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Keywords

infrastructure, architecture, data center, security

Cover Page Footnote

We give thanks to the University of Stirling for giving us access to their database

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Abstract

The most efficient approach to giving large numbers of students' access to computational resources is through a data center. A contemporary method for building the data center's computer infrastructure is the software-defined model, which enables user tasks to be processed in a reasonable amount of time and at a reasonable cost. The researcher examines potential directions and trends for a secured infrastructure design in this article. Additionally, interoperable, highly reusable modules that can include the newest trends in the education industry are made possible by cloud-based educational software. The Reference Architecture for University Education System Using AWS Services is presented in the paper. In conclusion, automation boosts efficiency by 20% while decreasing researcher involvement in kinetics modeling using CHEMKIN by 10%. Future work will focus on integrating GPUs into open-source programs that will be automated and shared on CloudFlame as a service resource for cooperation in the educational sector.

Keywords: Infrastructure, architecture, data center, security

Introduction

Currently, the data center is the most efficient way to give many students access to computational resources (Hellerstein, 2008; Alam, 2022). An interagency data center executes tasks from several classes using one task flow. It may execute queries from users with varying levels of competence, and when a user queries the interagency data center, the task class and user competence are determined. The interagency data center should enable users to complete their assigned activities (Zeeshan et al., 2022). Here, productivity refers to finding a superior solution to an issue in a reasonable amount of time and at a reasonable cost. The quality of this solution, in terms of the functionality offered by the data center, includes a user-friendly interface that enables one to describe the hardware needed for job execution, as well as the capacity of the data center to suitably meet these requirements (Haque et al., 2022). The time needed to remedy the issue, the time needed to configure the platform to meet user needs, and the time needed to access the platform are all acceptable. A data center's ability to efficiently organize itself so that its hardware is fully used to carry out tasks of various classes while meeting the requirement for excellent issue-solving is correlated with an acceptable cost (Gupta et al., 2022). The researcher examines potential directions and trends for a secured infrastructure design in this article.

Additionally, the educational system and associated practices always motivate every sector to grow. Information technology, which is developing, has the potential to be extremely important in the teaching and learning process (Williamson et al., 2022). However, improvements to the curriculum, delivery strategies, and learning procedures will significantly affect how well the education system works. A change from a knowledge-based education system to one based on critical thinking occurs as technology advances. The impact of IT may alter how data is distributed within the current educational system. The sector is more dynamic now that teaching, learning, and administrative procedures are digitalized (Singh et al., 2022).

Contrary to the conventional education system, the contemporary one requires regular updating with recent technologies and trends. Most organizations will find implementing a national or international education system challenging since standards are not integrated (Dahham & Fawareh, 2022). Maintaining the newest technologies and associated software to activate education services is challenging for many educational institutions. An integrated, tech-enabled education system must be implemented to learn the newest trends. IT-related tools and technologies are currently being employed extensively in the education sector to make some progress (Bishnoi et al., 2022).

Furthermore, one of the biggest problems with integration is the disparity in standards. As a result, it is crucial to upgrade the system using a widespread technology that can accommodate rapid changes. The primary area that can use web services to develop various services in the education sector is SOA (Service-Oriented Architecture).

The current shift of global education to a cloud-based system has the potential to make teaching and learning more engaging (Chatterjee et al., 2022). Utilizing cloud applications to manage the data and associated services will keep the data's dynamic character. Establishing a statewide standard education system will be more efficient and cost-effective thanks to adopting such an integrated system (Utami et al., 2022). A cloud-based education system entails turning on educational services that use the cloud's processing, networking, and data storage capabilities. A centralized education system built on the cloud enables us to integrate its features and keep the necessary data in the system (Attaran et al., 2017; Khan et al., 2022).

Additionally, utilizing cloud infrastructure for education demonstrates how to harness the potential of the cloud for use in administration, teaching, learning, and research. Additionally, interoperable, highly reusable modules that can include the newest trends in the education industry are made possible by cloud-based educational software. The Reference Architecture for University Education System Using AWS Services is thus presented in the paper.

