Overcoming the Challenges of Implementing Cloud Computing in Higher Education

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Abstract*—Education is one of the essential pillars of a country's social and economic growth. Despite the birth of the global pandemic in recent years, educational institutions must continue to innovate in providing the necessary means for faculties and students to perform academic tasks with limited resources. Now, everyone has become more technologically connected, in part, due to the Internet. Education systems all over the globe are slowly incorporating cloud applications into their learning environment because of the various benefits that it has to offer. Depending on the institution's needs, various cloud-based products are accessible by service providers to ensure the education system is running smoothly. This paper provides an overview of the benefits of cloud computing and outlines its main features, service, and deployment models for higher education, such as its ability to improve collaboration, reduce costs, and increase scalability. The paper also discusses the challenges that institutions face in implementing cloud computing, such as security and data privacy concerns. Finally, the paper provides recommendations for institutions that are considering implementing cloud computing. These recommendations include conducting a needs assessment, selecting the right cloud provider, and developing a security plan.

Keywords— Cloud Computing, Education Sector, Educational Institutes, Cloud Service Models, Cloud Deployment Models,

I. INTRODUCTION

The ongoing financial crisis has put learning institutions across the world under pressure to provide more high-quality services with extremely limited resources. Also, due to the education system's continuous growth, it has become more learner-centred than teacher-centred. Therefore, both innovative teaching methods and learning materials are required in the new learning environment. The educational system is advancing more quickly every day as more resources are made available by new technology. Most educational institutions now use e-learning and virtual classrooms, which allow all consultants to access the educational system, monitor it, and even give advice as needed [1].

A definition of cloud computing is the provision of information technology resources on demand via the Internet. The National Institute of Standards and Technology (NIST) lists five important characteristics that include on-demand self-service, broad network access, resource pooling, rapid expansion, elasticity, and measured service. The NIST also lists three service models (PaaS, SaaS, IaaS) and four deployment models (Community, Hybrid, Public, and Private) [2]. There are many different types of cloud computing, including hybrid, public, community, and private cloud, and the "cloud as a service" options. As cloud computing has developed over time, it has made immense and adaptable resources available that are scalable based on business demands. This has served huge interests for possibilities, as well as providing quick returns on investments. The total cost of ownership (TCO) is kept low for institutions by incorporating cloud computing into their IT strategy, which also allows for improvement in the overall capacity while keeping the necessary security level and infrastructure expenditure. Therefore, it is crucial that educational institutions find better ways to offer low-cost, high-quality services, employing scholarly tools, and research methodologies by establishing a compromise between cloud and on-premises services. Despite the many benefits of cloud computing, there are several weaknesses because of the reality that all apps and data are stored online. For both informal and formal uses in the education sector, cloud computing offers students and teachers free access to a variety of applications and services within the cloud. It also offers greater flexibility and mobility when it comes to resource utilization, and creates a learning atmosphere that is personalized, or rather virtual learning and teaching. Students and teachers may all access any kind of knowledge from any location using a device of their choice thanks to cloud computing. So, both private and public learning institutions can use this form of technology to improve services while utilizing the limited resources at their disposal.

The aim of this paper is to research the impact of cloud computing in higher learning institutions. Background research regarding cloud computing is explained, which comprises different service and deployment models. Furthermore, various cloud features including the benefits and challenges of cloud computing in higher education will also be investigated.

II. CLOUD COMPUTING IN THE EDUCATION SECTOR

The education sector has advanced significantly over time. Nowadays, computers and portable devices are used for teaching and learning instead of just textbooks and traditional classroom settings. Today's students are always linked, whether they are in or out of the classroom. The appropriate technology enables them to develop practical and employable abilities. This disruptive change is greatly influenced by technology. Cloud computing is one of the technological advancements that propels this sector's innovation. Unaffected by the users' locations, cloud computing is a system that allows users to share computing resources from any location. Using cloud computing, educators and students can collaborate on a single, common system. It is not necessary for educational institutions to manage and buy their own data centre and servers. As opposed to this, cloud computing has access to compute power databases, storage, and other essential facilities [3]. Also, users can be assured that the resources that are stored in the cloud are always safe. Cloud computing is essentially a sophisticated technology that emphasizes virtual resources over physical ones.

