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Research Article

Leveraging Cloud Computing for Intelligent Network Management in Smart Universities

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Abstract: Cloud computing has emerged as a transformative technology that enables users to access shared services over the Internet. Its functions include data storage, processing, and resource management through powerful hardware and effective safeguards. This study uses cloud computing to improve network performance management at Mahasarakham University (MSU), Thailand. The study emphasizes the use of cloud-based tools to improve intelligent network management and support administrators in addressing issues efficiently. This research collected data from IT administrators who manage the MSU network. User satisfaction with MSU-Net cloud-based management tools was significantly high (μ = 4.89). Security management (μ = 4.52), automation (μ = 4.50), and configuration management (μ = 4.43) were the most valued aspects. Additional variables, such as resource scaling, account administration, and real-time monitoring, scored highly. This research is significant as it offers practical insight into the potential of cloud computing to transform network administration into educational institutions. It demonstrates how cloud-based solutions can optimize administrative operations, improve system reliability, and maintain operational expenses. These improvements are particularly essential in higher education, where the need for accessible, efficient, and scalable IT infrastructure is increasingly essential. The study emphasizes the importance of using cloud technology to develop adaptive and resilient networks that support evolving educational requirements and promote innovation in learning settings. This research provides a practical framework for adopting cloud-based network management, providing a significant reference for organizations looking to enhance their IT systems and achieve long-term technological sustainability.

Keywords: Cloud Computing, Smart University, Intelligent Network Management

Introduction

Smart cities have gained considerable interest in recent years, accelerated by the increasing need to address challenges related to rapid development and the increasing demands for efficient management of resources (Esposito *et al.*, 2021). Several countries started to implement smart city concepts in various sectors, including transportation, energy, and public services (Huang, 2017). The education sector is also part of the smart city transformation journey, as it will help improve universities in teaching, research, and administrative processes (Huang, 2017; Wang & Yeh, 2018). The concept of smart university requires the use of new technologies such as cloud computing, the Internet of Things (IoT), and big data to provide a more efficient, sustainable, and accessible environment for students, teachers, and staff (Bastari *et al.*, 2021; Wang & Yeh, 2018). However, the implementation of smart university solutions involves several obstacles. Information Technology (IT) infrastructure and network management are essential aspects that require careful management. Universities can use cloud computing to optimize their network resources and IT infrastructure efficiently. This study aims to examine the important aspects that affect the adoption of cloud computing in universities, highlighting its impact on network management and an overall smart university environment.

Cloud computing has defined three primary service models that universities can utilize (Suttidee & Savithi, 2025), Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS). IaaS enables universities to use cloud provider computing capabilities, including virtual machines, storage, and networking, without the need to manage their physical infrastructure. PaaS offers universities a cloud-based framework for application development and deployment, reducing the requirement for IT professionals to maintain the essential infrastructure.

Cloud computing provides universities with flexible on-demand computing capacity, reducing the requirements for software and equipment investments. This approach can improve the online learning environment, make it easier to access different applications and resources, and maximize the use of available resources, which can save costs such as software license, system maintenance, and energy use (Oleksiuk & Oleksiuk, 2021; Xue-Ni, 2013).

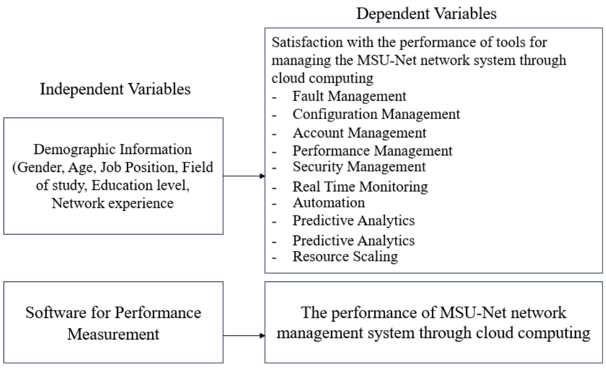

Fig. 1: The conceptual framework models

The adoption of cloud computing into smart universities requires comprehensive planning and analysis of many different factors (Riliskis & Osipov, 2013). This study attempts to examine the key factors influencing the adoption of cloud computing in Thai universities, especially its effects on network management and creating a smart university environment. Figure 1 shows how the smart university ecosystem is structured, with cloud computing placed at the core of the network management system known as MSU-Net. In this study, tools such as Cacti and LibreNMS are integrated to help monitor performance in areas such as real-time activity, automation, and system security. The framework also considers user-related factors, such as job role or education level, that might shape how individuals perceive and interact with the system. Rather than focusing solely on technology, it takes into account how people experience it. In general, the diagram underlines the role of cloud computing in making the university network more flexible, efficient, and prepared to meet growing demands.

Smart University Ecosystems

The concept of a smart university is to develop a framework in educational institutions that use intelligent technologies. This change could lead to better resource management, a more sustainable and effective academic environment, and a general improvement in the educational experience (Ercan, 2010).

A smart university environment consists of multiple elements as follows:

1. Internet of Things: The Internet of Things (IoT) is a component of the development of intelligent universities. It allows data collection and analysis to enhance decision-making processes, improve resource use, and improve the educational environment (Rico-Bautista *et al.*, 2019; Valks *et al.*, 2021).
2. Intelligent technologies: Technologies such as big data, cloud computing, and artificial intelligence have become essential for the development of smart universities. These technologies enable the integration of technology into institutional activities. However, the participation and commitment of senior management are essential to ensure effective implementation (Rico-Bautista *et al.*, 2020).
3. Smart Campus: Smart campuses are often regarded miniature iterations of smart cities that serve as experimental settings for the research and development of intelligent technologies. The potential of digital transformation spans various sectors, including economics, society, the environment and government; however, significant practical implementations are still in development (Chagnon-Lessard *et al.*, 2021; Polin *et al.*, 2023).

