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Original Article

Network Design for Bukidnon State University College of Technologies Annex B Campus

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Abstract - *In this fast-changing academic landscape, a sophisticated network infrastructure is crucial in merging administrative and academic functions within institutions of higher learning. The establishment of Bukidnon State University College of Technologies Centre has been a landmark decision affirming the university's commitment to technological advancement and better teaching techniques. At the start of its transformative journey, the university must implement an effective network that will guarantee productive engagements, collaborative efforts, and information sharing among students and staff members. This paper highlights the need for a customized network infrastructure to create an active and technologically enhanced environment. It also focuses on various advantages associated with solid networks, such as enhanced academic settings and better administration efficiency. To protect data integrity, confidentiality and security measures are built into the proposed design as it emphasizes seamless connectivity, efficient communication between users' devices, interdependent networked systems and stringent security measures against risks posing threats; these restrictions are intended to fortify defenses over vulnerabilities. To ensure that innovative teaching methods are encouraged and the learning environment is made more stimulating, this study visualizes a flexible web for fostering the continuous growth and achievements of the institution.*

Keywords - *Network design, Technological innovation, Educational excellence, Campus infrastructure, Collaboration, Advanced networking.*

1. Introduction

The rapid advancement of technology has led to the integration of computers and networks into various institutional operations, significantly influencing modern education. This integration has become particularly crucial in the context of computer networking, which has permeated all sectors, including higher education [1]. As universities increasingly rely on internet technology, robust network management has emerged as a cornerstone in nurturing the talents of the 21st century [2]. In line with this, Bukidnon State University College of Technologies (BukSU) has embraced cutting-edge technology through initiatives like the BukSU Notification System [3] and the Digital Research Portal. These innovations mark significant strides toward digital transformation. Despite the clear benefits, higher education institutions face unique challenges in network design, especially in terms of cybersecurity. Universities' large, open, and highly interconnected computing environments expose them to increased cyber risks [4]. In the Philippines, the rise of smart campuses underscores the critical importance of cybersecurity, as emphasized by the Philippine Department of Information and Communication Technology's (DICT) National Cybersecurity Plan 2022, which highlights the need to protect digital infrastructures in academic settings [5][6]. Although significant progress has been made in improving cybersecurity on campuses, there is still a notable gap in research on creating network infrastructures that specifically cater to universities in the region. Existing literature often overlooks key factors such as scalability, security, and the capacity to adapt to evolving technological demands in academic settings.While the DICT has taken steps to strengthen cybersecurity across the nation, most existing studies offer generalized solutions for network infrastructure without adequately considering the distinct needs of higher education institutions, particularly in the Philippine context. These institutions require a delicate balance between fostering an open academic environment that supports collaboration and ensuring robust security for sensitive academic and administrative data [4]. Moreover, previous research has typically focused on isolated components of network design, such as network optimization or security [7][8]. There is an apparent lack of a comprehensive framework that integrates scalability, security, and adaptability for university networks. This study addresses this research gap by proposing a novel network architecture explicitly tailored for Bukidnon State University College of Technologies Hub. Unlike previous studies, which have often been narrowly focused, this research provides a holistic solution that combines scalability, security,

and future readiness. The network design proposed in this study not only meets current institutional requirements but also anticipates future technological developments. The novelty of this approach lies in its comprehensive nature-integrating multiple facets of network design to offer a secure, scalable, and flexible infrastructure tailored to the unique needs of the university. The integration of network technology in educational institutions has been the subject of extensive research, as it facilitates communication, collaboration, and resource sharing across students, faculty, and staff [2]. However, many universities implement ad-hoc, unstructured network solutions, which often lack the necessary scalability and security. Studies indicate that Philippine universities, in particular, face challenges in developing network infrastructures that are robust enough to support modern teaching methods, such as e-learning platforms and digital research initiatives [3]. Current solutions often fail to align with the evolving technological needs and educational philosophies of these institutions, leaving a significant gap in the research landscape [5][8][10].This study proposes to fill this gap by offering a blueprint for designing scalable, secure, and adaptable networks in universities. The tailored network design for Bukidnon State University College of Technologies Hub is not only innovative in its approach but also serves as a model for other institutions facing similar challenges.

This research contributes to the field by providing a comprehensive solution that addresses the specific demands of university networks, ensuring they can support advanced digital initiatives and protect critical data from cyber threats [9]. Through this study, BukSU and similar institutions can establish a foundation for future digital transformation. The primary objective of this study is to create a networked environment that empowers both teachers and students by integrating advanced networking technologies with the institution's educational philosophy. The goal is to design a network architecture for the Bukidnon State University College of Technologies Hub that supports technological exploration, innovative research, and academic excellence [10]. Currently, the newly established College of Technologies Hub lacks a well-defined network infrastructure, making it crucial to implement a tailored and scalable solution that evolves with the institution's changing technological landscape. This study seeks to bridge the gap between theoretical research and practical implementation by developing a network infrastructure that not only addresses the university's current needs but also anticipates future growth. By doing so, the research will lay the groundwork for the institution's transition to a fully integrated smart campus. The proposed network design will create a secure, scalable foundation that enhances academic collaboration, streamlines administrative processes, and protects the integrity and confidentiality of institutional data [7][8][10]. This forward-looking approach ensures that the university can adapt to future technological advancements while maintaining robust security and supporting its educational goals.

1.1. Physical Assumptions

The physical infrastructure of this project includes a variety of buildings and facilities designed to support both academic and social functions within the College of Technologies Hub. The hub consists of four specialized three-story buildings, each dedicated to a specific academic subject, providing tailored environments for learning and research. In addition to these academic buildings, the Innovation Hub offers a dynamic space aimed at fostering technological advancements and entrepreneurship. The campus also includes a Motor Pool facility, which is responsible for transportation services and maintenance, ensuring the smooth operation of the university.

To promote social interaction and build a strong community, a centrally located cafeteria provides a shared dining area for students, faculty, and staff. These physical components play a crucial role in shaping the design of the network infrastructure. The diverse range of buildings and their functions require a carefully planned network that ensures seamless connectivity across the entire campus. The interconnected nature of the hub's facilities demands a robust architecture capable of supporting high data transmission rates while maintaining secure and reliable connections. Additionally, the scalability of the network must accommodate future growth as the institution evolves, ensuring that the infrastructure can adapt to expanding technological needs and increased data traffic and security threats.

1.2. Potential Vulnerabilities

1.2.1. Unauthorized Access Points

Unauthorized Access Points (APs) or rogue devices can be introduced into the network, either accidentally or maliciously. These can create unsecured entry points that attackers can exploit to gain unauthorized access to the network.Mitigation: Implement wireless security measures like WPA3 encryption for all access points, disable unused network ports, and regularly scan for rogue access points using specialized tools such as Wireless Intrusion Detection Systems (WIDS). Network Access Control (NAC) should also be implemented to ensure that only authorized devices connect to the network.

1.2.2. Data Breaches

A data breach occurs when sensitive data, such as academic records or personal information, is exposed or accessed by unauthorized individuals. This can result from vulnerabilities such as unencrypted data transmissions or compromised endpoints. Mitigation: To safeguard against data breaches, data at rest and in transit should be encrypted using AES-256 encryption or SSL/TLS for data transmission. In addition, implementing strict access controls with Role-Based Access Control (RBAC) will ensure that sensitive data is only accessible to authorized personnel. A Data Loss Prevention (DLP) system can also monitor data flow and detect potential breaches.