Related work

Cloud-based education systems aim to offer their stakeholders the most current educational services in teaching, learning, administration, research, and collaboration from any location at any time at a lower cost (Kumar et al., 2022). Numerous research reviews have been conducted to use the benefit of cloud computing in the education sector (Leu et al., 2017). The National Education Technology Plan, issued by the US Office of Education Technology, emphasizes the significance of reimagining the function of technology in education (Foulger et al., 2019). This article describes how IT may assist educators, decision-makers, and administrators make the most of educational services. El-Mhouti et al. (2019) described a cloud computing architecture and its benefits for e-learning systems. They covered the difficulties of implementing such structures and potential solutions in this essay. Moh-Noor et al. (2019) addressed the value of cloud computing services in the framework for mobile learning. They also examined the benefits and drawbacks of employing cloud computing in the educational sector. In order to comprehend how cloud computing infrastructure is now used in educational systems, numerous surveys are frequently undertaken. These studies detail the rate of cloud computing used in the education industry and its advantages. (Riahi, 2015; Baldassarre et al., 2018; Elgelany & Alghabban, 2017). Nan-Cenka and Hasibuan (2013) offered a plan to use the existing cloud services to improve the operations of the educational system, including teaching, learning, libraries, and labs.

Several architectures are put up to investigate the possibilities of cloud-based services in creating higher education systems. However, only some studies have focused on creating models for cloud-based architectures to address the education sector's issues. Bogdanovic et al. (2017) offered a cloud-based education model that addressed all the problems in creating a cloud infrastructure for education. They also show how using cloud-based infrastructure improves e-learning systems in meaningful ways. Mehdi (2015) presented an architecture to maximize network, storage, and computation resources. This research attempted to examine how architecture affected educational services. An example of vertical cloud architecture is to use a vertical IaaS (Infrastructure as a Service) cloud architecture to replace expensive computer lab infrastructure (Brummett & Galloway, 2018). Lakshmi (2016) presented a cloud computing-based architecture for e-learning applications. All suggested architectures were created using the provider's cloud infrastructure and services in the computing, network, storage, management, and monitoring domains. (Brummett & Galloway, 2018; Elhoseny et al., 2016). However, sensitive data operations in the cloud worry higher education organizations. In light of the education sector's need for security and data protection, hybrid cloud architectures are a good fit (El-Mhouti et al., 2018).

Another relative study is that of Caviglione et al. (2016), where an innovative approach to using personal cloud storage services for constructing covert channels has been researched to exchange data online stealthily. Researchers concentrated on the Dropbox program. Then, a performance analysis of this application's two covert communication methods was displayed. Finally, a production-quality deployment of Dropbox allowed for exploring its behaviors (Chen, 2017). To optimize the threshold value and weight in radial basis function (RBF) neural networks, the artificial bee colony (ABC) algorithm is used. After that, the nonlinear time series was examined. It was determined from the results of the experiments using the suggested model that it has a high degree of accuracy in predicting and reflecting the changing law of the data flow. Finally, Caviglione et al. (2016) concluded that the suggested model had good potential for traffic flow prediction. Additional pertinent research studies have been conducted on cloud systems' data storage security, encryption, and privacy. Yang and Jia (2013) suggested a practical and secure dynamic auditing technique for data storage in cloud environments. A data integrity protection (DIP) strategy was implemented, tested, and evaluated using various criteria in a cloud storage testbed (Chen & Lee, 2014). With effective, verifiable fine-grained updates, Liu et al. suggested a new technique to provide approved public auditing of dynamic ample data storage on the cloud. The complete cloud-based system was deployed with mediated certificate less public key encryption (mCL-PKE), and its security and performance were assessed to demonstrate its efficacy (Seo et al., 2014).