The integration of cloud computing with smart university ecosystems is essential to address network management issues and enable extensive digital transformation.

Cloud Computing for Smart University

Cloud computing has emerged as a tool for smart institutions, redefining conventional educational and administrative procedures by providing scalable, flexible, and cost-effective solutions. Cloud computing fundamentally enables colleges to reduce their trust in on-premises infrastructure, resulting in substantial savings on maintenance and infrastructure costs. Jadeja and Modi (2012) presented the benefit of cloud computing's capacity to reduce operational costs. According to Armbrust *et al.* (2010), universities can also modify their resources in response to changing student enrollments or research needs due to the scalability and flexibility included with cloud platforms.

The advantage of cloud computing adoption is its ability to promote collaboration between students, faculty, and researchers to easily communicate and share resources. Universities can use various technologies for their campuses regardless of their physical location, which improves the overall academic and research

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environment (Mircea & Andreescu, 2011). Additionally, cloud technology provides educational resources to users at any time and from any location, thus reducing digital divides and fostering more inclusive learning environments. This improved accessibility fosters equitable opportunities for students and staff in both developed and developing regions.

Cloud computing facilitates many practical applications in smart universities. A major influence is e-learning, such as Moodle and Blackboard, which improve the efficacy, accessibility, and scalability of educational platforms (Sultan, 2010). Buyya *et al.* (2009) agreed that cloud computing is important for research because it provides the processing power needed for resource-intensive tasks such as analyzing large amounts of data and running complex simulations, which are important for current academic work. Cloud adoption improves administrative efficiency by transforming processes such as student registration, classification, and payroll, streamlining institutional processes, and reducing complexity. As Pocatilu *et al.* (2010) stated, cloud-based virtual laboratories improve educational opportunities by allowing students to access laboratory environments and conduct experiments remotely, while reducing the cost of maintaining physical laboratories. The adoption of cloud computing in smart universities presents several challenges. For example, student information privacy and institutions remain vulnerable to illegal access or breach, making data security and privacy a major issue. A reliable Internet connection is essential for the effectiveness of cloud computing, and lack of infrastructure can be a problem. According to Alharthi *et al.* (2015), they highlight the critical role of intensive training for instructors and IT professionals in effectively implementing cloud technologies within educational institutions. The authors identify key challenges to cloud adoption in higher education, including legal policies, data privacy, and security concerns. The authors indicate that these challenges require extensive training courses to provide instructors and IT professionals with the skills required to implement effective cloud integration. Furthermore, effective use of cloud resources requires that educators and IT professionals acquire appropriate instruction to improve their ability to manage and deploy cloud-based solutions efficiently.

Cloud computing will play a crucial role in driving innovation within smart universities in the future. This study explores the key factors that contribute to the development of smart universities. This study explores the factors that influence the adoption of cloud computing in smart universities, including technological infrastructure, cloud-based learning management systems, and faculty instruction.

The study also assesses the performance of cloud computing integration within the university's network architecture. The study provides information on effective methods and techniques for universities trying to transform themselves into smart universities by examining the key variables that support and reduce cloud adoption.

Hypothesis Testing Results

This study evaluates the effectiveness of MSU-Net, a cloud-based computer network management system implemented at Mahasarakham University, with a particular focus on its role in supporting smart university development. Research adopts a mixed method approach to examine two core dimensions: user satisfaction and technical system performance. The study is guided by the following research questions:

RQ1: To what extent do demographic characteristics, such as gender, age, job position, field of study, education level, and network experience, influence user satisfaction with the efficiency of MSU-Net as a cloud-based network management tool?

RQ2: How can the performance of cloud-based network management systems be effectively evaluated using Cacti and LibreNMS monitoring tools?

To address RQ1, a quantitative approach was used to explore potential relationships between user demographics and satisfaction levels. Statistical methods, including Spearman's rho and the Phi coefficient, were applied to the survey data to assess the strength and significance of these relationships. The goal was to identify which user characteristics, if any, significantly affect perceptions of MSU-Net's efficiency, thereby informing future improvements in system design and support.

RQ2 was investigated using a qualitative approach to assess the functional performance and usability of the cloud monitoring tools Cacti and LibreNMS. The analysis focused on how these tools are implemented in practice, how administrators and IT personnel interpret the data they provide, and how these tools contribute to real-time decision-making and performance optimization. Data were collected through system observations and expert feedback to capture a more nuanced understanding of the capabilities, limitations, and contextual effectiveness of each tool.

Based on these research questions, the following hypotheses were tested:

- H_0 (Null Hypothesis): There is no significant relationship between user characteristics (gender, age, job position, field of study, education level, and network experience) and satisfaction with the efficiency of MSU-Net via cloud computing.
- H_1 (Alternative Hypothesis): There is a significant relationship between user characteristics (gender, age, job position, field of study, education level, and network experience) and satisfaction with the efficiency of MSU-Net through cloud computing.

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Materials and Methods

Methods and Sampling

This study used a mixed-methods approach that combined quantitative and qualitative techniques to assess the efficiency of Mahasarakham University's computer network management system (MSU-Net), which is supported by the cloud computing infrastructure. The implementation at MSU uses both Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS) models to improve network scalability, operational flexibility, and system-wide efficiency.

To contextualize these cloud service models: Infrastructure-as-a-Service (IaaS) provides the foundational infrastructure, such as virtual servers, storage, and networking, that allows organizations to build, deploy, and manage platforms and applications with a high degree of control. PaaS, by contrast, offers a pre-configured environment for developing, testing, and deploying applications without requiring users to manage the underlying hardware and software infrastructure. SaaS delivers fully functional applications through a web interface, minimizing the need for local maintenance and technical management.

At MSU, PaaS has been adopted to support the development and integration of customized applications, whereas SaaS is used to deploy accessible amd ready-to-use network monitoring tools. This combined approach was selected to balance the need for customization with ease of deployment, in line with the operational goals of a smart university.