A shared pool of reconfigurable computing resources (such as networks, servers, storage, applications, and services) that can be quickly deployed and released with little administration work or service provider involvement is made possible by the cloud computing concept. This cloud model consists of five essential characteristics [4].

- On-demand self-service: When necessary, a user can unilaterally provision computer resources like server time and network storage automatically without interacting with each cloud service provider (CSP) personally.
- Resource pooling: CSP must be able to efficiently share resources and be centrally accessible. When many different clients and users use cloud computing, cloud service providers must be able to efficiently share the load for the learning system to function at a maximum state.
- Measured service: By utilizing a metering capability at an abstraction level relevant to the type of service, cloud systems automatically manage and optimize resource utilization (e.g., storage, processing, bandwidth, and active user accounts). Monitoring, regulating, and reporting resource utilization allows for openness for both the service provider and the user of the service.
- Broad network access: To provide utilization of computing resources across many platforms, the network infrastructure must be able to communicate with a wide range of devices, such as tablets, workstations, laptops, and mobile phones.
- Rapid elasticity: In some circumstances, capabilities can be provisioned and released on an elastic basis to scale inward and outward quickly in response to demand. Users frequently see the capabilities that are available for provisioning as being limitless and able to be appropriated in any number at any moment.

Key elements that affect how successful cloud computing is implemented include:

- Security: Everyone can access an application if it is hosted on a server that is controlled by a CSP and is accessed online by educational institutions. Application security gaps will be exploited by hackers.
- Performance: When compared to conventional centralized systems, cloud computing places resources away from users, which results in reduced performance.
- Government Compliance: Regulations do not fully support cloud computing. They can leverage cloud computing provider services. For the usage of cloud computing technology, large educational institutions must have separately managed servers.
- Financial: The utilization of both fixed expenses and variable costs is considered while financing cloud computing. Owning (one-time payment) is more affordable in the long run, rather than paying rent continuously [5].

A. *Cloud Services and Deployment Models*

The general architecture of Cloud Computing, shown in Figure 1, may be separated into two parts: the front end and the back end, each of which is a network-connected area unit. The front is what the user sees, whereas the back is the system's cloud [6].

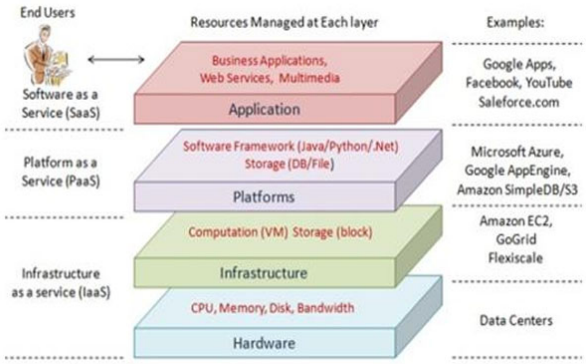

Fig 1. Cloud Computing Architecture [7]

- The Application layer includes the actual cloud services, such as Business Applications, Multimedia, and Web Services.
- The Platform layer comprises requisition structures and an operating system, and both depend on the infrastructure layer.
- The infrastructure layer divides the physical resources utilizing virtualization technologies to create a pool of storage and computing resources.
- The Hardware layer oversees handling the physical components of the cloud, switches, and servers, such as cooling systems, routers, and power.

B. *Cloud Service Models*

Modern learning institutions incorporate the three service models, as shown in Figure 2 [2], which include 'Platform as a Service' (PaaS), 'Software as a Service' (SaaS), and 'Infrastructure as a Service' (IaaS) and supply them as utilities by allowing clients to pay only for what they need (pay-per-use.) Data centres supply the hardware on which clouds operate and serve as the cloud's foundation [8].