Walsh et al. **(**2004) suggested a dynamic capacity allocation resolving model for multi-tier network applications that can determine how many resources should be allocated to each application service level and the ideal timing for allocating these resources using a combination of prediction methods. Wan et al. (2012), the authors suggested a controller for allocating resources that can maximize revenue under a specific charge model, and that can be employed in multi-tier data centers. The heuristic-solving approach is also created. Its disadvantage, however, is that this model uses a physical resource allocation approach and presupposes that readily available resources are adequate. Furthermore, distinctions between various application layers still need to be made. Using the resource reallocation plan offered by VMMs (Virtual et al., i.e., Barham et al., 2003; VMware, 2002), Through on-demand local resource scheduling models or algorithms within a physical server, many researchers concentrate on enhancing resource utilization as well as ensuring the quality of the hosted services. Xu et al. (2007) described a flexible two-level resource management system that can deliver excellent quality of service for a lot less money than worst-case provisioning. The global profit will be maximized thanks to its fuzzy model. All the methods mentioned above follow the single-tier application performance concept. However, only some of these methods might be reasonable compromises between SLA and resource utilization. A global resource scheduling function is required in a shared cloud computing environment. To give future researchers, the information they may use to develop an effective and efficient secured infrastructure in the fields of education and other research, the study set out to outline future trends and directions for secure infrastructure architecture.

Method

The well-known systematic review techniques for business and management studies given by Tranfield et al. (2003) have been used in this paper. There are three phases to these processes: Stage 1: "planning the review" by determining the necessity of it, clearly articulating this necessity, and creating the protocol for the review. Identifying the primary study area, choosing the appropriate studies, evaluating these studies, extracting the data, and analyzing the data are all steps in the second stage, known as "doing the review." In Stage 3, "reporting and disseminating the review," suggestions are reported, and data is introduced into the study area (Tranfield et al., 2003). The preliminary stage, "planning the review," was primarily influenced by the earlier research. A set of keywords was utilized in the second stage, "doing the review," to accurately identify journal papers that provided future trends and directions for protected infrastructure design from various angles, like Hiebl (2013). The Scopus databases were searched using these keywords. The titles, keywords, or abstracts of the articles had to have a combination (AND conjunction) of two groups of keywords for preliminary inclusion in this paper's review (secured AND infrastructure AND architecture AND data AND center).

Additionally, this research concentrates on recently released studies. The Reference Architecture for University Education System Using AWS Services Amazon Web Service includes several prior studies to enhance the quality of the research (AWS). Consequently, 7 of the 14 papers that successfully met all the criteria mentioned above as of May 9, 2022, were chosen for this publication. However, more articles have yet to be disqualified from the subsequent analysis stage for the following reasons: Future trends should have been mentioned in specific papers. To move to the second and third steps of the systematic review technique, as advised by the remaining chosen articles (Tranfield et al., 2003). The key findings of the data analysis and the anticipated future trends are presented in the following section, followed by the conclusion.

Future trends and direction

To ensure the privacy, accuracy, and availability of data stored on or transmitted across a network, security must be integrated into software-defined networking (SDN) design and offered as a service (SDxCentral, 2022). In addition to the existing threat vectors in traditional networks, Kreutz (2013) identified three threat vectors related to SDN, including attacks on control plane communications, attacks on and vulnerabilities in controllers, and a lack of mechanisms to ensure trust between the controller and educational management applications. By design, the controllers manage the entire network with upper-layer applications. As a result, when the controller is compromised, the whole network is impacted. The controller often programs the switches to return the first packet from any unknown flow. Attackers may utilize this as a way to sabotage the communication, flood the controller with erroneous packets from numerous switches, and subject the controller to distributed denial of service (DDoSTo counter potential DDoS assaults on the SDN controllers, control plane protection on the switches can be helpful). This can be achieved by ensuring that the data plane of network devices like switches is constructed with just the right amount of processing power to allow them to forward traffics under the maximum anticipated demand. If they are subjected to a DDoS attack, the processors cannot send the controller many packets. The use of graphical processing units (GPUs) to handle the processing of the portion of partial and ordinary differential equation (ODE) solvers that may be done separately is one area that we are investigating.

