Exploiting Edge Computing for Enhanced Data Management: A Case Study in a State University's Development Strategy

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Abstract- ***Managing massive quantities of data from various sources, including research, administrative functions, and student information, presents significant challenges in the constantly shifting digital environment of modern universities. Network latency, a prevalent problem in conventional cloud-based systems, affects application performance by affecting the distribution of workloads and the sharing of hosts. Although cloud-based solutions have proven to be effective in delivering dependable data storage and processing capabilities, emerging technologies such as edge computing show great potential for improvements. Edge computing, through the localized processing of data closer to its source, reduces latency and enhances efficiency, making it especially useful for immediate data analysis and applications requiring quick access to large datasets. This technology has the potential to reduce dependence on centralized data centers, which could lead to cost savings and improved scalability. Additionally, it can enhance data security by keeping sensitive information processing localized. This paper aims to investigate the exploiting the data management infrastructure of the universities in the Philippines can benefit from the implementation of edge computing. The purpose of this effort is to find solutions to the problems that are currently concerning scalability, responsiveness, and security. To evaluate existing systems, investigate the capabilities of edge computing, and locate possible areas of integration, the research makes use of a mixed-methods approach, which includes conducting surveys and interviews with professionals in the field of information technology. According to the findings, edge computing has an opportunity to significantly improve the effectiveness, safety, and performance of data management. This is to the objectives that the university established for itself in terms of sustainability. Among the recommendations are the prioritization of the adoption of technology, the development of infrastructure, and the implementation of strong data management practices to fully exploit the benefits of edge computing. (Edge Computing, Information Technology, Innovation)***

I. INTRODUCTION

In today's digital environment, universities are required to manage massive quantities of data coming from a wide range of sources, such as research, administrative operations, and information about students. additionally, network latency has a significant impact on the performance of cloud-based applications, which in effect includes an impact on the location of workloads and the sharing of physical hosts.(Popescu et al., 2017) .

Traditional data management systems that are organized in the cloud have been able to successfully meet the requirements of universities by offering dependable storage and processing capabilities for intellectual property. On the other hand, emerging technologies such as edge computing promote the development of interesting opportunities for the further improvement of these processes.

The term "edge computing" refers to the technique of processing data near its origin, which helps to reduce latency and improve efficiency. In the case of state universities, this indicates that data can be processed and analyzed in a more efficient manner, which ultimately leads to a quicker decision-making process and more immediate information. When it comes to research projects that require real-time data analysis or applications that rely on quick access to large datasets, this can be especially helpful. Additionally,

edge computing can help universities decrease their dependency on centralized data centers, which may result in cost reductions and an increase in flexibility. Rather than sending important information to a centralized data center like cloud computing, universities can improve data security and privacy by offering operations to a network of edge devices. This makes it possible for important information to be processed locally rather than being transmitted over the cloud.

Especially when it comes to dealing with data management, the university in Rizal which utilizes traditional centralized data management approaches, such as cloud computing, faces challenges in terms of scalability, responsiveness, and security. In additional to that, cloud computing has security problems that are associated with the data that is stored on clouds, which can compromise the integrity of the data and the availability of services.(Jogdand et al., 2015)

Edge computing indicates an advance towards decentralized computing, wherein data processing and storage develop nearer to the data source or end-user devices rather than at centralized data centers. Edge computing facilitates accelerated data processing, reduced latency, and enhanced efficiency, rendering it optimal for real-time analytics-intensive applications such as autonomous vehicles, industrial automation, and augmented reality.

This paper analyzes the exploiting of utilizing edge computing as a transformative approach for data management in state universities, with a particular focus on the university in Rizal. Edge computing provides advantages including decreased latency, improved privacy, and efficient resource utilization by situating data processing and storage nearer to the source.

And also the study seeks to improve efficiency and collaboration in an agile educational setting by creating data storage solutions for IT staff, faculty, administrative offices, and state universities. The research seeks to offer users efficient, accessible, and flexible storage solutions through the application of edge computing technologies. This will help in the transition to a more flexible and digitally-oriented instructional framework.

The primary objective of this study is to explore and create edge computing solutions for data management in a state university setting. The research aims to improve efficiency and collaboration in education by offering customized storage solutions for teachers, students, and academic institutions, thus enabling a smooth transition to a digitally oriented educational environment.