1.2.3. Weak Encryption Standards

Using outdated or weak encryption standards can make data transmissions susceptible to decryption by attackers. Encryption algorithms such as WEP or outdated SSL versions are no longer secure and should not be used. Mitigation: Implement industry-standard encryption protocols, such as SSL/TLS (Transport Layer Security) for secure communications and WPA3 for wireless security. Regular audits should ensure that encryption standards remain up to date with the latest best practices, and cryptographic systems should be regularly tested for vulnerabilities.

1.2.4. Phishing and Social Engineering Attacks

Phishing attacks and social engineering methods are often used to trick network users into revealing sensitive information or credentials, allowing attackers unauthorized access to the network. Mitigation: To prevent these attacks, Multi-Factor Authentication (MFA) should be enforced across the network. User education programs should also be implemented to raise awareness about phishing schemes and other social engineering tactics. Additionally, email filtering solutions can detect and block phishing emails before they reach users' inboxes.

1.3. Security Protocols to Implement

1.3.1. Firewall Configurations

Firewalls are the first line of defense against external threats. They filter traffic entering and exiting the network based on predefined security rules. Implementation: Configure firewalls with strict inbound and outbound rules that only allow necessary traffic. Implement a stateful inspection firewall to track the state of active connections and filter packets based on both the state and context of the connection. For added protection, consider deploying a Web Application Firewall (WAF) to guard against common web-based attacks such as SQL injections and Cross-Site Scripting (XSS).

1.3.2. Intrusion Detection/Prevention Systems (IDS/IPS)

IDS/IPS systems monitor network traffic for suspicious activity and can take action to block or mitigate threats. Implementation: Deploy IDS/IPS solutions across critical network segments to monitor for anomalies and potential threats in real-time. These systems should be configured to automatically block known threats and alert administrators to unusual traffic patterns. IDS solutions can identify potential threats, while IPS can block attacks such as Distributed Denial of Service (DDoS) or brute-force login attempts.

1.3.3. Virtual Private Networks (VPNs)

VPNs provide a secure channel for remote users to access the network, ensuring that all data exchanged is encrypted and protected from interception. Implementation: Implement a VPN for all remote access to the network, ensuring that employees and students connecting from outside the campus use secure channels. VPNs should use strong encryption protocols such as OpenVPN or IPSec, and users should be required to authenticate with MFA before establishing a VPN connection.

1.3.4. Encryption Methods (SSL/TLS)

SSL/TLS encryption ensures secure data transmission across networks by encrypting data during transit, protecting it from eavesdropping or tampering. Implementation: Implement SSL/TLS for all data transmissions, including web-based applications, email, and any system where sensitive information is exchanged. Use the latest version of TLS (currently TLS 1.3) to ensure maximum security. For wireless networks, WPA3 encryption should be enforced to protect wireless traffic from interception and tampering.

1.3.5. Access Control Mechanisms

Effective access control ensures that users only have access to the resources they are authorized to use.Implementation: Use Role-Based Access Control (RBAC) to assign permissions based on job functions or user roles. Combine RBAC with multi-factor authentication (MFA) for all critical systems and ensure that access logs are regularly monitored to detect unauthorized access attempts.

1.4. Regular Security Audits and Incident Response Plans

1.4.1. Security Audits

Conduct regular security audits to identify potential vulnerabilities in the network infrastructure. These audits should include vulnerability scanning, penetration testing, and reviewing security configurations across all devices and services.

1.4.2. Incident Response Plan

A comprehensive Incident Response Plan (IRP) should be in place to outline steps to be taken during a security breach or network compromise. This plan should include detection mechanisms, containment strategies, communication protocols, and recovery procedures to minimize the impact of any potential security incident.

2. Literature Review

The integration of technology in education has become an essential aspect of modern academic institutions, driving innovations in teaching, learning, and administration. However, the challenges associated with network design and cybersecurity in these environments are significant and warrant detailed investigation. This section provides a more comprehensive review of relevant literature, comparing the proposed network design for Bukidnon State University College of Technologies Hub with existing solutions implemented in similar academic settings.

2.1. Network Design in Educational Institutions

Numerous studies have emphasized the importance of robust network infrastructures in higher education to support seamless communication, resource sharing, and collaboration.

For instance, Ruaya and Buladaco [1] explored the benefits of Virtual Local Area Network (VLAN) technology in improving network efficiency in the administration building of NEMSU. Similarly, Agrawal and Yadav [2] discussed the campus network design process in universities, highlighting the necessity of scalable solutions that support future growth. These studies underscore the importance of efficient network architectures in facilitating smooth operations, but they often fall short of addressing the unique security challenges faced by academic institutions. The proposed network design for Bukidnon State University builds on these foundational concepts by incorporating not only VLANs for efficient segmentation but also advanced security protocols such as firewalls and Intrusion Detection Systems (IDS). This dual focus on efficiency and security distinguishes the current project from previous network implementations, which frequently prioritize one aspect over the other.

2.2. Cybersecurity in Higher Education

Cybersecurity is a critical concern for universities, which often have open, interconnected networks that leave them vulnerable to attacks. Singh et al. [4] measured the security dangers present in university networks, identifying malware, unauthorized access, and data breaches as primary threats. Yuhong et al. [5] designed a network security architecture specifically for smart campuses in the Philippines, focusing on the implementation of access controls and encrypted data transmissions to mitigate these threats. The network design for Bukidnon State University further advances the work of Singh et al. [4] and Yuhong et al. [5] by integrating advanced encryption methods, secure VPN access, and regular security audits to prevent unauthorized access. Unlike previous research, which primarily emphasizes security measures after network deployment, the proposed design incorporates security into the foundational stages of the network architecture, ensuring that the entire infrastructure is secure by design.

2.3. Scalability and Adaptability of University Networks

One of the most pressing challenges in network design for academic institutions is ensuring scalability and adaptability to future technological changes. Kariapper et al. [6] emphasized the need for university networks to support emerging technologies such as IoT devices and virtual learning platforms. One of the author examined the automation of campus networks and how they could evolve to meet increasing demands for bandwidth and resource allocation as institutions grow. In comparison, the network architecture proposed for Bukidnon State University places a strong emphasis on scalability, with dynamic routing protocols and subnetting to ensure efficient bandwidth management. Additionally, the integration of cloud-based solutions ensures that the network can adapt to future demands, such as the increasing use of e-learning platforms and research tools, a critical feature not always addressed in earlier research.

2.4. Gaps in Existing Research

Despite the extensive research on network optimization, security, and scalability in academic settings, there remains a notable gap in solutions explicitly tailored for institutions in developing regions, particularly in the Philippines. While Agrawal and Yadav [2] provided a broad overview of campus network designs, their work did not consider the unique security and scalability challenges faced by universities with rapidly expanding technological infrastructures.

The proposed network design for Bukidnon State University directly addresses these gaps by offering a customized solution that integrates scalability, security, and adaptability from the outset. This comprehensive approach is essential for institutions in developing regions, where network resources must be optimized to meet both current and future needs.

2.5. Novelty of the Proposed Network Design

The uniqueness of the proposed network design lies in its holistic approach, combining security, scalability, and future-readiness in one unified framework. Previous research has often focused on isolated aspects of network design, such as security or efficiency, without fully considering the need for an adaptable infrastructure that supports both academic and administrative functions.

The design outlined in this study for Bukidnon State University is tailored to the institution's specific requirements, ensuring that it can accommodate future technological advancements and the growing demands of a smart campus. By integrating VLAN segmentation, advanced encryption, dynamic routing, and a flexible design for future scalability, the proposed network infrastructure goes beyond what has been traditionally implemented in similar academic environments. This novel approach ensures that Bukidnon State University is well-positioned to embrace technological advancements and protect critical data, setting a new standard for network design in higher education institutions within the region.

