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Integrated Information Infrastructure of Georgian High Educational Institution

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Abstract: ***The paper presents the peculiarities of building information systems for high educational institutions in Georgia. A multi-level model for elaborating such systems has been developed, which involves integrating the main, external and internal information processes into a single information infrastructure. The importance of close information communication between higher education institutions and state educational structures is emphasized, and the analysis of application programs used for servicing individual information processes, as well as providing inter-process communication, is made.***
The presented paper also discusses the latest challenges of Georgian high educational institutions caused by coronavirus. In particular, the paper describes a model of transition to online education at a Business and Technology University of Georgia using cloud technologies, which made it possible to maintain a high level of education at the mentioned University and guarantee maximum access to the educational process for students and academic staff.
Keywords: High Educational Institutions of Georgia, Information Process, Data management infrastructure, Application, Application Integration, Cloud services, Digital Transformation.

I. INTRODUCTION

High educational institutions offer a large amount services to the students, professors and administrative staff. The services that were done in manual, become automated to increase the speed, quality, comfort and access easiness.
Automation of the processes require the digital transformation and extensive use of ICT infrastructure. There is no single software system solution for these purposes. So, each service needs to be run separately or semi-automatic mode of integration has to be implemented using third party tools. The automatization of information processes at Georgian high educational institutions (Further in the text: HEI) is a complex task. The information infrastructure of the HEI should meet all the information needs of students, academic and administrative staff as effectively as possible, guarantee continuous and fast access to the information services of the University, as well as ensure reliable storage, processing, and transportation of information.
Constant procurement of Server/storage/network equipment and the upgrade is a complex task for each university IT department each 4-5 years. The modern cloud services provide the enough flexibility and capacity to move the existing infrastructure from server rooms to sky and leave only critical services on premises.
Within the framework of the presented work, a multi-level model of information infrastructure for Georgian HEI's and methods of implementation of this model are proposed. Special attention is paid to the use of cloud technologies to minimize the risks of delay or interruption access to information services and particular components of the information infrastructure of HEI. Thus, the presented work can be useful both for established universities and for beginners. For the former, we hope to present convincing arguments for updating approaches to building information systems of the HEI, and the latter will be able to better find the best option for creating their information infrastructure from the very beginning, using all the advantages of cloud computing.

II. LITERATURE REVIEW

The rapid increase of users, content, services gives the large load to the university IT infrastructure, the modern approach to the problem can be the development of cloud-based environment for providing the appropriate services. One of the essential services is the learning or e-learning [1]. The information systems and model have been also developed for university management purposes, considered as a task of enormous complexity [2]. Introduction of ta software module to monitor and manage the educational processes in the university is essential to allow the efficiency and speed of decision-making. "solution enables efficient planning of the educational process, reduces the complexity of data processing, and improves the accuracy of the information processing and the performance of management activities" [3]. Universities as a constant competition to each other need to develop the infrastructure to achieve the fast growth and status of world class university. The second most important is the Digital infrastructure consisting of 25 services, among them are: Internet, Web, Online materials and digital library, publications, paperless office, paperless exams, online evaluation systems, online announcements, online registration, plagiarism software, social network promotions and more [4].

The characteristics of suggested cloud computer model are: the High scalability, Flexibility, cost-effectiveness, payment flexibility, unlimited storage space availability, support of green computing, support of backup and recovery, possibility to work from anywhere and fast deployment possibility [5]. Another study shows the impact of information technology infrastructure on innovation performance at the university and concludes that the "use of IT is relevant in improving innovation performance" [6]. "The interaction between the capabilities of information technology and human resources can influence the ability of IT to effectively improve innovation performance" [7]. The evaluation of the created university elaboration cloud-based system gives the result that "the platform is useful and allows a greater performance and efficiency and is considered a good idea" [8]. Another attempt of Development of the intelligent system for the use of University Information System "makes it possible to modernize teaching and learning process and enhance the new features that will improve its performance and adapt it to the needs of each user, without a drastic increase in the cost of organizing and implementing the teaching process [9]. The studies indicate the need of introducing of cloud services as a part of digital transformation of the universities and future development, confirming "ability of cloud services to be the digital transformation drivers of academic programs in the field of Software Engineering." [10]. Another research paper proposes the migration of the university IT infrastructure towards a cloud computing in order to "solve some of its problems related to the management and to the maintenance of its IT infrastructure, and in order to benefit from the new contributions of Cloud Computing" and suggested to use the private cloud IaaS, based on the OpenStack platform, defining the perspective of adopting a secure Hybrid Cloud for the university IT infrastructure [11].