A purpose-sampling method was used to recruit participants who were directly involved in the management and oversight of the university's network infrastructure. The sample consisted of ten MSU IT executives, each possessing professional expertise and hands-on experience with network systems. The selection of this sample size is supported by usability research, which indicates that evaluating systems with ten users can identify up to 95% of usability-related issues (Faulkner, 2003; Nielsen, 2000). Although Nielsen's original work suggests that five users can uncover most problems, the complexity of MSU-Net warranted a broader sample to achieve more comprehensive insights.

Research Tools

To evaluate the performance and user experience of MSU-Net, this study used a combination of quantitative and qualitative tools. On the quantitative side, a structured questionnaire was developed to gather information from IT executives regarding their views on the university's current network management system and its transition to cloud computing. The survey was divided into three parts: basic information from the respondents, satisfaction with cloud-based tools, and open-ended suggestions for future improvements.

Basic descriptive statistics, such as the mean and standard deviation, were used to interpret the responses. This helped summarize general satisfaction levels and offered a numerical overview of how cloud computing has been received at MSU.

For the qualitative part, we used real-time network monitoring and conducted semi-structured interviews with the same group of participants. Two open-source tools, Cacti and LibreNMS, were implemented on the MSU-Net system to observe actual performance. These tools collected live data on bandwidth usage, traffic load, and server responsiveness. This allowed us to track the system's behavior in a real-world environment.

Together, the survey, monitoring tools, and interviews offered a comprehensive view of MSU-Net. The survey captured how users felt about the system, while the monitoring and interviews gave us more technical and practical information. This mixed-methods setup provided a clearer picture of how cloud computing supports network management at a smart university.

Data Collection

This study used a mixed methods approach to understand how well MSU-Net performs and how satisfied users are with its cloud-based features. Data were collected from multiple sources: structured questionnaire, system monitoring tools, and interviews. All participants were IT executives who manage or work directly with the university's network systems.

First, a structured questionnaire was distributed to 10 IT staff members. It focused on their opinions on cloud computing adoption, how efficient they believed MSU-Net to be, and their satisfaction with areas such as automation, security, and system performance. This provided a foundation of quantitative data for analysis.

Additionally, real-time network monitoring was carried out using two widely used tools, Cacti and LibreNMS. These tools helped track key performance indicators such as server load, bandwidth use, and response times. The goal was to get a clear picture of how the system was performing under real conditions.

Finally, semi-structured interviews were conducted with the same group. These conversations allowed participants to share their personal experiences, explain any challenges they faced, and give feedback on system features, such as network integration and security.

By combining these three sources, the study aimed to capture both the technical performance of MSU-Net and how it was experienced by people using it daily.

Statistical Analysis

Data were analyzed using a mix of basic descriptive tools and some correlation techniques to explore possible relationships. To begin with, we calculated the mean, percentage, and standard deviation to get a general sense of how the respondents felt about different areas of the MSU-Net system, including its performance and ease of use in the cloud setup.

For the hypothesis testing part, we used two different correlation methods depending on the type of data. Spearman's rho helped us look at the connection between ranked variables, such as years of experience or education level, and satisfaction scores. When it came to binary variables, such as gender or whether someone held a specific job title, we relied on the Phi coefficient.

We also checked the reliability of our survey by calculating the Cronbach alpha, which helped confirm that the questions were consistent with measuring what we were trying to assess, namely satisfaction with cloud-based network management.

This overall approach gave us a solid mix of numbers and insights to work with and helped us better understand how different user traits might affect perceptions of MSU-Net.

Results and Discussion

This research was aimed at evaluating how effectively MSU-Net, the cloud-based network management system at Mahasarakham University, supports the institution's broader shift toward a smart university model. To do this, the study used a combination of methods, partly statistical, partly observational. The intention was not just to capture user opinions, but also to measure how the system actually performed under real conditions.

The process was split into two main parts. First, ten IT executives completed a structured survey that asked them to reflect on how the system functions in practice, whether it is reliable, efficient and suited to the needs of the university. The focus here was on cloud-enabled functions like automation and network visibility.

The second part was more technical. The research team used two monitoring tools, Cacti and LibreNMS, to track actual performance data, such as bandwidth usage, server load, and system response times. These numbers helped paint a picture of how the system behaves in real time.

By bringing these two types of data together, what users experience and what the system reports, the study aimed to form a balanced and realistic view of how well MSU-Net performs in a cloud environment.

The standard deviation (σ) values reported in Table 1 offer insight into the consistency of user satisfaction across different aspects of the MSU-Net cloud-based network management system. Generally, a lower standard deviation reflects greater agreement among users, whereas higher values suggest a wider range of responses.

Among the system's components, Account Management (σ = 0.45) and Security Management (σ = 0.47) showed the least variability, indicating that respondents were largely consistent in their positive assessment of these features. On the other hand, Real-Time Monitoring (σ = 0.82) and Predictive Analytics (σ = 0.75) had the highest standard deviations, pointing to more diverse user experiences or possibly varying expectations based on individual roles or technical familiarity. The rest of the components fall within a moderate range of variability, suggesting reasonably stable satisfaction levels. The overall average standard deviation of 0.48 reinforces the observation that user responses, while not identical, were largely consistent.

In terms of satisfaction ratings, users expressed the highest satisfaction with Security Management (μ = 4.52) and Automation (μ = 4.50), highlighting the perceived importance of system reliability and operational efficiency. Other highly rated features included Configuration Management (μ = 4.43), Resource Scaling (μ = 4.42), and Account Management (μ = 4.36). Slightly lower, but still high, satisfaction levels were recorded for Real-Time Monitoring (μ = 4.20), Performance Management (μ = 4.13), and Predictive Analytics (μ = 4.10).