Therefore, the increasing data management challenges faced by state universities, including the University in Rizal , required this research on "Exploiting Edge Computing for Enhanced Data Management." Traditional cloud-based systems are becoming insufficient for handling the massive amount of current data. My research attempts to address these inefficiencies by exploring the integration of edge computing. This technology reduces latency and improves data processing by establishing computation closer to the data source. This study is important because of its potential to enhance the performance, security, and scalability of data management systems in educational settings. My research question examines how to properly incorporate of edge computing into current frameworks to enhance their efficiency. The results seek to provide significant insights for enhancing data management practices, especially in real-time analytics, security, and infrastructure scalability. This study aims to offer strategic recommendations for the future implementation of technology in state universities by addressing these essential problems.

II. RESEARCH METHOD

This study aim to determine whether there is a relationship between the components (variables) being researched, the researcher employed a mixed explanatory method (quantitative and qualitative) study design. Variables, in particular in the Exploiting Edge Computing For Enhanced Data Management: A Case Study In A State University's Development Strategy? The study occurred at the state university in region 4 between 2023 and 2024. It aimed to assess the potential of employing edge computing in a state university to enhance data management. The evaluation utilized validated questionnaire checklists and open-ended questionnaires distributed among IT experts. Criteria

for evaluation encompassed aspects such as current data management systems and infrastructure in place within the state university, areas within the university's data management framework where edge computing can be integrated to improve efficiency and performance, the recommendations of the respondents for the future adoption and optimization of edge computing technology in the state university's data management strategy. Furthermore, it entails recognizing potential threats to internal and external validity within the proposed study.(Creswell et al.,2018).

III. RESULT AND DISCUSSION

A. Current Data Management Systems and Infrastructure in Place within the State University

1. Performance

The findings suggest that there is a strong agreement among experts and end-users regarding the necessity of enhancing system scalability and internet speed. The mean scores of 4.67 for both groups indicate that all participants agree that the current system's performance is restricted by the internet speed and the inadequacy of scalability to meet future demands. Froilan Paz, an engineer, remarks that the system functions satisfactorily; however, the slow internet speed offers an important challenge, reducing efficiency and accessibility to online resources. The system's capacity to accommodate the university's increasing needs is a source of concern. It is important to address these issues by improving the internet infrastructure and evaluating the system for scalability improvements.

2. Access Controls

In terms of access controls, the current system's efficiency in securing sensitive information was deemed deficient by both respondent groups. The higher mean scores suggest that there is a consensus regarding the need for improvement. System ability concerns are underscored by the average scores of 4.50 for experts and 4.24 for end-users. Dr. Michael Intia is of the opinion that the current access controls are insufficient and that the system has deficiencies in its ability to respond promptly to security threats. In order to more effectively protect sensitive data, it is imperative to enhance the system's responsiveness to breaches and improve access controls.

3. Data Storage Capacity

The data storage capacity of the university was concluded to be inadequately accurate by both groups. The median scores of 4.44 for experts and 4.28 for end-users indicate that there are challenges with information accessibility and concerns regarding ineffective security measures. Engineer Paulo Jurada emphasizes the challenges related to data retrieval, particularly in critical situations, and contends that the current security measures might not be sufficient to prevent unauthorized access. To ensure reliable access and effectively secure data, the university must enhance its data storage infrastructure and security measures.

B. Areas for Integration of Edge Computing in the University's Data Management Framework

1. Data Security

Experts and end-users showed a strong agreement that edge computing may significantly enhance data security in the university's data management system. Experts rated the potential impact of edge computing on data security with an average score of 4.31, whereas end-users gave a score of 4.39. The overall mean score was 4.23 for experts and 4.35 for end-users. This indicates an understanding that edge computing enhances secure access controls and improves measures to prevent unauthorized access and data breaches. The ability of edge computing to process data closer to its source reduces the risk of data breaches during transmission, indicating an important improvement.

2. Performance and Reliability

Regarding performance and reliability, both groups strongly agree with edge computing, with experts giving a mean score of 4.50 and end-users 4.46. The average scores were 4.28 for both experts and end-users. This indicates that edge computing is regarded as capable of addressing latency demands for real-time applications and enhancing overall system performance. Edge computing reduces latency and improves application efficiency by processing data locally, which is important for the university's data management system.

3. Environmental Considerations

Experts and end-users evaluated edge computing favorably, with the highest mean scores of 4.25 for experts and 4.54 for end-users, with respect to environmental considerations. Experts achieved an average score of 4.17, while end-users achieved an average score of 4.27. This suggests a well-established comprehension that the integration of edge computing has the potential to improve the university's sustainability objectives and decrease energy consumption. Edge computing reduces the demand on data centers and conserves energy by processing data closer to its source, thereby reducing data transmission across networks. This approach delays the usefulness of computing devices and reduces operational expenses.