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III.FOUR-LEVEL SCHEMA OF THE INFORMATION INFRASTRUCTURE AND INFORMATION PROCESSES OF HEI IN GEORGIA

The main goal of the HEI is to provide educational business processes so that each delay in the processes does not exceed the limits specified in the business continuity plan of the institution. The information infrastructure of any HEI is characterized by a fairly complex structure and consists of many services and hardware and software components. Management of information processes of the HEI requires the use of high-level software, as well as the availability of an effective and reliable computer network, server equipment, data storage, and security devices and services.

The model of information infrastructure of a higher education institution can be described using a four-level scheme (Fig. 1).

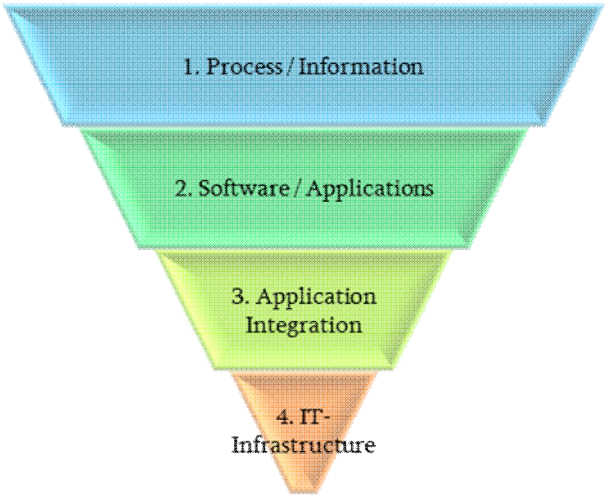

Figure 1. Common schema of the information infrastructure of HEI

The different levels of the presented diagram can be linked as follows:

A. Processes search for, process, and store information using software/applications (Level 1 <-> Level 2)

B. Particular software/application components of the information infrastructure are integrated to ensure fast and reliable exchange of information between different information systems and services (Level 2 <-> Level 3)

C. High-available and reliable IT-infrastructure is necessary to provide uninterruptable and efficient access to the programs and data (Level 2,3 <-> Level 4).

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We will conduct a more detailed analysis of the scheme from fig. 1 in relation to Georgian HEIs. All information processes of Georgian HEIs can be divided into three interrelated groups (Fig. 2).

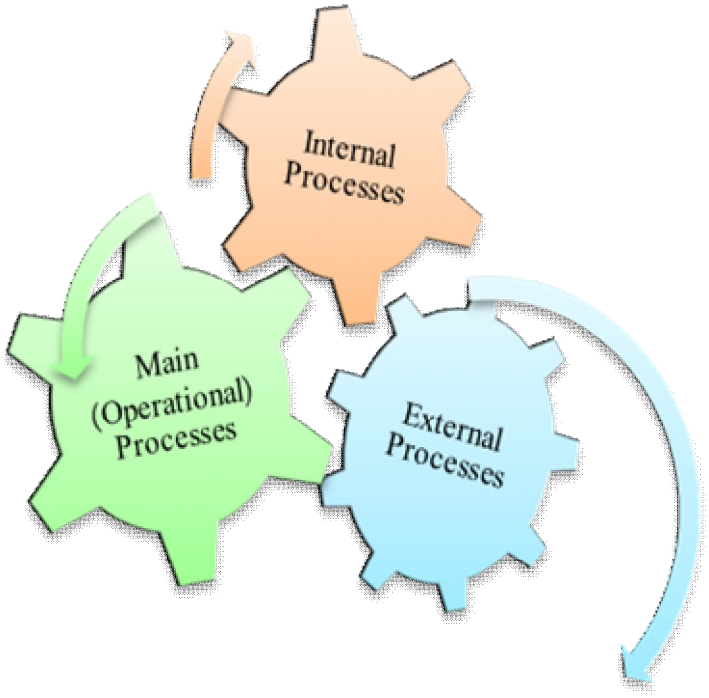

Figure 2. Classification of Information Processes of HEI

The main information processes include all the functionality for managing the educational process in the HEI. The implementers and participants of these processes are the academic and administrative structures of the HEI, which conduct synchronous exchange of information based on the predefined policies and regulations of the HEI. There are several main information processes, such as:

1) Organization and management of the educational process
2) Organization and management of the activities
3) Organization and management of the research process
4) Library service
5) Document management service
6) Collaboration and communication service