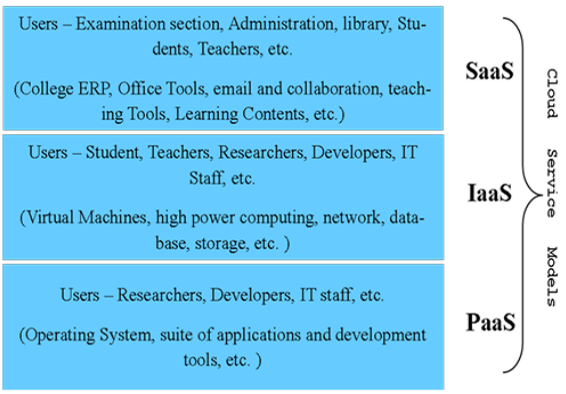

Fig 2. User Cloud Service Models in Higher Learning Institutions

- Platform as a Service (PaaS): PaaS is a combination of services and expansion tools used for efficient and quick application coding and deployment. Using PaaS, students, and teachers can create platform-independent services or applications in the cloud and make them broadly available to Internet users. In addition, it offers services for developing, building, hosting, collaborating, and sustaining applications.
- Software as a Service (SaaS): SaaS refers to installed programs on a service provider and is reachable online. The burden of managing software, applications, and other on-premises IT-related activities is lessened or eliminated. SaaS provides students with access to applications anywhere and anytime with any device that is web-enabled. Administrating and maintaining these tasks are handled efficiently and at minimal cost on the cloud [9]. SaaS makes it very simple to scale an application or to add more users.
- Infrastructure as a Service (IaaS): Utilizes a 'cloud' system to supply a variety of basic computing resources, including processing, networking, and storage. The user has control over the installed applications, storage, and operating systems but not the underlying cloud infrastructure [3].

C. *Cloud Deployment Models*

Many varieties of cloud computing have emerged due cloud's quick development, all of which employ the same technology. The right kind of cloud computing depends on the demand, the cost, future scalability, the anticipated performance level, and the amount of privacy necessary. The four types of cloud computing — 'public cloud, private cloud, community cloud, and hybrid cloud'— are the most utilized, Figure 3 [10].