C. Future Adoption and Optimization of Edge Computing Technology

1. Technological Adoption

The implementation of edge computing technology has been strongly agreed by experts and end-users. The transition to edge computing required comprehensive training and support, as shown by the mean scores of 4.5 experts and 4.65 end-users, respectively. This suggests that there is an overall mean regarding the importance of comprehensive training to effectively prepare and support faculty and staff during the transition.

2. Infrastructure Development

Both groups strongly agree on the importance of improving the existing IT infrastructure to support edge computing. Overall mean for infrastructure development were 4.44 for experts and 4.5 for end-users. . It indicates that respondents agree with the importance of enhancing IT infrastructure to facilitate the effective integration of edge computing and to support future growth.

3. Data Management Practices

It was strongly agreed by both experts and end-users that the integration of edge computing into data management practices would significantly enhance the security and privacy measures in effect. The mean score for end users was 4.67, while the mean score for experts was 4.38. This implies that there is a general agreement that edge computing demands enhanced privacy and security measures to resolve the current challenges it is providing. This involves hard access controls, strong security measures, and regular security assessments.

IV. DISCUSSION

1) Current data management systems and infrastructure in place within the state university.

a. Performance

The study shows that the current information management systems at the state university are functional but require enhancements in internet speed and scalability, as observed by both specialists and users. These results align with current research on edge computing and data management. Shi et al. (2016) and Premsankar et al. (2018) emphasize the significance of edge computing in reducing latency and processing issues in IoT applications, thereby underscoring the necessity for improved system performance. Ali Sunyaev (2020) and Sadeeq et al. (2021) similarly highlight the scalability of cloud computing and the corresponding security challenges, which need enhanced data management and strict security measures, as shown by the study's results.

It was found that there were problems with performance and scalability, which proved that the system needs to be updated. These findings show that edge computing and more advanced data management methods are needed to handle more data (Oikawa & Kondo, 2021; Carvalho et al., 2021). However because the study only used subjective feedback, it might not have caught all technical problems. Edge computing also comes with problems, like keeping track of limited resources and making sure data is safe (Journal of Cloud Computing, n.d.; Malak, 2021). These problems need to be fixed with more technical assessments.

In the future, researchers should look into machine learning techniques for better data processing and security and do in-depth reviews of edge computing solutions (Carvalho et al., 2021; Baig, 2022). Updating the university's infrastructure should be the primary concern if they want to improve system performance and flexibility. For safety and effectiveness to remain excellent, there will need to be constant monitoring and improvement.

b. Data security

A review of the existing data management systems and infrastructure at the state university reveals several important insights regarding data security. Although these higher evaluations, the data indicate that the current access controls are insufficient for securing sensitive information and that the system shows a lack of responsiveness in cases of potential data breaches. This conclusion corresponds with Dr. Michael Intia's observations that existing access controls are ineffective and that the system does not respond quickly to security threats.

The research reviewed supports these findings by emphasizing the essential importance of data security and the challenges inherent in cloud and edge computing environments. Shi et al. (2016) contend that edge computing is essential for reducing latency and data volume challenges in IoT applications, proposing that real-time processing at the network edge can improve data security. Cao et al. (2020) similarly suggest that edge computing enhances security and privacy by decentralizing data processing, compared to conventional cloud computing models. Still, they also highlight that edge computing offers unique security challenges, including the management of privacy-sensitive data and the formulation of effective safety measures in environments with limited resources (Carvalho et al., 2021).

Ali Sunyaev (2020) emphasizes that although cloud computing offers many advantages, it also offers considerable security risks, such as data breaches and unauthorized access. This is supported by the concerns expressed by Datta (2013) and Yang et al. (2020) concerning data privacy and the necessity for strong security protocols in cloud environments. The review emphasizes that the transition to cloud-based data management, although advantageous for scalability and resource accessibility, presents concerns regarding data protection and demands strong security protocols (Sadeeq et al., 2018).

Given these findings, it is clear that the university's current data management system requires significant enhancements to its security framework. The incorporation of edge computing could reduce certain concerns by improving data processing capabilities at the edge and reducing dependence on centralized cloud storage. Future research should investigate the deployment of advanced edge computing solutions and their effects on data security and management. Furthermore, there is an importance for additional studies to assess the efficacy of several different security measures and protocols in both edge and cloud computing environments.

c. Data Storage Capacity

According to the findings of the study, there are significant potential areas for improvement in the data storage capacity and security measures of the state university. Even though both experts and end-users rated the data storage capacity a positive rating, with experts giving it a mean score of 4.33 and end-users giving it a mean score of 4.08, there is still no question that the systems need to be improved to ensure that users have access to information that is both reliable and secure. This input is supported by the concerns mentioned by Engineer Paulo Jurada regarding the difficulties in retrieving data during times of emergency and the lack of proper safety protocols.