3. Materials and Methods

To build a robust cybersecurity framework, a range of technologies and strategies must be integrated [11]. The initial stage of this study involves a thorough analysis of the new network infrastructure design, focusing on the specific requirements of each building within the College of Technologies Hub.

Subsequently, a tailored network architecture will be crafted, prioritizing robust security measures, smooth connectivity, and streamlined administrative processes. Implementing this framework will necessitate close cooperation among IT experts, faculty, and administrators to ensure seamless integration and adoption of the network infrastructure.

3.1. Requirement Analysis and Planning

The first step involved analyzing the specific requirements of the College of Technologies Hub. This analysis covered both the academic and administrative needs of the institution. A comprehensive audit of the current infrastructure and projected technological growth was conducted, ensuring that the new network would be capable of handling increased data traffic and future demands. Meetings were held with IT staff, faculty, and administrators to gather insights on current challenges and expectations for the network infrastructure. The focus was on identifying essential requirements such as high-speed data transmission, robust security measures, scalable architecture, and seamless integration with e-learning platforms and digital research portals [10].

3.2. Network Design Process

The design of the network followed a phased approach, starting with the physical layout of the network and progressing through logical network design.Physical Design: The physical design phase involved mapping the locations of network components such as routers, switches, and cables throughout the campus buildings. The specific functions of each building (academic, administrative, etc.) were taken into account to determine the optimal placement of hardware, ensuring that high-priority areas like computer labs and faculty offices received adequate bandwidth and reliable connections. Tools like Cisco Packet Tracer and AutoCAD were used to simulate and plan the physical layout of the network [10]. Logical Design: Following the physical design, the logical network design was created to outline the network's data flow and connectivity structure. VLANs (Virtual Local Area Networks) were used to segment the network, ensuring secure communication between different departments while allowing for efficient resource allocation. Subnetting was performed to allocate IP addresses based on each building's needs, ensuring efficient use of available IP space. Dynamic routing protocols such as OSPF (Open Shortest Path First) were chosen to optimize network traffic and ensure high availability [10].

3.3. Security Measures

Given the importance of data security, multiple layers of protection were incorporated into the network design. Firewalls, intrusion detection systems (IDS), and Virtual Private Networks (VPN) were integrated to protect against external threats. Encryption protocols such as SSL/TLS were employed to secure sensitive academic and administrative data during transmission. Additionally, regular audits and security patching schedules were planned to maintain the network's integrity over time. The security measures were tested using penetration testing tools like Kali Linux, which helped identify potential vulnerabilities and provided insights on further strengthening the network's defenses [10].

3.4. Simulations and Testing

Simulations played a critical role in validating the network design before implementation. Cisco Packet Tracer was used to simulate network traffic, data flow, and device configurations. This allowed for the testing of different scenarios, such as network congestion, failure of network components, and potential cyber-attacks. These simulations ensured that the network could handle peak loads and prevent bottlenecks while maintaining security. To evaluate network performance, Quality of Service (QoS) metrics such as latency, packet loss, and throughput were measured under simulated conditions. Adjustments to the design were made based on the results of these simulations to ensure the highest possible efficiency [10].

3.5. Project Benefits

The planned network design for the College of Technologies' new campus brings forth numerous project benefits. Firstly, it facilitates seamless data exchange and connectivity among all facilities within the College of Technologies Hub, fostering effective communication and collaboration. This enhanced connectivity also translates into improved access to a diverse array of online resources, research databases, and digital learning materials for both students and educators, thereby elevating the quality of education. Moreover, the network architecture drives productivity and efficiency in various administrative tasks by optimizing administrative operations. The incorporation of robust security measures ensures the integrity and confidentiality of sensitive academic and administrative data. Additionally, the integration of cutting-edge e-learning resources enhances instructional methodologies and offers students innovative learning avenues. Furthermore, the network design promotes a culture of collaborative research and innovation between students and faculty members, nurturing continuous learning and growth. Looking ahead, the infrastructure's flexibility and scalability position the university as a leader in educational innovation, enabling it to adapt and embrace future technological advancements seamlessly.

3.6. Project Business and Technical Goals

This project is all about creating a cutting-edge environment at Bukidnon State University's College of Technologies Hub. It is not just about technology; it is about boosting academic success, sparking innovative research, and supporting students in every way possible. The goal is to make things run smoother, improve how to connect and communicate, and open doors for students to explore new technologies and excel academically. Ultimately, the researchers want to set the university apart, encouraging teamwork in research, fostering a love for learning, and helping everyone grow, from students to faculty. At the Bukidnon State University College of Technologies Hub, we have put together a network plan that's all about making things easier for everyone. The goal is to blend all the campus buildings seamlessly so that teaching and admin work can flow smoothly. Taking security seriously to protect important data, and making sure that everyone can quickly get online to access what they need for learning and teaching. With simpler admin

tasks and cool e-learning tools, we are aiming high for academic success. The network is built to keep up with the latest tech changes, pushing the university forward as a top spot for cutting-edge education and research.

3.7. Project Gantt Chart

Table 1 presents a Gantt chart outlining the chronological sequence of critical tasks associated with network implementation, each scheduled within specific months. The phase of network planning encompasses the initial stages of strategizing and planning for the deployment of the network infrastructure. Subsequently, the stage of overall analysis encompasses the ongoing assessment of project progress and the formulation of strategic decisions to optimize outcomes. Requirement documentation involves a detailed articulation of the specific network requirements essential for successful implementation. Procurement activities are focused on the acquisition of requisite hardware, software, and resources aligned with project specifications. Network Installation encompasses the practical execution of network infrastructure deployment, encompassing hardware setup, configuration, and integration procedures. Finally, line testing constitutes a comprehensive evaluation process to validate network connections and functionalities, ensuring alignment with predefined requirements and standards.

3.8. Proposed Capital and Operating Requirements

Table 2 provides a detailed breakdown of the financial investments required for the proposed network design at Bukidnon State University. For capital expenditures, the table outlines allocations of 30 million for network infrastructures, 15 million for hardware procurement, 7.5 million for software acquisition, and 5 million for security measures, totaling 57.5 million. On the operational side, annual expenses include 4 million for maintenance and upkeep, 3 million for technical support, 1.5 million for software licensing, and 2.5 million for security measures, amounting to 11 million per year.

In total, the combined capital and operating expenditures for the first year of implementation totalled 68.5 million. This detailed breakdown provides a comprehensive view of the financial aspects associated with implementing the proposed network design, ensuring transparency and informed decision-making at Bukidnon State University.

3.9. Summary of Recommendations

Setting up a robust and adaptable network infrastructure at Bukidnon State University's College of Technologies Hub is highly recommended. This infrastructure should emphasize strong security measures, consistent maintenance, and reliable technical support to ensure smooth connectivity and efficient data management.

It is crucial to prioritize the integration of cutting-edge teaching techniques and virtual learning platforms, aligning the network design closely with the university's educational goals to cultivate an engaging and inclusive academic environment.

Table 1. Gantt chart

Activities	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Network Planning												
Overall Analysis												
Requirement Determination												
Procurement												
Network Installation												
Line Testing												

Table 2. Capital expenditures

Particulars	**Estimated Cost**
Network Infrastructures	30,000,000
Hardware Procurement	15,000,000
Software Acquisition	7,500,000
Security Measures	5,000,000
Total Capital Expenditures	**57,500,000**

Maintenance and Upkeep	4,000,000/year
Technical Support	3,000,000/year
Software Licensing	1,500,000/year
Security Measures	2,500,000/year
Total Operating Expenditures	**11,000,000/year**
Total Capital and Operating Expenditures for the First Year of Implementation	68,500,000

Furthermore, the network design should be scalable to accommodate future technologies seamlessly [12], addressing the university's evolving needs and promoting a technology-enhanced learning environment that supports academic excellence and fosters innovation in research.