Through external information processes, the HEI carries out exchanges of information with partner organizations. The functioning of some of these processes is vital for Georgian HEIs to carry out their activities. Examples of such processes are:

a) Information service managing the number of students enrolled in higher education institutions on the basis of unified national examinations held in Georgia
b) Information service managing the number of students who received state funding for their studies on the basis of unified national exams
c) Student mobility service

Other external information processes do not play a decisive but important role in the functioning of the HEI. Examples of these are:

i) Research project management services in Georgia and abroad
ii) Scientific online databases

Communication of internal information processes with the main and external information processes is carried out primarily in the financial direction. Georgia has a rather complex system of financing higher education. For applicants with the best results of the unified national exams, the state of Georgia implements funding schemes with 30%, 50%, 70% or 100% shares. Many HEIs also have their scholarship systems. On the other hand, the tuition fee rule, based on a difficult economic background, is quite flexible and implies a step-by-step payment during the academic semester. Based on the above, it is clear that the process of information exchange between the internal information processes of the HEI and the main and external information processes is quite intensive.

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IV. APPLICATIONS AND APPLICATION INTEGRATION

To implement information processes, it is necessary to use appropriate programs/applications. However, to implement some information processes, it is necessary to use two or more applications, and Vice versa, some applications implement more than one information process.

The diagram of application integration of main, external and internal information services (applications) of Georgian HEIs is presented in fig. 3

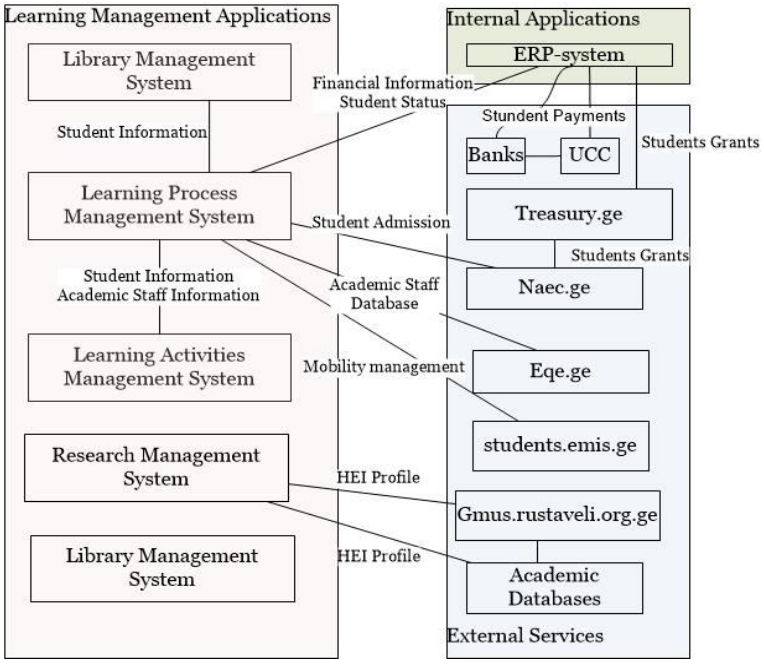

Figure 3. Application Integration Schema of Georgian HEI

A. Here is a Brief Description of the Main Information Systems of Georgian HEIs

1) The Learning Process Management System is a core information system of the HEI that serves the information process with the same name. Despite the presence of many powerful applications of this kind in the HEI software market, most Georgian universities use their own products (In-House Applications). For example, the application for managing the educational process of the University of Business and Technology of Georgia is called BTU CLASSROOM.

2) Learning Activities Management System or simply LMS is closely relates to LPMS and automatically receives from the latter a lot of important information, such as the list of active students and lecturers, their distribution by subject and group, and much more. The most popular of these systems in the Georgian educational space is primarily Moodle, as well as ILIAS.

3) Library Management Systems used in Georgian HEIs are mainly “Open Source”-applications, such as Evergreen, KOHA, OpenBiblio, etc.