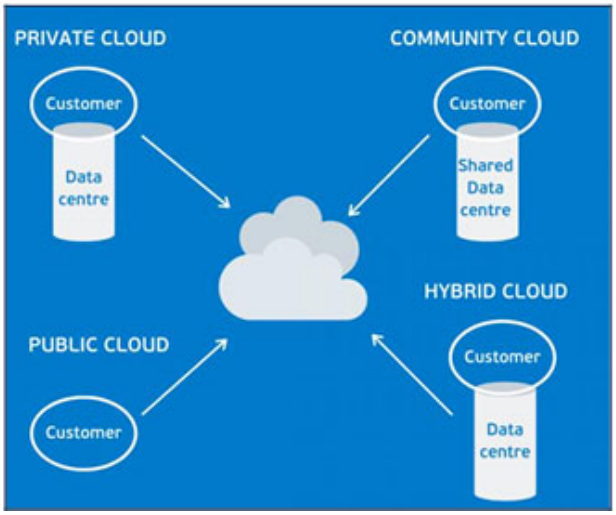

Fig 3. Cloud Deployment Models

- Public Cloud: The public cloud, which is the most widely used kind of cloud computing, is accessible to all users. On a network made available for public use, this kind of cloud service allows users to enter and store data on service provider servers. The location of the infrastructure cannot be controlled by the user because the service providers own the servers' hardware and infrastructure required to run the public cloud. Resources can be scaled as necessary for enterprises using the public cloud because cloud providers provide resources as an online service. The cost of the public cloud is constrained since it uses a single-cost model for all users. Despite the benefits of public clouds, dependability is one of its disadvantages. Institutions are unable to control where the data is stored in the public cloud or guarantee that others won't access it. Despite the ease of accessibility, security and privacy is an issue in the public cloud.
- Private Cloud: It is held by a particular organization as opposed to the public cloud, which is accessible to everyone. Under this arrangement, the system is run by internal staff and maintains its equipment in the organization's nearby data centre. Since the private cloud belongs only to the organization, it has control over all information technology-related matters. The private cloud has the tremendous advantage of achieving data privacy, making the data accessible only to personnel who are authorized to work for the organization. The private cloud's main drawback is the enormous cost increase brought on by the substantial venture in software and hardware coupled with running and managing expenses.
- Community Cloud: Given that the institutions involved in the same infrastructure have similar tasks, they also have the same performance, privacy, and policy standards. Therefore, accessibility to a particular group of businesses that are members of a certain community and sharing mutual connection is made possible. Management and hosting of the community cloud can be done externally via a cloud service provider (CSP) or within the organization's premises. Increasing organization-to-organization collaboration and efficiency are two benefits of community clouds. The bandwidth and storage sharing that is one of the community cloud's disadvantages, despite its many benefits, may result in blockage. Additionally, the cost to operate is more expensive than a public cloud.
- Hybrid Cloud: The advantages of a community, private, and public cloud are all combined in a hybrid cloud. It offers all the advantages of every deployment method for cloud computing. This kind of cloud computing enables institutions to integrate other deployment models that work for them. Additionally, it allows for the control and preservation of important data, as well as the efficient use of resources and the simple transfer of legal data. By pooling resources and saving money like a community and public cloud, a hybrid cloud offers data security and privacy protection of a private cloud while maintaining independent entities when necessary. Scalability, security, and flexibility are all features of hybrid clouds [11].

D. *Cloud Features*

Some of the benefits of implementing cloud computing in higher education include:

- Virtual Classroom: Cloud-based software enables educational institutions to provide virtual classrooms for their students. The concept reduces the price of infrastructure by a substantial amount. Even expenditures associated with recruiting regular faculty members can be lowered. Alternatively, they may collaborate with remote trainers who are competent, cost-effective resources. Instructors can also construct and offer online lessons to students worldwide. In addition, students can take virtual exams, which saves both time and money.
- Cost Savings: Due to cloud computing, software and physical resources like books are not required because of the availability of learning resources. Management expenses are reduced by automating operations like registration and task tracking, which also lowers infrastructure costs. The "Pay-As-You-Go" concept enables institutions to only pay for the resources that are utilized.
- Accessibility: Users can quickly and simply access the course materials, software, and data from any location. Users can also sign up for classes and take part in group activities. Because of the cloud, there are no longer any limitations on when and where material can be sent. Cross-content access on mobile devices is also made possible by cloud computing, allowing students to conveniently learn even when they are on the road.
- Scalability: It is quicker and easier for universities to scale up learning applications and experiences, which results in more students that can be managed. Scalability also aids in controlling traffic surges and usage peaks such as assignment submission and sign-ups. In addition, institutions can quickly reduce their operations during periods of low activity to avoid wasting resources.
- Secure Data Storage: Cloud computing offers safe data storage. By using VPN to protect data, institutions can safely use the cloud to learn. Network activity of "outgoing data and traffic are automatically encrypted by VPN protocols like IKEv2" [12]. Therefore, users can quickly and conveniently access educational material without sacrificing its integrity. Using a Virtual Private Network (VPN), students may preserve their privacy while using cloud-based applications.
- Hardware Requirements: Applications that use the cloud place minimal demands on hardware resources. Both desktops and smartphones can run these programs instantly. It is not essential to purchase a computer to take the course; instead, students are able to use personal web-enabled devices to learn. Also, students do not require additional storage devices as they are provided with free storage in the cloud.
- Automation: Users and institutions do not require a highly specialized IT department to manage backups and system updates, as the CSP and vendors will constantly update the server in response to user or institution needs.
- Backup and Recovery: Cloud computing offers users ease in terms of backup and recovery, as the backup and recovery procedure is managed by the CSP, hence reducing maintenance expenses [13].
- Efficiency: Using email services supplied by email providers such as Gmail and Yahoo.com is an illustration of cloud computing's efficiency. The institutions can rely on mail providers to receive professional email, hence eliminating the need to purchase mail server infrastructure for their personnel. In addition, the institution does not need to purchase software to operate a mail server. These are the responsibilities of cloud mail system providers. Users can utilize all services from anywhere, regardless of computer kind, storage capacity, etc., allowing for increased productivity [14].