Overall, the findings indicate that users were most satisfied with features related to security, automation, and system configuration. Meanwhile, the somewhat lower and more variable ratings for predictive and real-time monitoring tools suggest opportunities for improvement, especially in tailoring these features to better meet the diverse needs of users across different technical backgrounds.

Table 1: Satisfaction with the Efficiency of Computer Network Management

Data Satisfaction	μ	σ	Satisfaction Level
Configuration Management	4.43	0.49	High level
Account Management	4.36	0.45	High level
Performance Management	4.13	0.72	High level
Security Management	4.52	0.47	Highest level
Real Time Monitoring	4.20	0.82	High level
Automation	4.50	0.52	Highest level
Predictive Analytics	4.10	0.75	High level
Resource Scaling	4.42	0.51	High level
Configuration Management	4.27	0.54	High level
Overall average	4.89	0.48	Highest level

Table 2 presents the results of an analysis exploring the relationship between gender and satisfaction with the efficiency of MSU-Net's cloud-based network management tools. Using the Phi coefficient, the correlation was found to be -0.333, with a p-value of 0.292. Since the p-value exceeds the significance threshold of 0.05, the result is not statistically significant. Therefore, the null hypothesis (H_0), which posits that there is no relationship between gender and user satisfaction, is retained.

This finding indicates that gender does not significantly influence users' perceptions of MSU-Net performance, at least within the context of this study. The absence of a statistically significant relationship suggests that satisfaction levels are relatively consistent between male and female users when it comes to evaluating efficiency through cloud computing.

Table 2: Relationship Between Gender and Satisfaction with the Efficiency of MSU-Net via Cloud Computing

Gender	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
Male	0(0.0)	3(30.0)	3(30.0)
Female	5(50.0)	2(20.0)	7(70.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 3 shows the results of the analysis of whether the job position is associated with satisfaction with the efficiency of MSU-Net in a cloud computing environment. The Phi coefficient was calculated at -0.655 and the p-value was 0.038. Since the p-value falls below the 0.05 threshold, this result is statistically significant.

This means that we reject the null hypothesis and accept the alternative: There is a meaningful relationship between job position and satisfaction with the system. It suggests that users in different roles may experience network management tools differently, possibly due to varying levels of access, responsibility, or familiarity with the features of the system.

Table 3: Analysis of the Relationship Between Job Position and Satisfaction with the Efficiency of MSU-Net via Cloud Computing

Job Position	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
Executive	0(0.0)	3(30.0)	3(30.0)
Computer Scientist	5(50.0)	2(20.0)	7(70.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 4 shows the results of the test to determine whether the field of study has any bearing on their satisfaction with the efficiency in a cloud-based setting. The Phi coefficient was found to be 0.632, and the p-value was 0.406. Since this value is well above the 0.05 threshold, the result is not considered statistically significant.

In simpler terms, the data suggest that there is no strong link between a person's academic background and how they rated the system. Whether users came from technical or nontechnical fields, their satisfaction levels with network management tools did not differ in any meaningful way. As such, the null hypothesis holds in this case.

Table 5 summarizes the analysis performed to determine whether age is associated with satisfaction with MSU-Net efficiency in a cloud-based environment. Spearman's rho was -0.258, with a p-value of 0.471. Since the p-value is considerably higher than the significance level of 0.05, the result is not statistically significant.

In other words, this analysis does not provide evidence of a relationship between age and how users perceive the system performance. Satisfaction levels appeared fairly consistent across age groups. Therefore, the null hypothesis remains valid for this variable.

Table 4: Analysis of the Relationship Between Field of Study and Satisfaction with the Efficiency of MSU-Net via Cloud Computing

Field of Study	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
Technical Field	0(0.0)	3(30.0)	3(30.0)
Non-Technical Field	5(50.0)	2(20.0)	7(70.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 5: Relationship Between Age and Satisfaction with the Efficiency of MSU-Net via Cloud Computing

Age	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
31-40	2 (20.0)	1(10.0)	3(30.0)
41-50	2(20.0)	2(20.0)	4(40.0)
51-60	1(10.0)	2(20.0)	3(30.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 6 shows the outcome of the test to determine whether working age is related to satisfaction with MSU-Net efficiency under a cloud-based system. Spearman's rho value was 0.072, and the p-value was 0.844. Since this is well above the 0.05 threshold, there is no statistically significant relationship.

In short, the data doesn't suggest that the number of years someone has worked affects how they rate the system's performance. Satisfaction scores were fairly similar regardless of how long respondents had been in the field. As such, the null hypothesis is accepted in this case.

Table 6: Relationship Between Working Age and Satisfaction with MSU-Net's Efficiency via Cloud Computing

Working Age	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
6-10	2(20.0)	1(10.0)	3(30.0)
11-15	0(0.0)	2(20.0)	2(20.0)
16-20	1(10.0)	1(10.0)	2(20.0)
21-25	2(20.0)	1(10.0)	3(30.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 7 summarizes the results by examining whether the education level has a connection to how users perceive the efficiency of MSU-Net under cloud computing. Spearman's rho value was 0.848, and the p-value was 0.002. Since this is well below the

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significance threshold, the result is considered statistically significant.

This means that the null hypothesis is rejected and we can reasonably conclude that education level does influence satisfaction with the system. In this case, participants with different educational backgrounds did not respond uniformly: those with higher education may have had different expectations or a stronger grasp of the features of the system, which could have affected how they rated its performance.

Table 7: Relationship Between Education Level and Satisfaction with MSU-Net's Efficiency via Cloud Computing

Education Level	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
Bachelor's degree	4(40.0)	0(00.0)	4(40.0)
Master's degree	1(10.0)	2(20.0)	3(30.0)
PhD	0(00.0)	3(30.0)	3(30.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

Table 8 presents the analysis of whether there is a relationship between the work experience and their satisfaction with the efficiency of MSU-Net, a cloud-based network management system. The result showed a Spearman's rho value of -0.187 and a p value of 0.605. Because the p-value is greater than the significance level, the finding is not statistically significant.