Contrary to CPUs, which devote a large portion of their processing power to caching, GPUs devote 95% to handling data and calculations. As a result, they are more effective in modeling kinetics and combustion ODEs. This has already been accomplished by Shi et al. (2012) and Shi et al. (2011). The addition of the GPUs within a cloud-based environment for sharing and collaboration marks a contrast with our strategy, nevertheless. Another area to consider is the future development of algorithms to connect open-source modeling tools like OpenSMOKE++, CHEMKIN II, and Cantera with paid modeling programs like CHEMKIN PRO. Since CHEMKIN PRO is a limited commercial tool, we cannot use the simulation codes for sharing in CloudFlame now. Teachers can provide the source codes to their students, and students can share among themselves thanks to open-source components. Another area to be used in our future work is creating an XML data schema that supports additional species to enhance the search processes based on species' molecular structures and chemical compounds. According to Wan et al. (2012), future research should concentrate on deploying the Trusted Private Virtual Datacenter (TVPDc) architecture built using open-source tools. The next research project will focus on the more effective and secure TVPDc deployment and VM migration protocol.

Memos et al. (2021) stated that future studies should incorporate security algorithms into proposed methods in the literature and provide greater security in data encryption and data storage areas in the cloud. New features, such as an intelligent sandbox in the client antivirus program and system-changes-based virus signatures developed in the cloud, should be proposed soon. Finally, regarding how it affects our promising transmission strategy, the data error ratio is a significant parameter that should be further researched. It is also important to note that cloud technology will optimize energy consumption in future communication networks. This could be another area of study. The forecasted future trends from the review papers are shown in Table 1.

Table 1 *Future Trends and Directions*

Author & Date	Aim	Findings	Future work
Choudhari and Sasankar (2021)	In order to meet future needs with improved service delivery, increased throughput, and increased efficiency to provide secure cloud services and to close the gap between cloud service providers and end users, this paper investigates, studies, and analyzes the cloud architecture of the Government of India. It then makes recommendations for modifications that should be made.	The GI cloud architecture offers the best use of ICT resources for utility computing with features like generic architecture, usage simplicity, and a variety of self-service portal components over integrating existing network infrastructure across the country like the NICNET, SWANs, NKN, and NOFN and ICT resources to adopt cloud computing by the government. E-Governance applications into schools following common standards at one location using a set of common protocols	Choudhari and Sasankar (2021) proposed that in order to integrate developing technologies, cloud service providers and government educational cloud management work. They proposed that future efforts should focus on security in cloud computing as security is the main challenge in implementing upcoming cloud computing technologies. A strategy for future work in cloud computing security in government educational institutions was put up by Choudhari and Sasankar (2021).

		can be developed and deployed more quickly and on a broader scale while minimizing technical exercises.	
Jabarulla and Lee (2022)	presented a proof-of-concept (POC) design for a patient-centric image management (PCIM) system, a distributed framework built on blockchain technology and intended to provide safe patient-centric access to and storage of encrypted medical pictures across a distributed open network in higher educational institutions.	The suggested solution allows for shared access to medical pictures while facilitating patient access to an immutable medical database that improves efficiency, data provenance, and effective audit in higher educational institutions.	A study by Jabarulla and Lee (2022) implemented the proposed POC architecture in the public blockchain using actual scenarios to create a worldwide PCIM system and to assess the laws and rules needed to adopt this cutting-edge technology within the healthcare system. Future research should incorporate an adaptable educational market model into their suggested framework by applying a credit mechanism in smart contracts and artificial intelligence components. Incentives for patients in higher educational institutions to contribute their medical photos to Deep Learning research projects could be provided through the market model (Report Linker, 2022), which is impossible with traditional image management systems. Clinical staff in higher educational institutions can better evaluate diagnostic images using artificial intelligence without communication hiccups.
Baker et al. (2020)	To improve the integrity, security, and privacy of SCADA-based IoT critical infrastructure at the fog layer, a novel security "toolbox" has been proposed.	The trial results show that the secure fog-based platform performs better than the multilevel user access control platform, adding virtual machines (VMs) in 2.8 seconds	In order to fully illustrate the benefits of the suggested toolbox, Baker et al. (2020) future work will concentrate on validating the proposed approach against the expectations of the critical infrastructure providers and