With the help of external information services, the HEI provides various types of information communication with public and private entities, to receive numerous academic and financial services from them. External information services can be distributed into two main groups:

a) State and financial services for student body management

b) State academic personnel management services

B. Services of the First Group Provide

1) Annual enrolment of HEIs by students based on the results of unified national examinations conducted by the assessment and examination center of the Ministry of Education of Georgia (naec.ge)

2) Management of students' financial data both from the point of view of tuition fees (Financial services of individual banks, Services of United Clearing Company of Georgia) and from the point of view of state funding of education

3) Management of student mobility in the inter-semester period by means of the education management information service of the Ministry of education of Georgia (mobility.emis.ge)

C. Services Of The Second Group Provide

1) Management of academic staff by means of service of the National Center for Educational Quality Enhancement of Ministry of Education of Georgia (eqe.ge)
2) Management of research projects by means of the Grant Management Unified System of Shota Rustaveli National Science Foundation of Georgia (gmus.rustaveli.org.ge)
3) HEI-profile management in different academic online databases (Scopus, ScienceDirect, WoS, etc.)

Internal information services of HEI consists of management of administrative and financial processes inside the organization and first of all, they determine student's current status, which is important for all subsequent processes. Georgian HEIs actively use a Georgian ERP-system Oris Manager to manage financial services, although many universities use their own programs for this purpose.

V. PROVIDING INFORMATION TECHNOLOGIES FOR THE INFORMATION INFRASTRUCTURE OF HEI

The information technology system of HEI provides users with uninterrupted and reliable access to information resourcesю Such systems have a certain specificity in comparison with similar systems of other organizations, which has become especially clear in recent months, against the background of the spread of the coronavirus, which has led to a sharp change in the paradigm of the educational process and put information technology systems in front of completely new challenges.

First of all, it should be noted that in the standard situation, the peak load on the information systems of Georgian HEIs is observed twice a year, at the beginning of the academic semester, during academic registration. the process of choosing subjects is competitive, so most students turn to the University's information services in a very short period, which leads to a sharp increase in loads on both information systems and network and server resources, and some cases may cause the provision of services to users to stop.

The COVID-19 pandemic of 2020 has created new challenges for information technology systems of Georgian HEIs [12] and schools [13]. the massive transition to online training and the introduction of appropriate technologies and software products caused a sharp rise in demand for hardware resources of data centers and only using cloud services as an addition to existing local systems made the transition procedure less painful. The effectiveness of using cloud computing in education has been proven by numerous studies [14], [15]. Today, most Georgian universities rely on a hybrid infrastructure model, where part of the information systems are managed in a local data center, and the other part is located in the cloud. In local data centers, like the cloud, almost all hardware and software platforms are virtualized. Benefits of virtualization, such as the ability to run multiple virtual machines on the single host, or optimal distribution of critical hardware resources (CPU Time, RAM, Storage) between virtual machines, significantly increase the availability and reliability of information systems. Using virtualization clusters minimizes the risks of interruption or termination of access to information services in emergencies or even during the disaster.

VI. IMPLEMENTATION OF CLOUD TECHNOLOGIES FOR INFORMATION SERVICES OF BUSINESS AND TECHNOLOGY UNIVERSITY OF GEORGIA

In February and March 2020, the Business and Technology University of Georgia experimented on the implementation of cloud services, which was unique in the educational space in Georgia. Along with industry experts, students were also actively involved in the implementation process, gaining unique experience in the field of cloud computing. AWS (Amazon Web Services) was chosen as the platform for implementing cloud services for BTU, which is currently ahead of its main competitors Microsoft Azure and Google Cloud Platform, in particular in the segment of IaaS ("Infrastructure as a Service") (Fig. 4).

Figure 4. Gartner's Quadrant for Major IaaS Service Providers

The following services of AWS has been used during the implementation: EC2, VPC, ELB, Auto Scaling Group. Orchestration of the services listed has been also performed.

During the implementation procedure, the main attention was paid to two important architectural solutions of AWS: High Availability and Fault Tolerance. For the implementation of High Availability architecture following technical steps has been performed:

1) Creation of custom VPC with the appropriate IP-address range and addition of one subnet within the availability zone of VPC

2) Configuration of Internet Gateway component and addition of the route to it in the route table of gateway router, making the subnet within the custom VPC (and, accordingly, the instances/server located within this subnet) accessible from the internet

3) Since the primary task of HA-architecture is to ensure the resilience of information systems and automatically replace failed instances with new ones, the first server configuration template created by means of Launch Template service. Corresponding BASH-script contains all the necessary software packages

4) Using Auto Scaling Group Service to define rules for automating server start, stop, and delete. Specification of maximal and minimal numbers of servers as well as the current number of servers for actively running processes (Desired Servers)

5) After configuring Auto Scaling Group, the start of the configuration to satisfy the requirements specified for Desired Servers.

6) Stress-test on the Auto Scaling Group. Different loads tested to fix how quickly the Auto Scaling system responds to various requests

An example of the HA-architecture of the described system is shown in fig. 5.

