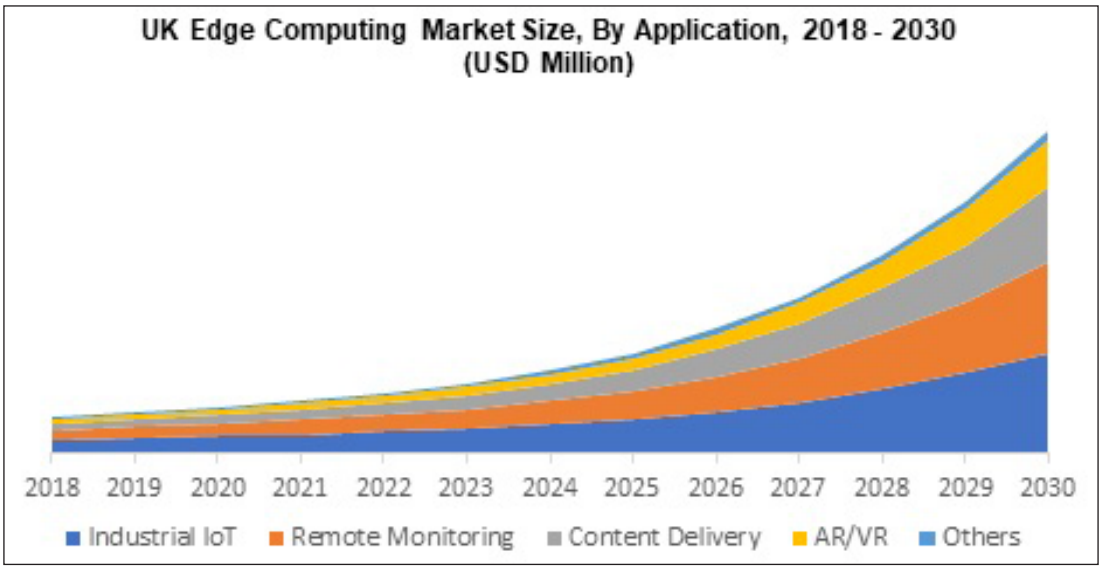

Fig. 4: Edge Computing projected market share in United Kingdom (in USD)

(***Source:*** gminsights)

CONCLUDING REMARKS

Worldwide uses of Edge Computing are rising due to the different benefits of these types of computing systems. Edge Computing is finally helpful in managing and advancing basic automation and the digital world and as a result worldwide market share of Edge Computing also rising. Though according to the expert, most of the latest technologies such as cloud, IoT, AR, and VR help in better Edge Computing uses, and this scenario can be noted in Fig. 4 where the trend of sharing past and future prediction is provided systematically in the context of UK (source: gminsights), and this can guide us about future potentiality around the world. As far as education, training and research is concerned this technology comes with flexibility, elasticity, scalability, and so on. School education and higher education both are important stakeholders in Edge Computing applications. Learning Management, Learners Management, Teachers and Staff Management become cost effective with edge computing and allied systems adaptation. Improved communication becomes possible with such system powered by additional technologies like AI and ML, Virtual Reality and Augmented Reality, and so on. Though there are many benefits of Edge Computing in education but few concerns should also be noted at this point viz. technological support of allied systems and emerging technologies, financial involvement, manpower, and unwillingness to change. Therefore, educational institutions must look into the benefits and challenges of Edge Computing for perfect utilization.

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