The one that can be made from these findings is that despite current data storage capacity can satisfy basic demands, they are not capable of providing the required level of reliability and security, which is essential for efficient academic and administrative duties. The limitations of the currently available systems will likely increase as the volume of data continues to grow and the demand for quick access continues to rise. The insights provided by Jurada illustrate the risk of unauthorized access and data breaches, thereby drawing attention to the pressing requirement for increased security measures.

A review of the relevant literature provides light on how emerging technologies such as cloud computing and edge computing could potentially address these issues. Edge computing, which has been defined in detail by Shi et al. (2016) and Premsankar et al. (2018), is the process of processing data closer to its source in order to improve real-time processing and meet latency requirements. This is in line with the university's requirement for improved data storage solutions. In addition, Xue et al. (2020) point out that the integration of edge computing with Internet of

Things applications offers potential solutions for the management of growing data volumes and the enhancement of processing efficiency.

Both the evaluation of existing data management systems and the investigation of potential solutions for edge computing have been accomplished as a result of this study. According to the findings, the currently in place systems, although they are somewhat efficient, are not sufficient in terms of reliability and confidentiality. Future research should concentrate on determining whether or not it is practical to include edge computing into the data management infrastructure of the university. This is particularly important to address the difficulties related to data retrieval and the concerns regarding data security. It would also be beneficial for further research to investigate the efficacy of various edge computing architectures and the impact that these architectures have on data management practices.

The university ought to take into consideration the possibility of upgrading its data storage infrastructure by incorporating edge computing solutions to enhance the accessibility and safety of recorded data. At a time when data volumes and technological requirements continue to grow, it will be essential to implement advanced security protocols and continuously monitor these improvements to keep data management systems that are both effective and secure operational.

2) The areas within the university's data management framework where edge computing can be integrated to improve efficiency and performance.

a. Data security

This study shows the advantages of integrating edge computing into the data management framework currently being utilized by the University 's, particularly in the enhancement of data security. Edge computing received high ratings from both experts and end-users. This indicates that there is strong support for the part that edge computing performs in enhancing secure access controls and preventing unauthorized data access.

These findings are supported, by stating that edge computing reduces transmission delays and enhances security by processing data closer to its source (Shi et al., 2016; Premsankar et al., 2018). This is a significant innovation in the field of information technology. It was additionally mentioned in the study that there were limitations, such as limited resources for implementing extensive safety measures (Cao et al., 2020). This indicates that there is a requirement for additional evaluation and systematic implementation.

The improvement of edge computing methods and security protocols should be the primary focus of future research, with limited resources being taken into consideration. To maintain efficiency and adapt to new threats, it is essential to conduct regular security checks and ongoing training for personnel working in information technology. In general, the incorporation of edge computing shows promise for enhancing data security; however, to fully realize its potential, additional research and improvement are required.

b. Performance and Reliability

There is a strong agreement among respondents regarding the performance and reliability of edge computing, as shown by the results of the discussion regarding the integration of edge computing into the data management framework of the university. The fact that this understanding prevails shows the importance of edge computing in satisfying the requirements of the university for real-time data processing and security measures.

The data suggests that edge computing can be most effective in minimizing latency by processing data closer to its source. This reduces the need for use transmissions to centralized databases thereby reducing the amount of time that is expended on the process. By taking this approach, not only is performance improved, but also the security of the data is improved. Edge computing has been reported to have developed as a solution to the limitations of cloud data centers, particularly in situations that require real-time processing, as stated by Shi, Weisong, and others (2016). As a similar example, Premsankar, Gopika, and others (2018) demonstrated that edge computing is essential for addressing

latency requirements in mobile applications while confirming the importance of its function within the context of the university.

The insights provided by Engineer Paz are by these findings, emphasizing the fact that the local data processing capabilities of edge computing are essential for applications that require minimal delay. Because even minimal delay can affect performance, this capability is for ensuring that real-time applications continue to function properly. In addition, the increased data security that edge computing provides, as pointed out by Xue, Huihui, and others (2020), is the result of a reduction in the transmission of sensitive data over networks. This, in turn, reduces the possibility of unauthorized access and data breaches.

Despite these benefits, some restrictions should be taken into consideration. Despite their many advantages, edge devices have limited resources, which could limit their capacity to perform all data processing tasks on the local level. It has been observed by Khan, Wazirzada, et al. (2019) and Carvalho et al. (2021) that the limited resources of edge devices mean that there is a need for further exploration of computational methods and machine learning techniques to optimize performance and resource allocation.