4. Results and Discussion

4.1. Network Management

Managing a network involves juggling many moving parts, from hardware and software to protocols and data, all to keep things running smoothly, safely, and reliably. It is about keeping an eye on how the network is performing, fixing any problems that crop up, setting up devices correctly, making sure security measures are in place, and making the most of the resources available. Network management also covers handling who can access what, making sure data stays intact, and defending against cyber threats and unauthorized entry.

4.1.1. Network Administration

Network administration encompasses a range of responsibilities focused on the effective management and coordination of network infrastructure. These tasks include user management, configuring user permissions, overseeing network resources, and enforcing network policies and procedures. Network administrators play a crucial role in ensuring the network operates efficiently, maintains security, and aligns with the organization's goals and objectives.

4.1.2. Network Operation

Operating a network involves the day-to-day tasks of keeping it running smoothly and at its best. This means keeping an eye on how traffic is flowing, fixing any hiccups in connections, handling network devices, and making sure data moves seamlessly between different parts of the network.

Operators are all about keeping the network reliable and available, jumping in quickly to solve any problems and keep things running without interruptions or delays.

4.1.3. Network Maintenance

Network maintenance involves keeping everything in good shape and preventing problems before they happen. This means staying on top of software updates, installing patches, upgrading hardware when needed, and regularly checking for any potential issues so they can be fixed early. It is all about making sure network equipment lasts as long as possible, performs well, and avoids unexpected breakdowns.

4.1.4. Network Provisioning

Network provisioning involves setting up and configuring network resources like bandwidth, IP addresses, and devices to meet the requirements of users and applications. This includes tasks such as creating new services, assigning resources to specific users or departments, and making sure the network has enough capacity to support the organization's activities.

4.1.5. Network Security

Network security is all about protecting the network from unauthorized access, data breaches, malware attacks, and other potential security threats. This includes using tools like firewalls, intrusion detection systems, encryption methods, and access controls to defend the network infrastructure and sensitive information from malicious actions.

4.2. Proposed Physical Design

The diagrams below showcase the envisioned architectural layouts for different departments and amenities within the Colleges of Technology: Information Technology, Electronics Technology, Food Technology, Automotive Technology, Innovation Hub, Motor pool, and Cafeteria. Each building is designed with distinct network configurations on every level. These designs are meticulously planned to promote smooth connectivity not just within each floor but also throughout the entire building complex. This approach aims to enhance communication and collaboration among different departments and facilities, fostering a productive and interactive environment.