As a result, the null hypothesis is retained, suggesting that work experience does not have a meaningful association with user satisfaction in this context. Respondents with varying years of field experience reported similar levels of satisfaction with MSU-Net performance, indicating that practical exposure alone does not appear to influence how the system is evaluated.

Table 8: Relationship Between Network Experience and Satisfaction with MSU-Net's Efficiency via Cloud Computing

Network Experience	Satisfaction Level, n (%)		
	Moderate	Satisfied	Total
6-10 years	2(20.0)	3(30.0)	5(50.0)
11-16 years	1(10.0)	1(10.0)	2(20.0)
16-20 years	1(10.0)	0(00.0)	1(10.0)
21-25 years	1(10.0)	1(10.0)	2(20.0)
Total	5(50.0)	5(50.0)	10(100.0)

Note: Sig<0.05*

In order to examine the financial implications of adopting cloud computing, a cost comparison was carried out between the MSU-Net system before and following its transition to a cloud-based model. The analysis took into account hardware expenditures, system maintenance, upgrade costs, and staffing for ongoing operations. As outlined in Table 9, there was a noticeable decrease in overall IT spending in all examined categories after the implementation. These results suggest that, beyond improving technical efficiency, the shift to cloud computing also contributed to measurable cost savings for the university.

Table 9: Comparison of IT Costs Before and After MSU-Net Cloud Implementation

Cost Category	Pre-Cloud (Annual)	Post-Cloud (Annual)	Savings
Server Maintenance	$10,000	$4,000	$6,000
Hardware Upgrades	$8,000	$2,000	$6,000
IT Staffing (Support)	$15,000	$12,000	$3,000
Software Licensing	$5,000	$1,500	$3,500
Total	$38,000	$19,500	$18,500

Hypothesis Testing Results

The general hypothesis (H_1) is partially supported. Based on data collected from 10 IT executives, the analysis found that the job position and the level of education were significantly related ($p<0.05$) to the satisfaction with the efficiency of MSU-Net through cloud computing. On the contrary, gender, field of study, and network experience did not show statistically significant associations. These findings suggest that among the characteristics examined, the role of a user within the organization and level of education have a greater influence on his perception of the system's effectiveness. A summary of these results is presented in Table 10.

Table 10: Summary of Hypothesis Testing Results on the Relationship Between User Characteristics and Satisfaction with MSU-Net via Cloud Computing

Variable	Test Used	Coefficient	p-value	Result
Gender	Phi	-0.333	0.292	Not significant
Job Position	Phi	-0.655	0.038	Significant
Field of Study	Phi	0.632	0.406	Not significant
Educational Level	Spearman's rho	0.848	0.002	Significant
Network Experience	Spearman's rho	-0.187	0.605	Not significant

As part of this study, we looked at how MSU-Net's performance could be measured using the tools currently in place, Cacti and LibreNMS. This was done in response to Research Question 2, which asks how these monitoring programs can be used to evaluate cloud-based network performance effectively. Rather than just focusing on technical specifications, we considered how these tools are actually used day to day: how easy they are to work with, how they present data, and whether they help IT staff make informed decisions. What follows is a summary of our findings based on practical use and observations.

Cacti Results

Cacti is a web-based programmed developed to work in conjunction with RRDTool, an advanced graphing utility, to provide advanced network monitoring and analysis. The user can monitor important system metrics,

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such as memory and CPU use, the number of users on the network, and network traffic statistics. Cacti provides administrators with the ability to make intelligent decisions and strategic strategies to improve system resources through efficient data management. This improves overall network performance and stability, ensuring efficient and effective system operation.

Figure 2 illustrates that the Cacti program provides a comprehensive overview of the performance of all network devices, including the operational status of switch devices within the MSU-Net network. Displayed details include an analysis of overall CPU usage, allowing users to select specific time periods for a more convenient and detailed performance assessment. The Cacti can display the temperature values for each switch device, enabling administrators to monitor the operating temperature at different times. This feature helps ensure that network devices work within safe temperature ranges. The programmed also offers a complete analysis of network data transmission, allowing administrators to assess data traffic density over different periods.

Users can further customize the display by selecting sub-sections to view port-level data for each network device. This functionality provides insight into which ports are operating efficiently and which may be experiencing issues. Cacti also make it easier to manage traffic paths in the MSU-Net network. This makes the network more efficient overall and ensures that users can get what they need from the system.

Fig. 2: The dashboard page displays details of the operating status of the network devices

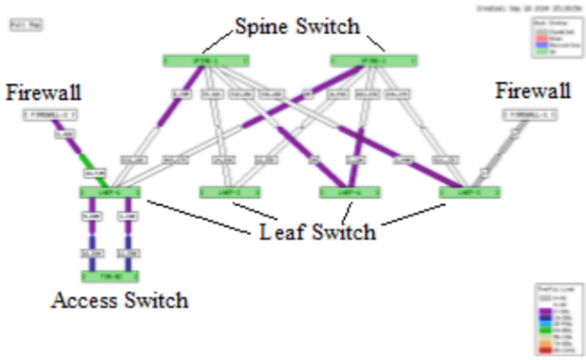


Fig. 3: The data center network diagram

Figure 3 illustrates that the primary network of MSU is organized around a central switch, which enables connectivity to the switches located in different buildings throughout the university. In addition, it provides connectivity to five campuses in Mahasarakham.

The network is also secured and operated by two primary core switches that are connected to two sets of firewall devices. Firewall devices connect to the router, which serves as the gateway for external communication. This gateway provides network traffic to the Internet through two separate routes, guaranteeing redundancy and consistent connectivity.