III. Critical Review of Education Related Cloud Features Provided by Major CSPs

A. Microsoft Azure

Microsoft offers a broad range of cloud services to assist businesses in meeting their demands. These services come from a variety of cloud platforms, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). All services are accessible in the form of hosting, application development and tools for productivity. Depending on the institution's needs, Microsoft PaaS named Azure enables the hosting and development of services and online apps that can swiftly scale up and down. Super Hyper-V is an organization-specific private cloud platform. Organizations can manage compliance, costs, and security with this platform. Also, this platform gives access to enterprises in the form of Economic and Enterprise private clouds, based on their business requirements and processes. Another service offered by Microsoft is Office 365. Office 365 provides an array of cloud-based apps including SharePoint, Exchange, and Lync [15].

B. Amazon Web Services (AWS)

AWS provides cloud services in Software, Compute, Database, Content Delivery, Storage, Deployment and management, Application Services, and Workforce [16].

- Software: Customers may search, purchase, and instantly begin using applications that operate on the Amazon cloud through the AWS Marketplace. The online store consists of several widely used open-source products [17].
- Compute: Amazon Elastic MapReduce, Elastic Compute Cloud (EC2), Elastic Load Balancing, and Auto Scaling. Elastic MapReduce is a web service that makes it simple and affordable for developers, data analysts, researchers, and businesses to handle huge quantities of data. EC2 offers scalable, pay-as-you-go compute power. With Elastic Load Balancing, several Amazon EC2 instances receive automatic distribution of incoming application traffic. While AutoScaling is enabled, EC2 capacity can scale up or down depending on circumstances.
- Content Delivery: With the help of a vast network of edge sites, Amazon CloudFront's web service allows content to be delivered with minimal lag.

- Storage: AWS Storage Gateway, Amazon Glacier, Amazon Simple Storage Service (S3), AWS Import/Export, Amazon Elastic Block Store.
- Deployment & Management: Includes AWS Direct Connect, Amazon Virtual Private Cloud (VPC), and Amazon Route S3.
- Application Services: Includes Amazon Simple Email Service (SES), Amazon Simple Queue Services (SQS), Amazon Simple Notification Service (SNS), Amazon Simple Workflow Service, and Amazon CloudSearch.
- Workforce: Via Amazon Mechanical Turk, businesses can instantly hire tens of thousands of workers from across the world and integrate their labour into a variety of operational procedures.
- Database: Amazon Elastic Cache – In-memory cache that is scalable and easy to operate, Amazon SimpleDB – NoSQL database service for a small dataset, Amazon DynamoDB – high-performance NoSQL database service that is scalable, and Amazon Relational Databases (RDS) - an easy-to-use database that resides in the cloud, which is also scalable [18].

C. Google Apps for Education (GAFE)

GAFE is a robust cloud computing tool that functions regardless of location or device type. The platform is used by hundreds of educational institutions across the world to effectively utilize the faculty and student collaboration tools that are readily available with the primary goal of improving teaching and learning. Users can collaborate online on projects, presentations, and papers in the cloud using GAFE capabilities. In addition to traditional classroom instruction, GAFE is utilized to create course websites that effectively provide material to students. Google+, Google Sites, Google Documents, Google Calendar, Google Groups, Google Drive, and Gmail are all part of the GAFE package. The main factors that academic institutions consider while deciding whether to implement GAFE are price, storage, reliability, and the range of services it provides.

With the use of online collaboration tools, students with similar interests may now share content on discussion forums, wikis, and in a variety of online-editable file formats. Google Docs makes it simple for several editors to work together and propose adjustments to a single document at once in real-time. Furthermore, limitations caused by geographical location, platform dependence, and compatibility problems are no longer an issue. Users may compare various copies of the same document, merge documents, and easily view all changes with different time stamps thanks to revision history. Users can also easily go back to earlier versions of a document. Furthermore, users can engage in discussions using the chat feature, and the document's owner can offer access permissions to individuals with different roles like watchers or collaborators [19].