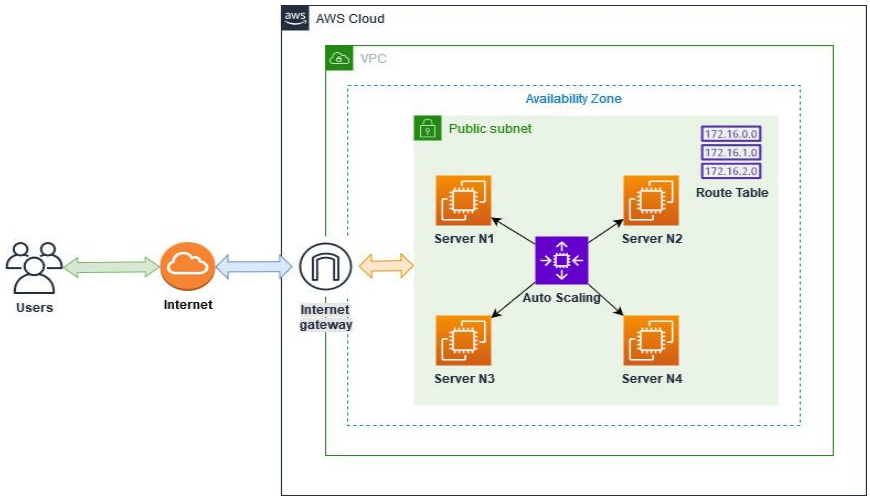

Figure 5. AWS High-availability Architecture

For the implementation of Fault Tolerance architecture following technical steps has been performed:

a) Creation of custom VPC with the appropriate IP-address range and addition of two subnets within two availability zones of VPC

b) Configuration of Internet Gateway component and addition of the route to it in the route table of gateway router, making both subnets within the custom VPC (and, accordingly, the instances/server located within this subnet) accessible from the internet

c) Creation and launch of 4 EC2-servers according to the configuration specified in BASH-scripts

d) Since the primary task of Fault Tolerance architecture is to ensure instant switching of control from active to passive servers during a crash ("Active-Passive" concept), it became necessary to use ELB-service which offers to use three different types of load balancers – CLB, ALB and NLB

e) Initially, the creation of a Classic Load Balancer (CLB) created and connected to the VPC and to the subnet within the availability zones. Stress-test of CLB

f) Creation of Application Load Balancer (ALB) using Target Groups, where the Fault Tolerance server has been registered. Assignment of traffic rules in ALB based on ports, subdomains, and network paths. Stress-test of ALB

g) Replacement of ALB by Network Load Balancer (NLB). Creation of static IP-address and its assignment to the NLB. Stress-test of NLB with different loads and disaster simulations. Specification of advantages and drawbacks of NLB in comparison to ALB.

An example of the Fault tolerance architecture of the described system is shown in fig. 6.

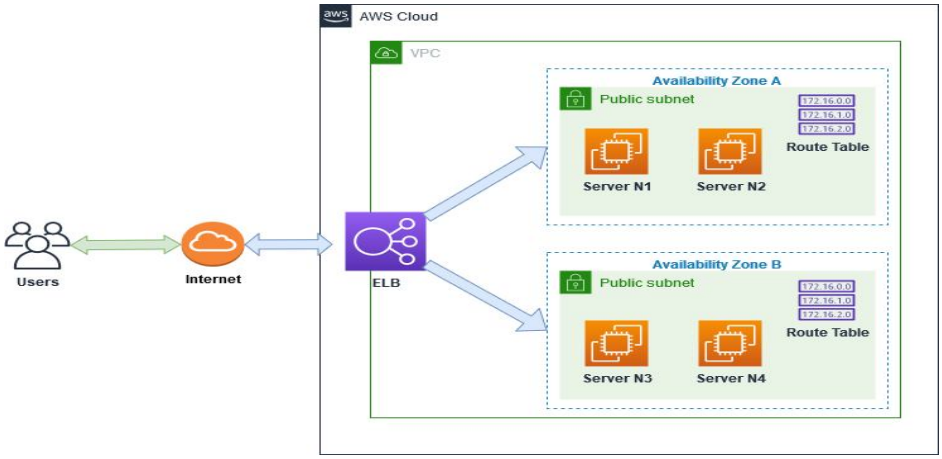

Figure 6. AWS Fault Tolerance Architecture

VII. CONCLUSIONS

In the presented work, an attempt was made to create the most complete and at the same time easily perceived picture of the typical information infrastructure of a Georgian HEI. We have tried to show that building such systems requires a thorough preliminary analysis of all the numerous information processes related to higher education in Georgian universities. with proper modeling of processes, the final result in the form of ready-made information systems and services will always meet the tasks set for the HEI, even in critical conditions, when it is necessary to quickly rebuild all educational processes on new tracks. using the example of the Business and Technology University of Georgia, it was shown that modern information technologies and especially the cloud service provide HEIs with sufficient opportunities for effective implementation of new methods of managing educational processes in HEIs in Georgia and other countries.