4.2.1. Information Technology Building

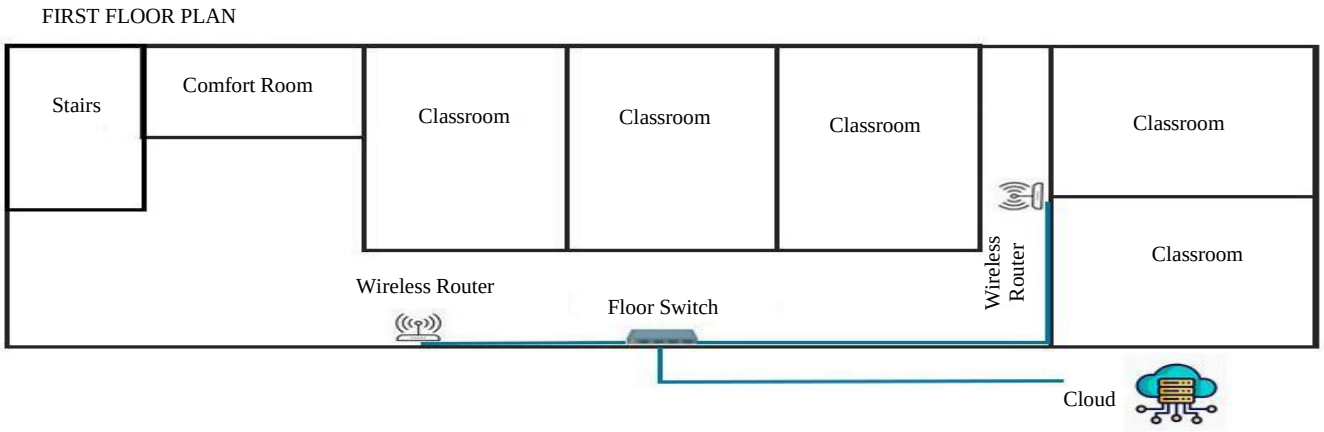

Fig. 1 Physical network design of information technology first floor

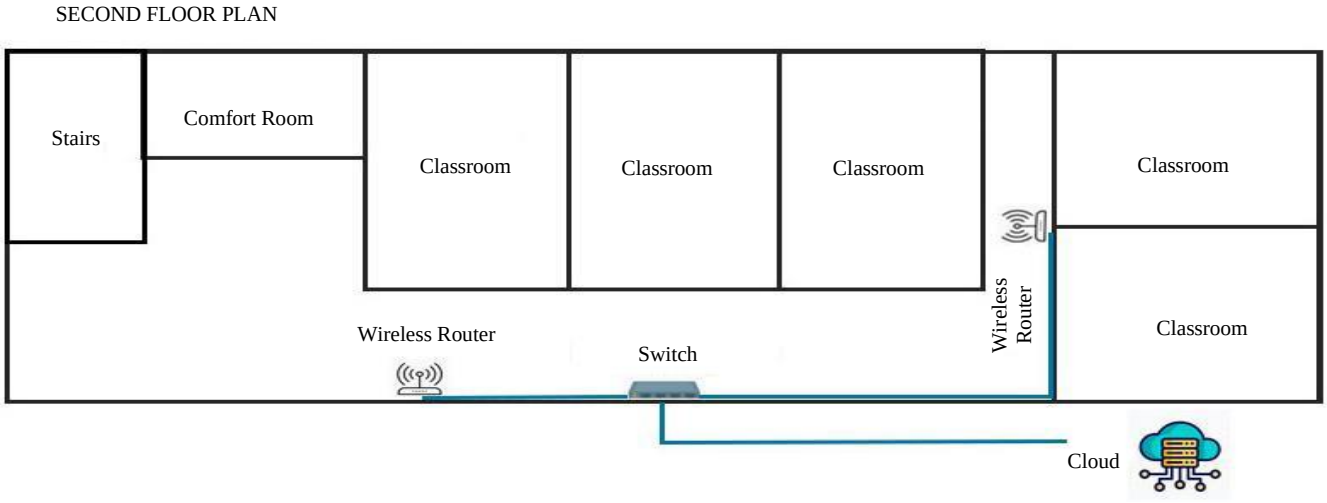

Fig. 2 Physical network design of information technology second floor

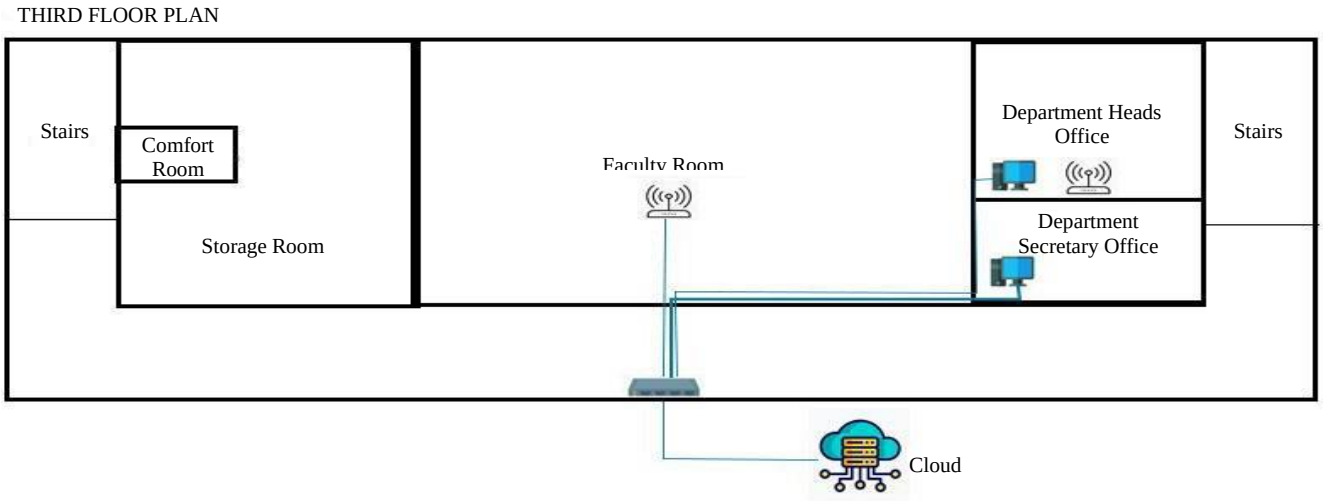

Fig. 3 Physical network design of information technology third floor

4.2.2. Electronics Technology Building