At the MSU main network level, which includes five campuses, Figure 4 shows the state of connectivity of all the computer network devices. The figure utilizes color-coded symbols to represent various status indications. These indications encompass traffic load status, temperature status, and host status, offering a clear and comprehensive representation of the current operating condition of the network.

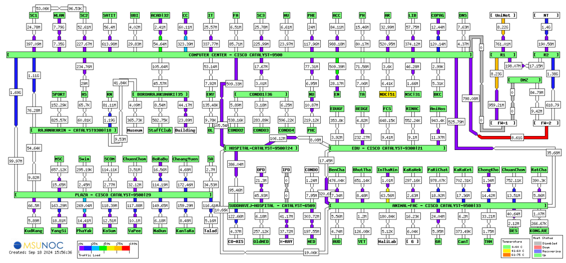
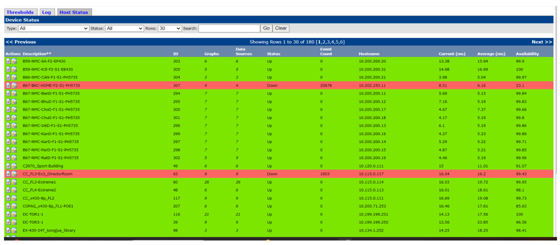
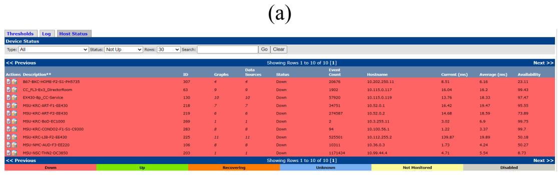


Fig. 4: Network full map

Figure 5 illustrates the features of the Cacti programmed during the monitoring of network devices. It offers real-time status updates, indicating whether a device is active (up) or inactive (down). Cacti also maintains a detailed record of network issues, including resolution strategies implemented, which acts as a significant resource for administrators. This feature enables current analysis, through troubleshooting, and strategic planning; therefore, it improves system efficiency and network reliability.



(a)



(b)

Fig. 5: Host status up (a) and status down (b)

Evaluation of the MSU network using Cacti includes the key components below.

Fault management: Cacti can detect all errors, identify problems, and prevent effect on the network. Reduce network disruption and reduce the risk of service interruption by allowing administrators to take immediate corrective action. In addition, it maintains comprehensive logs of errors and corrective measures for future reference, allowing the preparation and management of potential risks.

Configuration management: Cacti offers the ability to manually provide IP addresses and maintain comprehensive records of network devices, including brand, model, features, and software / software versions. Cacti may produce network topology visualizations, monitor data traffic routes, and modify hardware or software settings as required. This includes the addition or replacement of network locations, the installation of subnets, and the update of settings to conform to system policies and structural modifications.

Account Management: Cacti offers comprehensive information on IP transmissions and explores user access levels to network resources. These data assist in user utilization rates and access patterns across network services.

Performance Management: The system continuously evaluates critical performance indicators, including CPU, RAM, Jitter, MOS, RTT, and CRC, ensuring that network service levels adhere to high-efficiency benchmarks. Using the analysis of the collected information, managers can analyze and improve bandwidth distribution, guaranteeing that all network parameters adhere to defined criteria and meet performance objectives.

Security Management: Cacti's security is structured according to the Triple A security framework authentication, authorization, and auditing-to safeguard the network against cyber threats. The system manages security by ensuring the implementation of access rules, the encryption of critical information, and the ongoing surveillance of unauthorized activity. It also facilitates the installation of patches for problems and provides a commitment to network security regulations.

Real-Time Monitoring: Cacti facilitate the ongoing surveillance of network activities, systematically recording device operations, and reporting instantaneous network occurrences. This feature ensures that administrators receive prompt notifications of network alterations or potential problems.

Predictive Analytics: The system uses automated data analysis to help managers make informed decisions about network management. Using report data, Cacti can predict trends in system performance and improve network resource allocation accordingly.

Resource scaling: Cacti demonstrate considerable scalability by using multiple pullers and distributed pullers to efficiently allocate workloads over large and multisite networks. Administrators can customize servers and databases to accommodate an increasing number of devices and applications, facilitating ongoing network expansion.

LibreNMS Results

LibreNMS is an open source, cost-free network monitoring system that monitors many features of the network. It supports many operating systems and network devices, including Linux, Cisco, and Juniper.

Figure 6 illustrates the detailed status of the Internet Control Message Protocol (ICMP), a set of communication rules that devices use to communicate errors in data transmissions on a network. In the exchange of messages between senders and receivers, some unexpected errors can occur. For example, a message may be too long, or the data packets may arrive out of sequence, so the receiver cannot reassemble the data. In such cases, the receiver uses ICMP to send an error message to the sender and requests to resend the message.

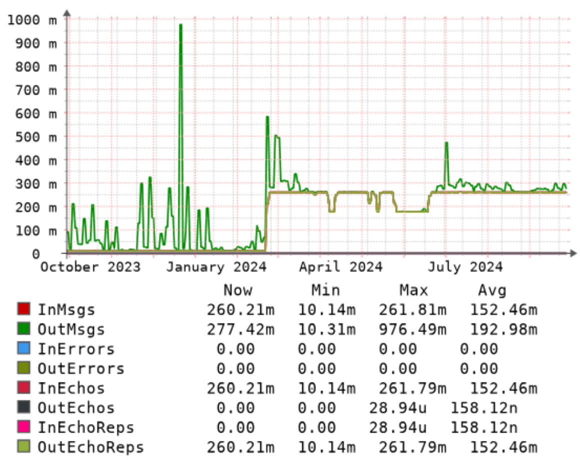


Fig. 6: The status of network administrators via LibreNMS

Figure 7 illustrates the status of the tools for monitoring the network system, verifying service availability, and the amount of bandwidth used by devices on the network. Traffic monitoring on LibreNMS can be selected according to the protocol. This includes SNMP, ICMP, TCP, UDP, and other types of traffic, as well as the ability to monitor through specific ports or VLANs on the client. Administrators and systems to check operating status, such as abnormally increased traffic volume, memory usage, network operating status, and hardware devices; they also help analyze and digest data for administrators to easily understand and alert for abnormal usage behavior that may affect organization services. There are also various features, such as automatic discovery, which automatically searches the entire network using CDP, FDP, LLDP, OSPF, BGP, SNMP, and ARP. There is a customizable alerting system with high flexibility, alerting via email, IRC, and many

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more. There is full API access to manage graph creation and extract data from the installation, and there is an automatic update of the latest status.