		for five, 3.2 seconds for ten, and 112 seconds for one thousand.	further developing, integrating, and evaluating the identified functionalities to assist higher educational institutions.
Narayanan et al. (2022)	proposed Secure Authentication and Data Sharing in Cloud, a revolutionary system architecture (SADS-Cloud).	The researchers suggested SADS-Cloud architecture for an E-healthcare application for students and evaluated performance. They compared several metrics (information loss, compression ratio, throughput, encryption time, decryption time, and efficiency) with the existing approaches. The SADS-Cloud proposal for an E-healthcare application for educational institutions was deemed superior by the study.	Narayanan et al. (2022) intended to present additional real-world uses for the SADS-Cloud system and contrast it with other encryption techniques in the future. Future research should improve the SADS-Cloud system to further hasten encryption and decryption processes
(Abrar et al., 2018).	A metering network that gathers real-time load data for smart grid monitoring, theft detection, line losses in distribution networks, and renewable energy resource scheduling optimization has been proposed.	Results and simulations have demonstrated the system's dependability and effectiveness. Future applications could include the levels of educational institutions, industrial and small business regions while still involving residential neighborhoods.	According to Abrar et al. (2018), tackling residential neighborhoods and industrial and small business areas at once can help this field more. However, future studies can tackle all levels of educational institutions worldwide.
Kassim et al. (2018)	present a design and validated framework architecture for disaster recovery (DR) using high data availability server virtualization at one campus network center.	Results showed that 99.91% of the data were recovered during the recovery process using multi-side network RAID, including Recovery Point Objective (RPO), Recovery Time	Future research into cloud technology for data security for DR good archiving and DR resources is possible. Research into cloud computing server performance and the effects of its effectiveness and efficiency in the event of a disaster are both possible. Undoubtedly,

		Objective (RTO), data loss, and data availability. In terms of high availability and data protection, this strategy safeguards many disaster recovery workloads.	the cost of cloud technology relies on the needs of educational institutions.
Ezefibe and Shayan (2016)	presented an overview of how network function virtualization and software-defined networking (SDN) might support the further growth of wireless networks.	By separating the control logic from the data plane, SDN makes networks more scalable and manageable, which boosts performance. SDN holds excellent potential for the future of networking.	By employing certified certificates from CAs like Symantec, and Entrust, the communication line between the controller and the network parts can be more secure. Second, the SDN controller and applications are created on a common platform, such as the Linux operating system, which has security flaws. To prevent the platform from becoming a potential attack surface, effective platform hardening must be done.

Reference Architecture for University Education System Using AWS

The most well-known cloud provider, Amazon Web Service (AWS), provides various cloud services that can be used to build dependable cloud systems. Fig. 1 depicts the suggested reference design for the Amazon Web Services-based university education system. The university education system's on-premises data centers are connected to the AWS cloud through a VPN. To maintain the connection, Customer Gateway is utilized at the university data center, and the cloud service Virtual Private Gateway is used in the cloud environment. To keep the resources in the AWS cloud functioning, a VPC is created across several availability zones. Each availability zones contain private and public subnets; its workload is balanced among multiple availability zones by Amazon Load Balancer. The resources needed to be connected to the internet are in the public subnet. The resources that need more security are in the private subnet and cannot be accessed directly from outside. Web servers are maintained in public subnets, and the application database servers are with the private subnets. All the business logic is in the application server. These application services relate to different educational requirements of this architecture for various operations (Amazon Web Services, 2020).