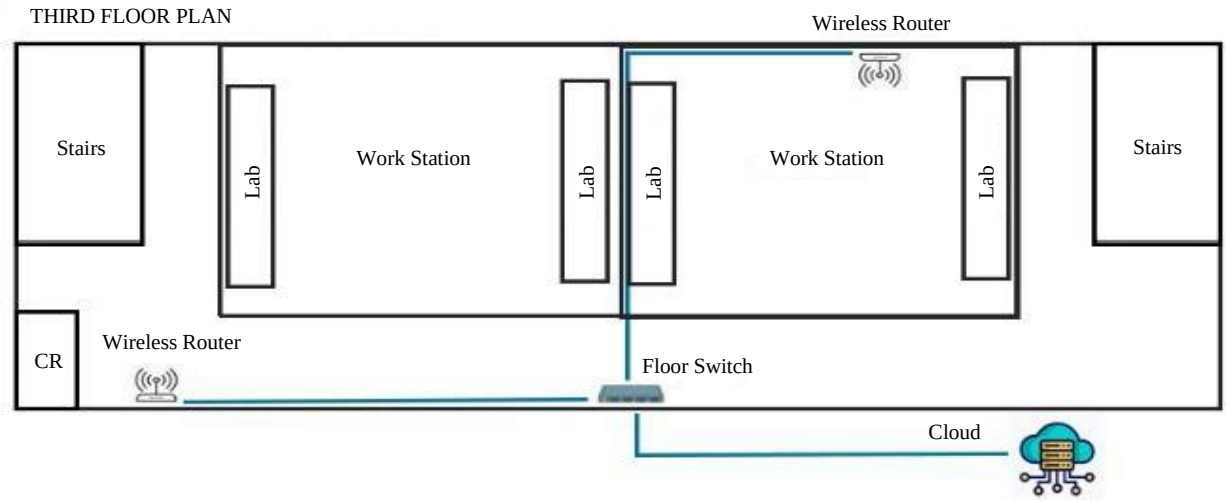

Fig. 4 Physical network design of electronics technology third floor

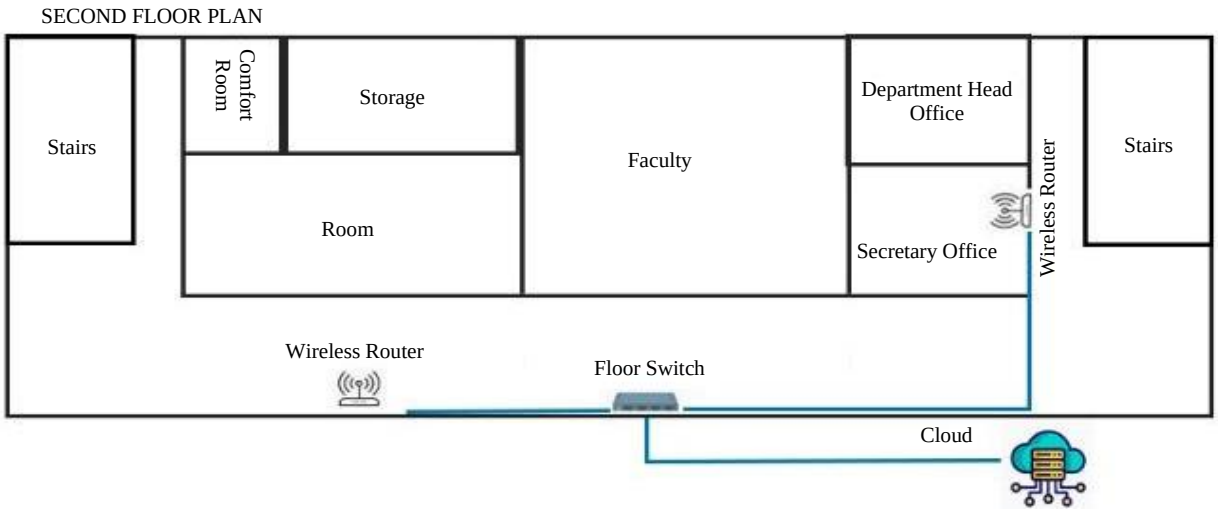

Fig. 5 Physical network design of electronics technology second floor

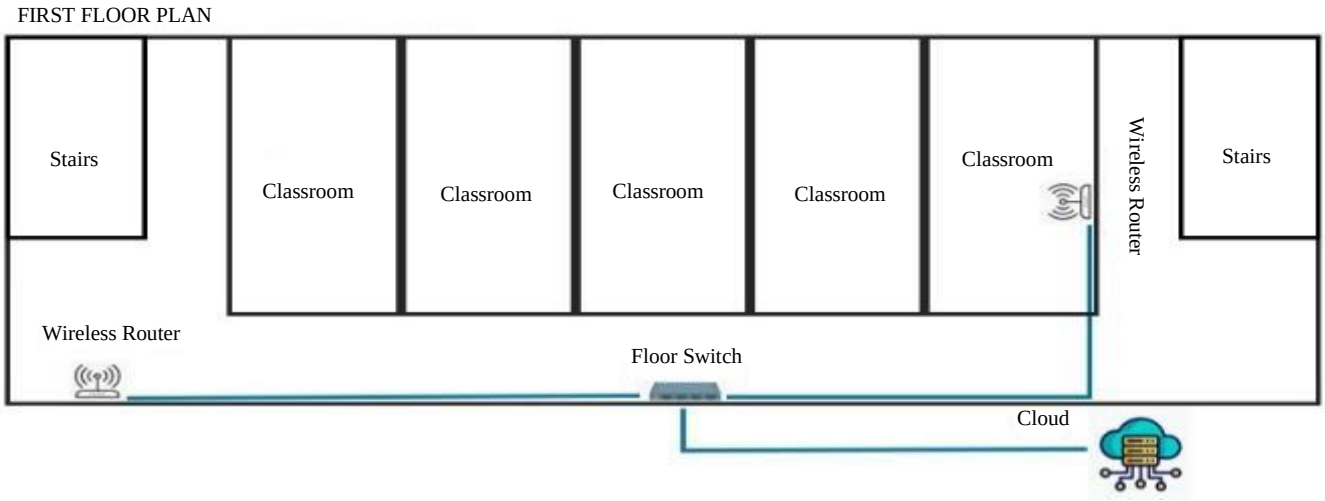

Fig. 6 Physical network design of electronics technology first floor

4.2.3. Food Technology Building

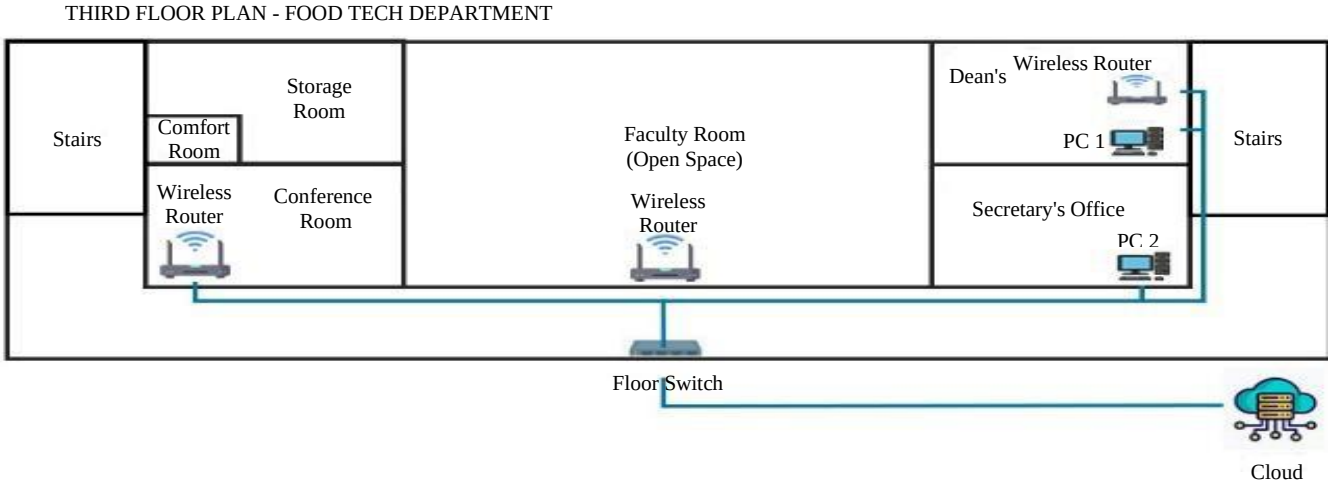

Fig. 7 Physical network design of food technology third floor