IV. Challenges of Implementing Cloud Computing in the Education Sector

Organizations in higher education institutions desire cloud services that are not dramatically dissimilar from those wholly handled within their own centres. Though, they are confronted with several significant new obstacles. Access control, Network, Data Security, and Cloud Infrastructure are the four major categories of cloud computing challenges that the education domain is currently facing.

A. Access Control

Authentication, identification, and authorization are crucial Access Control security concerns. As authorized personnel have internet access to the cloud, cloud computing security threats are increased. The online application's insecure interface exposes an educational institution to the risk of unauthorized access. In addition, a weak authentication mechanism may increase the likelihood of unwanted access to globally accessible and shared data or services through the multi-tenancy cloud. To protect the privacy of user information and data kept on a cloud provider's server, a cloud system must employ a strong authentication mechanism as a fundamental and essential need. The primary duty of the service provider is to prevent unauthorized access to cloud services and customer data. The current best intervention strategy is through Virtual Private Network (VPN) technology, Next Generation Firewalls, and Privileged Access Management to prevent any intrusion [20].

B. Network Security

Concerns regarding a transmission medium's security that could prevent a user from connecting to a cloud infrastructure. Sensitive data during transmission is prevented from leaking by provisioning a secure medium. For as long as cloud computing operations are completely dependent on networks, which users utilize to transfer their data to cloud servers, the network is where most security issues arise. To protect users' data from common network-based attacks such as: Man-in-the-Middle, DoS, DDOS, packet sniffing, IP spoofing, port scanning, session hijacking, and phishing the service provider must offer access to a remote cloud server where the data is stored [21]. In response to network security, hacking and intrusion are two vulnerabilities that a cloud environment is subject to. Strong network security methods like the Transport Layer Security (TLS) and Secure Socket Layer (SSL) protocols are needed [22]. To further secure the system and prevent service hijacking, appropriate auditable access privileges, firewall router rules, and some security protocols are required.

C. Data Security

The main obstacle to cloud computing adoption in higher education institutions is data security issues. Several higher learning institutions still favour keeping their important data in the local repositories rather than transferring it to a distant cloud. Customers want cloud service providers to demonstrate to them their capacity to address various data security concerns. Data-at-Rest and Data-in-Transit are two cloud data states where security problems have been observed and categorized. Data at rest is the term used to describe information that is kept on cloud servers and must be protected to ensure that it has not been altered by an unauthorized user [23]. Particularly when data is kept in a remote location without any physical access to it, such as on a public cloud. When data is in transit, there is a greater chance that it will be lost or leaked as it moves from one place to another. The combination of an inadequate encryption technique with a weak key in a cloud setting poses the biggest risk to data security.

D. Cloud Infrastructure

Cloud infrastructure refers to the physical equipment that is used as the backbone for cloud computing, which also

includes virtual software that is used to operate the cloud resources. The virtualization environment is particularly connected to the cloud infrastructure, which includes key components of cloud service models. By dividing the computing power of a cloud server's computing resources into various execution contexts, virtualization is a core technique utilized by cloud vendors to create multi-tenant architecture. Due to the shared environment with multiple users, where every virtual instance is on the same physical system, the virtualization-based cloud is not secure. Lack of VM protection is one of the security issues associated with virtualization that cloud systems must deal with because several VMs must share a single computer, making it impossible to place a hardware protection device like a firewall between them [24]. VMs are automatically created, terminated, or migrated in a dynamic environment, which makes it difficult to monitor traffic and establish whether an attack is taking place. Attacks such as VM Rollback Attacks, Botnets, Phishing, Cross-VM Side Channels, Malware Injection, DoS, and Theft-of-Service are some of the common attacks that can place cloud infrastructure in a vulnerable state.

V. Conclusion

Cloud computing has changed the education industry by providing cost savings, flexibility, scalability, and security, among other benefits. It enables educators to access online instructional materials and resources, collaborate in real-time with students and colleagues, and save data on remote servers. Yet, there are still obstacles to overcome, such as the requirement for dependable internet connectivity, privacy and security concerns, and the lack of knowledge among administrators and educators. Thus, educational institutions must implement cloud computing while addressing these obstacles to ensure that the technology is utilized properly and optimally to enhance the quality of education.

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