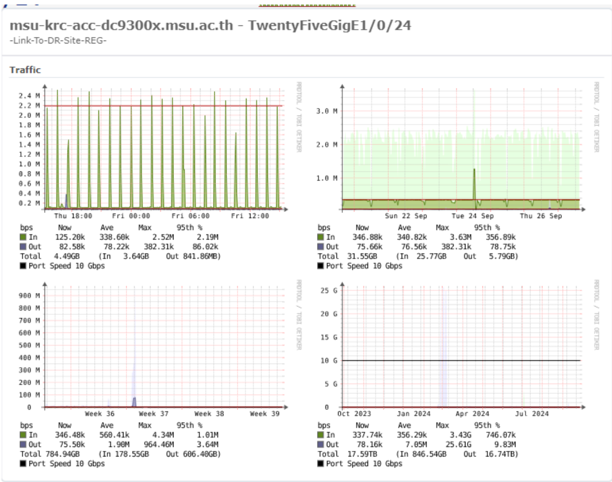

Fig. 7: The status of network administrators via LibreNMS

The evaluation of the MSU network using LibreNMS includes the key components in the following.

Fault Management: Automatic detection and alerts of LibreNMS are capable of identifying the point of failure, isolating the issue from the network system, and implementing corrective measures to prevent and mitigate the risk of downtime. Reports, logs, and troubleshooting are available. The details of the corrections are recorded for retrospective review and future guidance.

Configuration Management: Manual or automatic IP address assignment through DHCP (dynamic host configuration protocol). Store and record information about various devices on the network, such as brand, model, features, and software / software version. The process involves creating connection diagrams for various devices using the Topology View tool. The task involves managing the routing (path) of data traffic on the network. Changes can be made to hardware or software, including the addition or removal of stations from the system. Subnets, links, and other components of the network system are installed, along with management and configuration tasks, and reconfiguration is necessary when changes to the system policies or structure occur.

Account Management: LibreNMS has statistics and data transmission through IP. It defines the level of user access and usage of network resources in terms of grouping of users. Create a database of personal identity (identity), including user & password and PIN. It stores and records information on various activities in the network system to measure the level of use (utilization) of users. It stores usage events. The user can check, analyze, and evaluate it to determine various policies or plans.

Performance Management: LibreNMS has a network monitoring system that monitors all types of measurement on the device, such as CPU, RAM, jitter, MOS, RTT, CRC, etc. We maintain the level of network service to the highest efficiency standards. We ensure sufficient bandwidth to meet the network needs through testing, analysis, and collection of various data, including response time values. Traffic in/traffic out rates, throughput values, etc., are performed to keep the parameter values at a standard level or in line with the specified target.

Security Management: The LibreNMS security management plan is based on the AAA security framework (authentication, authorization, and accountability), which can verify and authenticate identity, control access rights, and keep records of what each person has changed. Be vigilant against cyberattacks or threats. Patching vulnerabilities to maintain the network. Control access and usage of network resources in accordance with established policies through data encryption, checking authorized activities, authenticated devices, and users' access to the network.

Real-Time Monitoring: LibreNMS can continuously monitor network activities. Ability to monitor the operation of automatic equipment and report results in real time. Automatically records network device events.

Automation: LibreNMS has a process to support automatic use for daily work, to check the operation of the equipment, and to report the results in real time. Automatically notify administrators when there is an abnormality on the network.

Predictive Analytics: LibreNMS can use the data to make proactive decisions. Ability to automatically analyze data from device reports. Network administrators can use the data from the report to make decisions about network management and predict system performance.

Resource Scaling: LibreNMS can scale and adapt to changes. Network administrators can expand support for more users. The system is flexible and can accommodate changes in the number of users. It can be configured to manage devices on the network easily and conveniently.

The research examined feedback from a sample group including professionals and staff involved in monitoring the MSU-Net computer network system at Mahasarakham University. The sample consisted of 10 people, all of whom were MSU-Net network administrators. The demographic study indicated that the main participants were men, 41-50 years old, with the majority employed as computer science professionals. The respondents had 6-10 years of professional experience, mainly in computer science, with most possessing a bachelor's degree and 6-11 years of work experience.

The level of satisfaction with the performance of cloud-based computer network administration tools for MSU-Net was found to be the highest, with an overall satisfaction score of 4.89. The variables rated highest, when evaluated individually, were security management (μ = 4.52) and automation (μ = 4.50), both receiving the highest rating. Additional essential elements are ranked as follows:

- Configuration management (μ = 4.43)
- Resource scaling (mean = 4.42)
- Account management (μ = 4.36)
- Configuration management (μ = 4.27)
- Real-time monitoring (μ = 4.20)
- Performance management (μ = 4.13, elevated level)
- Predictive analytics (μ = 4.10, elevated level)

The research investigated factors related to satisfaction with the efficacy of cloud-based network management tools and identified two main correlations.