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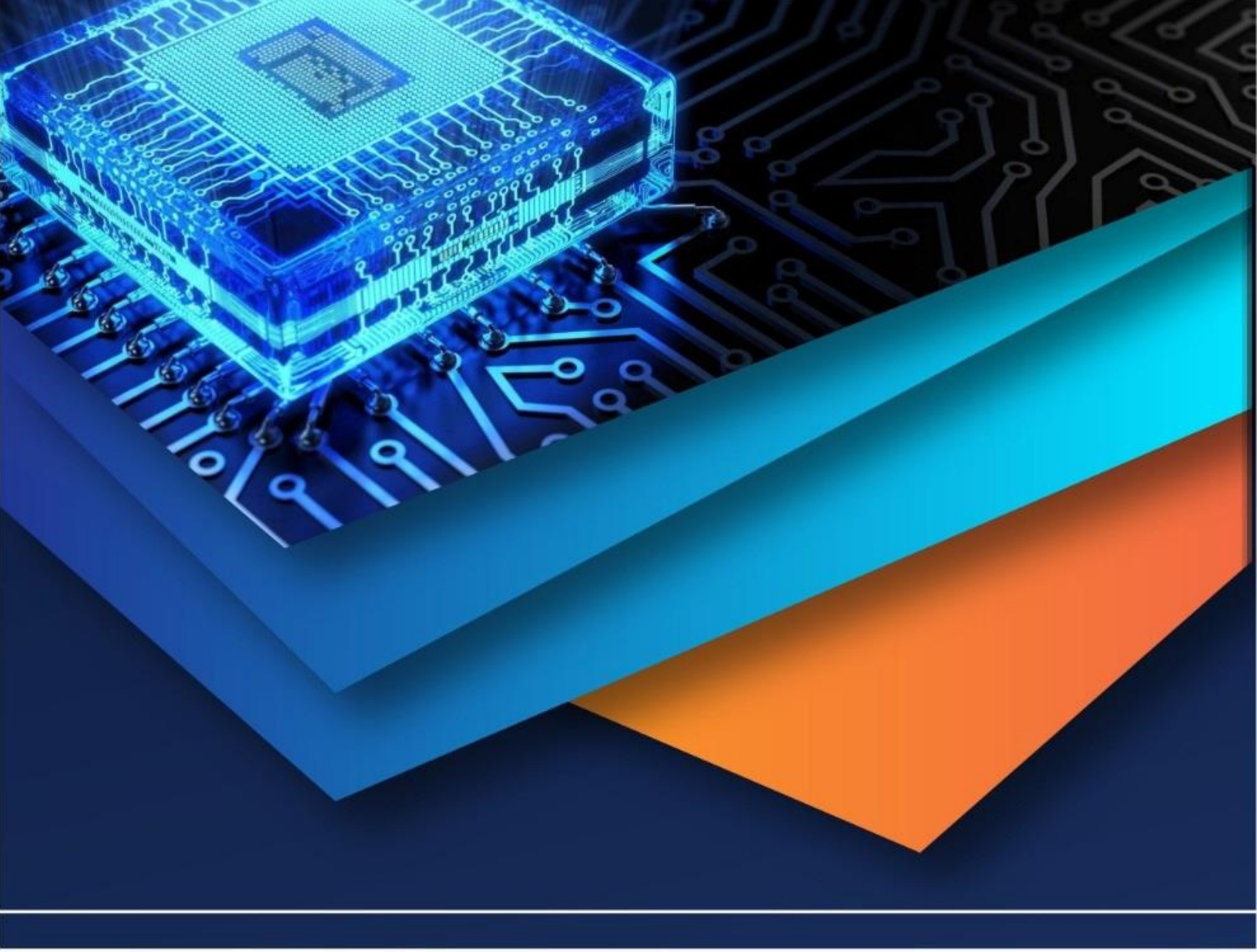

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