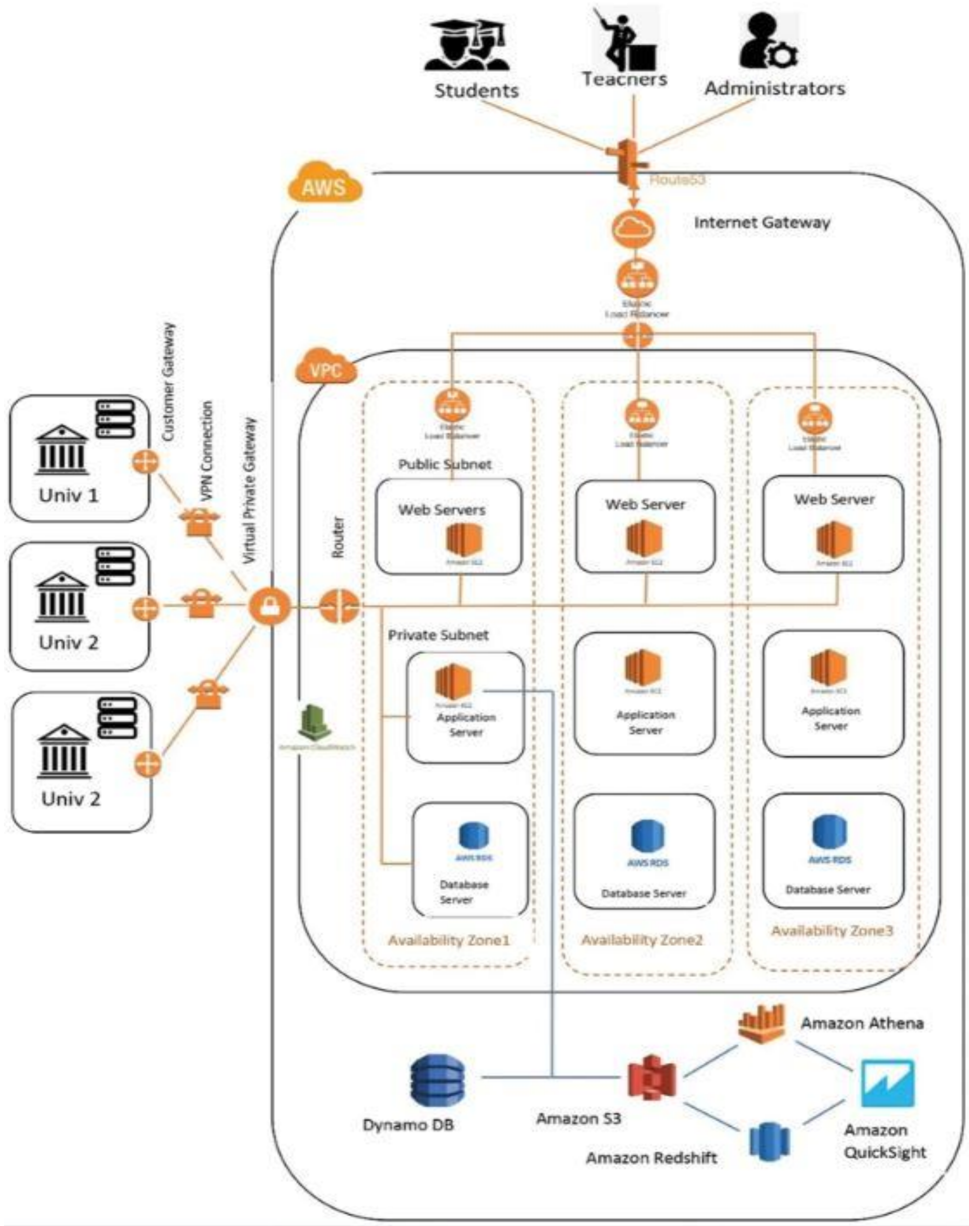

Figure 1 *AWS educational cloud architecture*

Web servers are operated with EC2 (Elastic Compute Cloud) instances to run the web application and various cloud services. The database server is maintained with Amazon RDS