The relationship between job position and satisfaction was evaluated using the Phi coefficient, obtaining $\Phi = -0.655$ and a p-value of 0.038, which is below the significance threshold of $\alpha = 0.05$. This result indicates that a job role influences the capacity to perform tasks and the technical understanding of network management, including the utilization of software tools, the administration of wired and wireless networks, and data security. Employees who demonstrate strong technical expertise, adept problem-solving abilities, and efficiency are valued in the organization, as they are regarded trustworthy, flexible, and effective in their duties. Effective planning and systematic work processes improve efficiency and yield excellent results.

The relationship between education level and satisfaction was evaluated using Spearman's rho, generating a result of $\rho = 0.848$ and a p-value of 0.002, which is below the significance threshold of $\alpha = 0.05$. This result indicates that a higher level of education improves proficiency in network management. Advanced education improves reasoning ability, problem solving skills, and understanding of network data, including the ability to analyze dashboard and system metrics.

Further education and specific instruction enhance the design, configuration, and security principles essential for proficient network management. The results indicate the importance of job title and education in assessing job satisfaction and performance of network administrators who operate the cloud-based MSU-Net system.

Research Contribution

This study offers several contributions to the fields of network management and cloud computing, particularly in the context of higher education. By examining user satisfaction with MSU-Net, a cloud-based network management system implemented at Mahasarakham University, the research sheds light on how different user characteristics influence perceived system efficiency. In particular, the position of the job and educational background emerged as significant factors in user satisfaction, whereas variables such as age, work experience, field of study, and technical background did not show a significant association. These findings suggest that a user's professional role and level of formal education may shape how effectively they engage with cloud-based network tools.

The study also contributes to practical decision making by comparing Cacti and LibreNMS, two commonly used network monitoring tools. While Cacti is recognized for its strength in time-series graphing and SNMP support, LibreNMS provides broader functionality, including autodiscovery, multi-protocol monitoring, and alerting. By detailing their respective advantages and limitations, this comparison can help IT administrators and decision makers select tools that best fit their operational needs and technical environments.

Beyond the selection of individual tools, the research underscores the broader importance of real-time monitoring, system alerts, and integration features in maintaining the reliability and performance of large-scale network infrastructures. These insights are particularly relevant for universities and similar institutions transitioning to cloud-based systems, where reliability and adaptability are essential.

Furthermore, the finding that the level of education is linked to satisfaction highlights the value of continuing training and capacity-building among IT personnel. Ensuring that staff are equipped with up-to-date skills can improve overall system usability and promote better outcomes in security and performance management.

Although participants generally perceived cost savings following the adoption of cloud computing, particularly in terms of reduced hardware needs and less routine maintenance, the study did not include a full financial breakdown. Due to a lack of access to budgetary records, a detailed cost-benefit analysis could not be performed. While some initial training costs were incurred during the transition, no long-term increases in operating expenses were reported. Future studies should explore this aspect more thoroughly by incorporating institutional financial data to assess the economic impact of cloud computing in higher education settings.

In summary, this research provides both theoretical and applied contributions: it offers a clearer understanding of user satisfaction determinants in network management, a practical evaluation of monitoring tools, and a basis for future policy and training decisions within IT departments managing cloud infrastructure.

Conclusion

This study explored the relationship between user satisfaction and the efficiency of MSU-Net, a cloud-based network management system implemented at Mahasarakham University. Among the demographic and professional factors examined, the job position and the level of education were found to be significantly associated with satisfaction levels. On the contrary, variables such as age, years of work experience, field of study, and prior experience with network systems did not show a significant impact. Although these results provide useful insights into the roles that institutional responsibilities and educational background can play, the relatively small sample size limits the generalizability of the findings. More detailed studies involving a more diverse range of participants are needed to confirm these patterns and deepen our understanding of user engagement with cloud-based IT systems in academic settings.

To assess the technical dimension of network performance monitoring, the study also evaluated Cacti and LibreNMS, two tools integrated into MSU-Net. Cacti stands out for its strength in SNMP-based data collection and its ability to generate clear time-series graphs. Its straightforward setup and focus on long-term resource tracking make it a practical choice for environments that prioritize historical data analysis over real-time responsiveness. However, the tool's limited built-in alerting and need for additional configuration reduce its utility in dynamic or high-demand network contexts.

On the other hand, LibreNMS provides a broader and more flexible network management solution. Its features include autodiscovery of devices, real-time alerting, and support for various network protocols. With advanced notification systems and active development support, LibreNMS is well-suited for complex infrastructures such as those found in smart universities. Although it requires more effort to implement and maintain, its capabilities are aligned with institutions that demand proactive monitoring and flexible integration with other systems.

In conclusion, the choice between Cacti and LibreNMS should be guided by institutional priorities. For environments focused on basic SNMP monitoring and historical trend analysis, Cacti may be sufficient. For more dynamic, integrated, and large-scale network operations, LibreNMS offers a more powerful and forward-looking solution. These conclusions support informed decision making in cloud-based network management and highlight areas for further study in both user-centered design and technical tool evaluation.

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Author’s Contributions

Sitthichai Kao-Ngam: Developed the research plan, designed the methodology, collected data, and performed the data analysis.

Charuay Savithi: Provided essential support, contributed to the development of the study, monitored progress, provided research guidance and served as the corresponding author for the publication of this study.

Naruemon Pantucha: Coordinated the communication efforts for the study and was responsible for administering and collecting the questionnaires.

Ethics

This study represents an original and significant contribution to the scholarly community. It is an entirely new work that has not been previously submitted or published elsewhere. The authors have diligently ensured compliance with all the necessary requirements for this research and strictly adhered to ethical research standards. Before participating, all respondents received a data privacy and consent form, ensuring informed consent before completing the survey. Furthermore, the study received ethical approval from the Institutional Review Board (IRB) of Mahasarakham University, confirming that all research procedures are in accordance with ethical guidelines and standards for human subject research.

Data Availability

The data supporting the findings of this study are available upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest associated with this study.

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