The possibilities for future research include the investigation of effective computational methods that make use of machine learning to improve the features of edge computing. In addition, the combination of edge computing with emerging technologies like 5G has the potential to further enhance data management systems. For future research, the challenges of maintaining data security and optimizing resource allocation in many different kinds of environments should be the main focus.

c. Environmental considerations

The results indicate that there is a strongly agree among respondents regarding the environmental considerations that are being discussed in the context of integrating edge computing into the data management framework of the university. Both the expert and the end-user strongly agree regarding the advantages of edge computing in terms of lowering energy consumption and improving sustainability.

Edge computing is being considered as a potential solution to reduce the amount of energy that data centers require because it processes data in a location that is closer to its source. Dominic (2020) makes the observation that this localized processing reduces the requirement for data transfer across networks. This not only reduces the amount of energy that is consumed but also contributes to the fulfillment of broader sustainability goals. During the process of transferring tasks to edge devices, the operational load that is placed on central data centers is reduced, which in turn reduces the amount of energy that is consumed and increases the lifespan of the equipment. For the university to successfully implement these changes, it is recommended that they first analyze the energy consumption that is currently occurring within their data centers to identify the areas in which edge computing could be of the most benefit. Following this, it is recommended that a progressive deployment of edge computing technologies be planned, with the primary focus being on monitoring energy savings and making adjustments as required to derive the maximum possible benefits.

This approach aligns with the research that has been done on the environmental advantages of edge computing. The limitations of centralized cloud data centers are addressed by edge computing, as stated by Shi, Weisong, et al. (2016). Edge computing achieves this by providing localized data processing, which reduces energy consumption and reduces latency. Through the reduction of the amount of energy that comes from data processing, the transition from cloud-based computing to edge-based computing not only improves efficiency but also contributes to the conservation of the environment.

Edge computing is particularly advantageous in situations that require real-time data processing, as highlighted by Premsankar, Gopika, et al. (2018). This further supports the part that edge computing performs in reducing latency and energy consumption. In light of this, the implementation of edge computing not only satisfies the requirements of the operations but also aligns with the objectives of

the university, which are to achieve energy efficiency and environmental sustainability.

However, some restrictions must be taken into account when implementing edge computing. It is the resource limitations of edge devices that present the most significant challenge, as they may limit the amount of data that can be processed locally. It has been suggested by Oikawa and Kondo (2021) that although edge computing offers important benefits, its effectiveness is dependent on the development of more advanced computational methods and machine learning techniques to overcome these limitations.

The fact that both expert and end-users have expressed their satisfaction with edge computing is evidence that it has the potential to support the university in achieving its sustainability objectives.

CONCLUSION AND RECONDITION

The purpose of this study was to investigate the possibility of incorporating edge computing technology into the data management framework of the university in order to significantly improve its efficiency, security, and performance. Based on the findings, it was discovered that the existing centralized cloud-based systems have significant limitations, particularly with regard to the speed of the internet, the scalability of the system, the access control, and the capacity of the data storage. Experts and end-users alike have emphasized the importance of addressing these limitations in order to accommodate the growing data demands of the university, as well as to guarantee data security and responsiveness in emergency situations.

In order to address these challenges, edge computing presents some promising solutions. Using edge computing, latency can be reduced, data security can be improved, and real-time data processing capabilities can be enhanced. This is accomplished by processing data closer to its source. The research and administrative operations of the university, which require immediate access to large datasets, are particularly able to benefit from this. In addition, the study highlighted the environmental benefits of edge computing, such as decreased energy consumption and increased sustainability. These benefits are in line with the broader development goals of the university.

In conclusion, although the data management systems that are currently in place at the universities are operational, they are in need of significant upgrades in order to guarantee long-term efficiency, security, and scalability. An effective solution is provided by edge computing, which enables faster data processing, enhanced security protocols, and improved system reliability.

Several recommendations were made in order to address these concerns. The first recommendation was to upgrade the internet infrastructure in order to improve speed and scalability. The second recommendation was to implement more robust security protocols, which included regular audits and staff training. The third recommendation was to adopt edge computing in order to improve data management and real-time processing. The fourth recommendation was to improve data storage infrastructure in order to enhance accessibility, particularly in critical situations. The fifth recommendation was to focus on environmental sustainability by leveraging the energy-saving benefits of edge computing. Finally, comprehensive training was provided to ensure a smooth transition to the new technology. By implementing these recommendations, the universities will be able to improve their data management processes, enhance the performance of their systems, and ensure the scalability and security of their systems over the long term through the utilization of edge computing technology.

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