(Relation Database Service) instances which will not be accessible from outside. Students, teachers, and administrators can access the web application and related services by using the website of their respective institutions. The stakeholders can access their website through the Internet Gateway using the domain name service Amazon Route53. The EC2 instances are in the auto-scaling group, and Amazon Load Balancing Service balances their workload. This setup is also scaled across several availability zones. Here, the services Amazon S3 and Dynamo DB are the storage options to store the data of various formats. These services are outside the VPC and can be accessed using the Amazon EC2 instance from the private subnet. Based on the privilege given to the stakeholders, they can access the services of the education system. Real-time analytics will be done with Amazon Kinesis so that the stakeholder can get actionable insights for immediate response. Major education reforms will be taken based on big data processing by Amazon EMR (Elastic Map Reduce). Here S3 can act as the data lake for storing vast amounts of data flowing through the education setup (Amazon Web Services, 2020). All users of the educational system receive insights from Amazon QuickSight via interactive dashboards. Table 2 describes this architecture's AWS cloud services, domain, and function. The cloud services integrated into this architecture can help build a dependable, effective, and secure cloud education system to solve the current education sector issues. Other leading cloud service providers, like Google Cloud and Microsoft Azure, can also be used to construct the proposed architecture.

Table 2 *AWS Services used in the architecture*

Service name	**Service domain**	**Role in the architecture**
EC2	Compute	to maintain the architecture's instances of web and database servers.
AWS RDS	Database	managing organized data in conjunction with the educational system
Elastic Load Balancer	Network and Content Delivery	To improve performance, distribute the workload among the different computational resources employed in the architecture.
Route 53	Network and Content Delivery	It links user queries to the AWS cloud's educational infrastructure.

Dynamo DB	Database	stores the analytics-related education data that has been gathered from various sources.
Amazon S3	Storage	The object storage serves as the complete educational system's data lake.
Amazon RedShift	Analytic Service	Scalable data storage for analytics in education
Amazon Athena	Analytic Service	Interactive query service to examine the S3-stored object data.
Amazon QuickSight	Analytic Service	This program provides stakeholders in the education system with analytical information.
Amazon Cloud Watch	Management and Governance	Monitors and optimizes the resource utilization of the architecture
AWS Direct Connect	Network and Content Delivery	A dedicated network connects the institution's on-site data center and the AWS cloud infrastructure.
AWS VPC	Network and Content Delivery	It enables the management of the cloud education setup's resources within a private network.

Conclusion

With this cloud architecture, several future improvements can be made to meet educational requirements. Cloud service providers like AWS permit the creation of VPCs in several regions that can interact via VPC peering. So that internal resources within the VPC can connect without using the internet, this design can be expanded to build numerous VPCs in various areas. Furthermore, in this environment, permission, and authentication of stakeholders to access particular services are crucial. Cloud providers provide identity, access control, and security services to address this issue. A safe and dependable education system will come from selecting the proper services. To improve the performance of cloud-based systems, leading cloud providers constantly roll out new and cutting-edge services. Such services can also be included in the planned education system to handle future advances in the educational field. The on-site data center can operate a private cloud where cloud resources can be virtualized like in a public cloud environment. The use and integration of cloud services in the on-premises data center and cloud architecture are even better in such circumstances. Cloudflare is connected to the Rocess Informatics Model and Amazon EC2 to improve its scalability and availability. In conclusion, automation boosts efficiency by 20% while decreasing researcher involvement in kinetics modeling using CHEMKIN by 10%. The research will focus on integrating GPUs into open-source programs that will be automated and shared on CloudFlame as a service resource for cooperation in the educational sector.

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