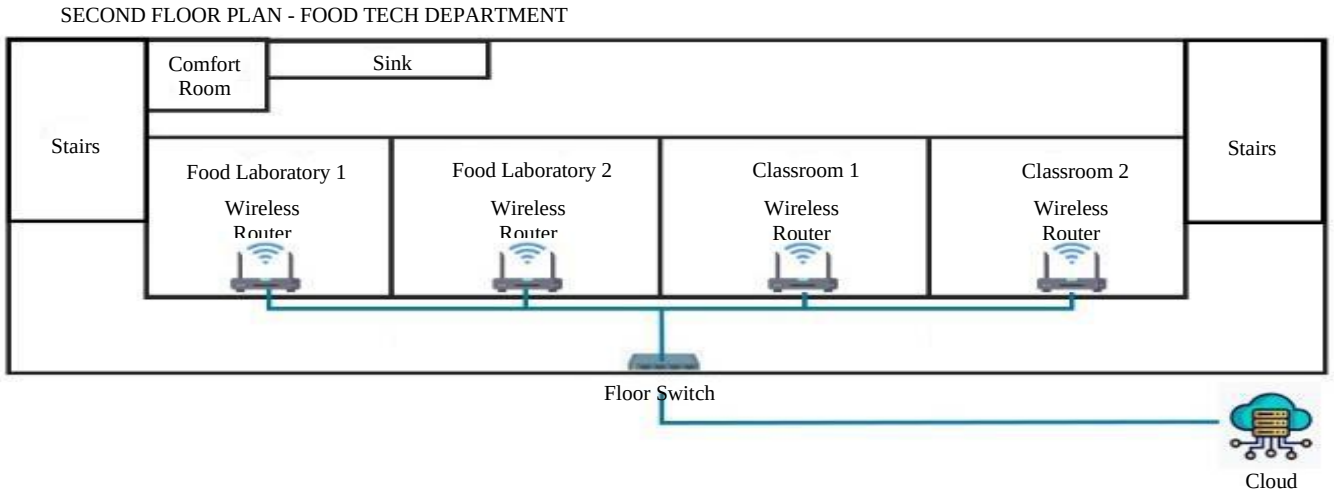

Fig. 8 Physical network design of food technology second floor

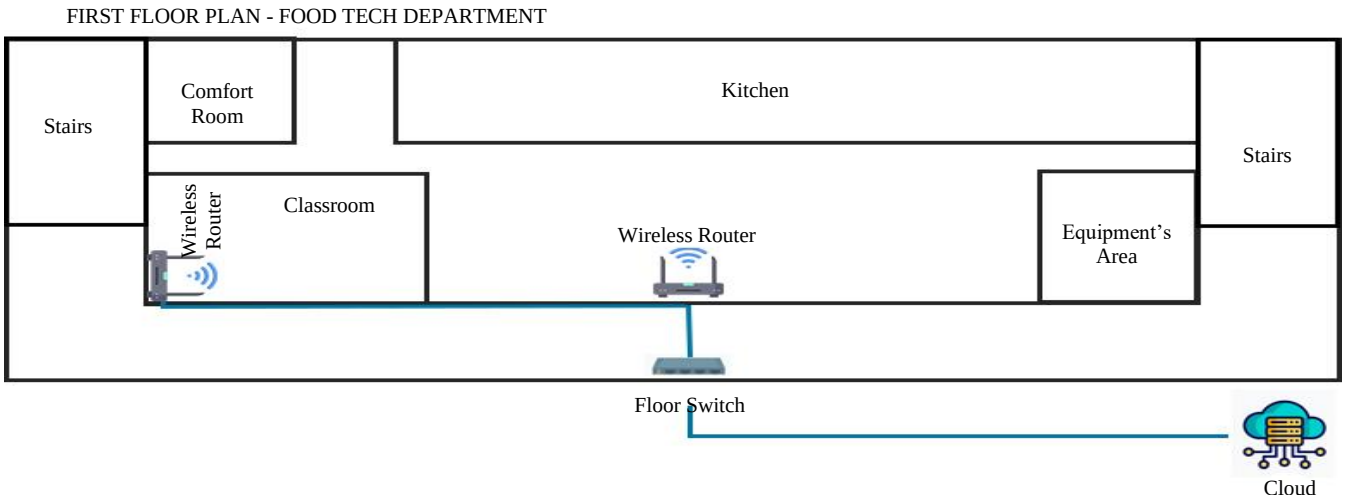

Fig. 9 Physical network design of food technology first floor

4.2.4. Automotive Technology Building

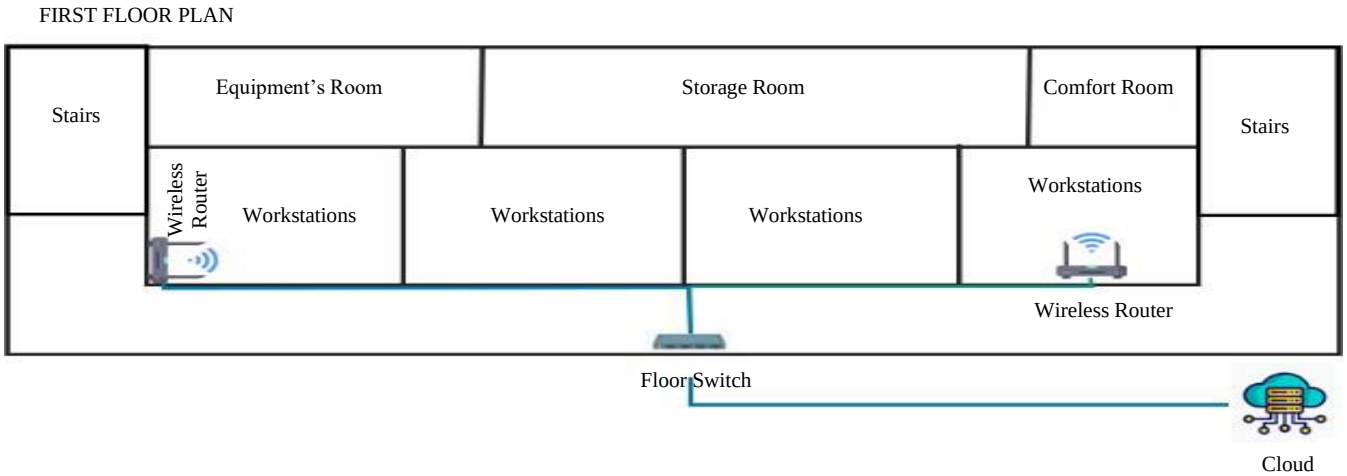

Fig. 10 Physical network design of automotive technology first floor

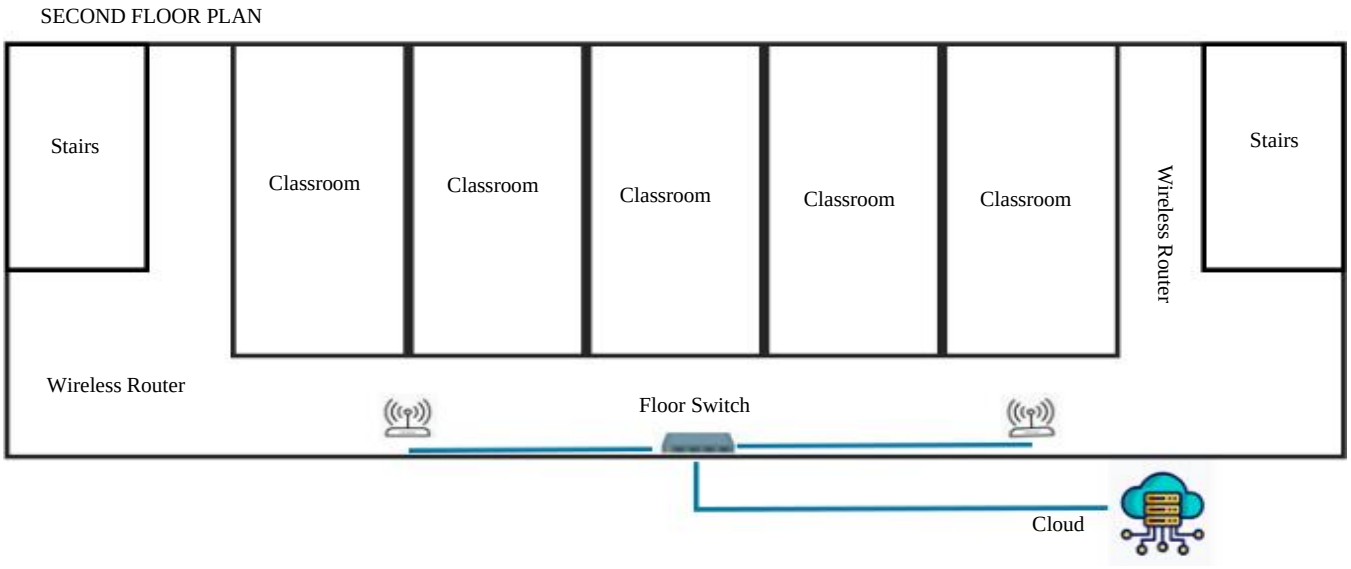

Fig. 11 Physical network design of automotive technology second floor

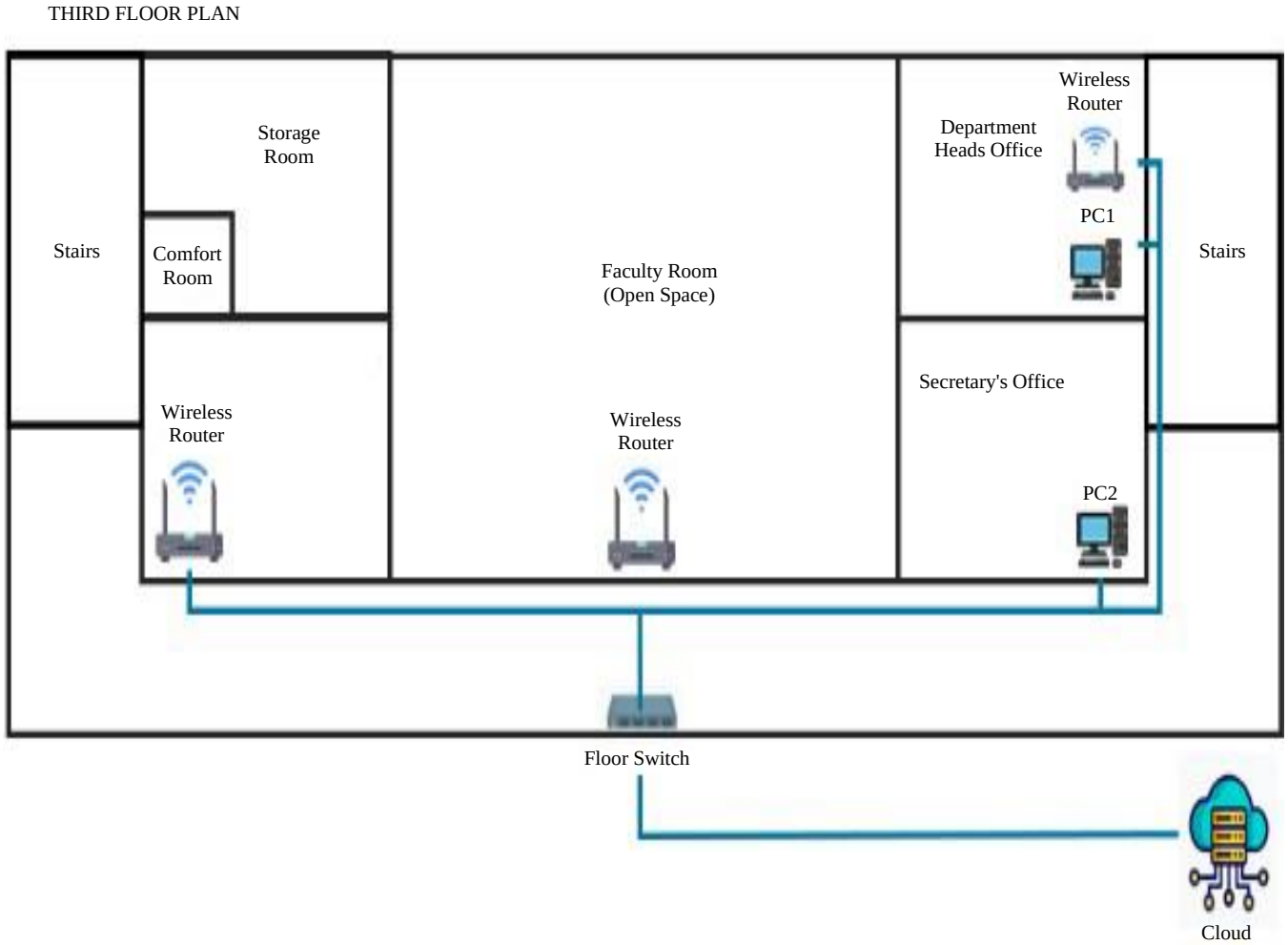

Fig. 12 Physical network design of automotive technology third floor

4.2.5. Innovation Hub

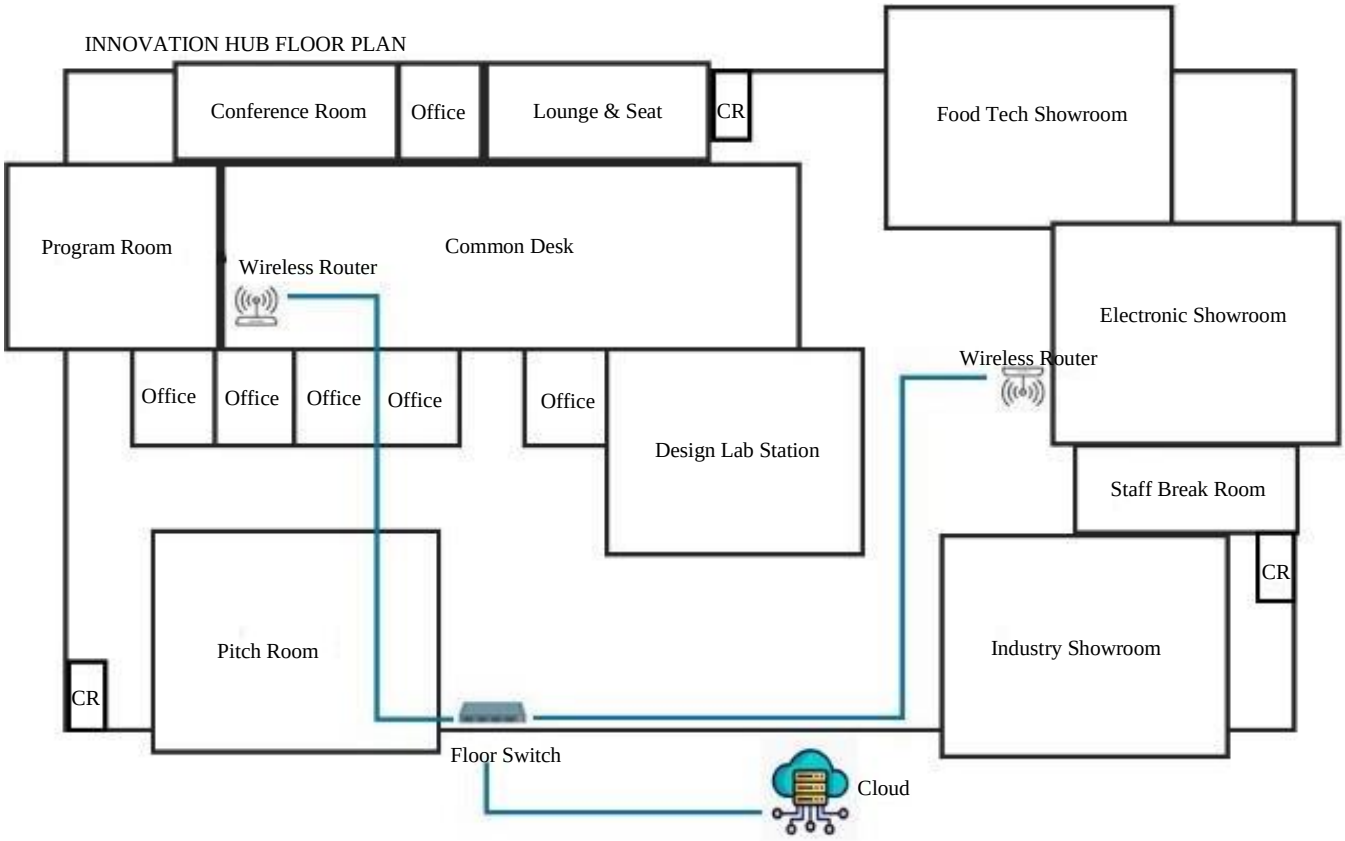

Fig. 13 Physical network design for the innovation hub

4.2.6. Motor Pool

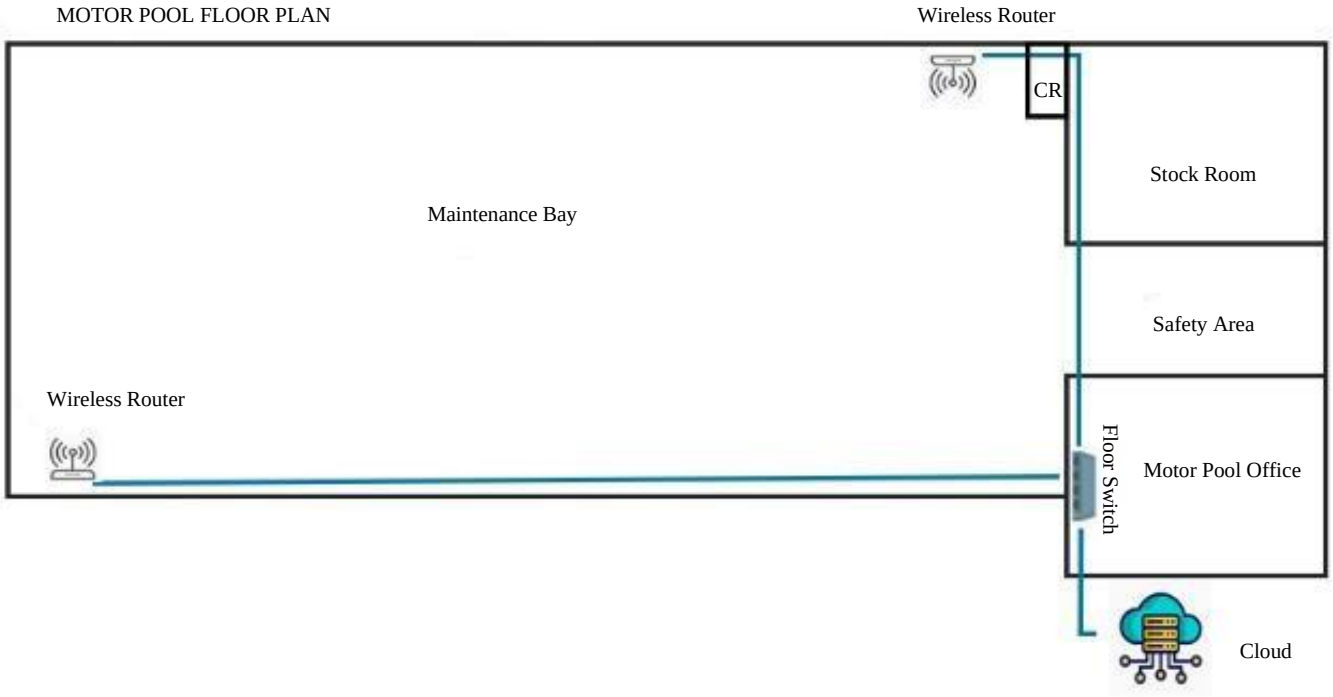

Fig. 14 Physical network design for Motor Pool

4.2.7. Cafeteria

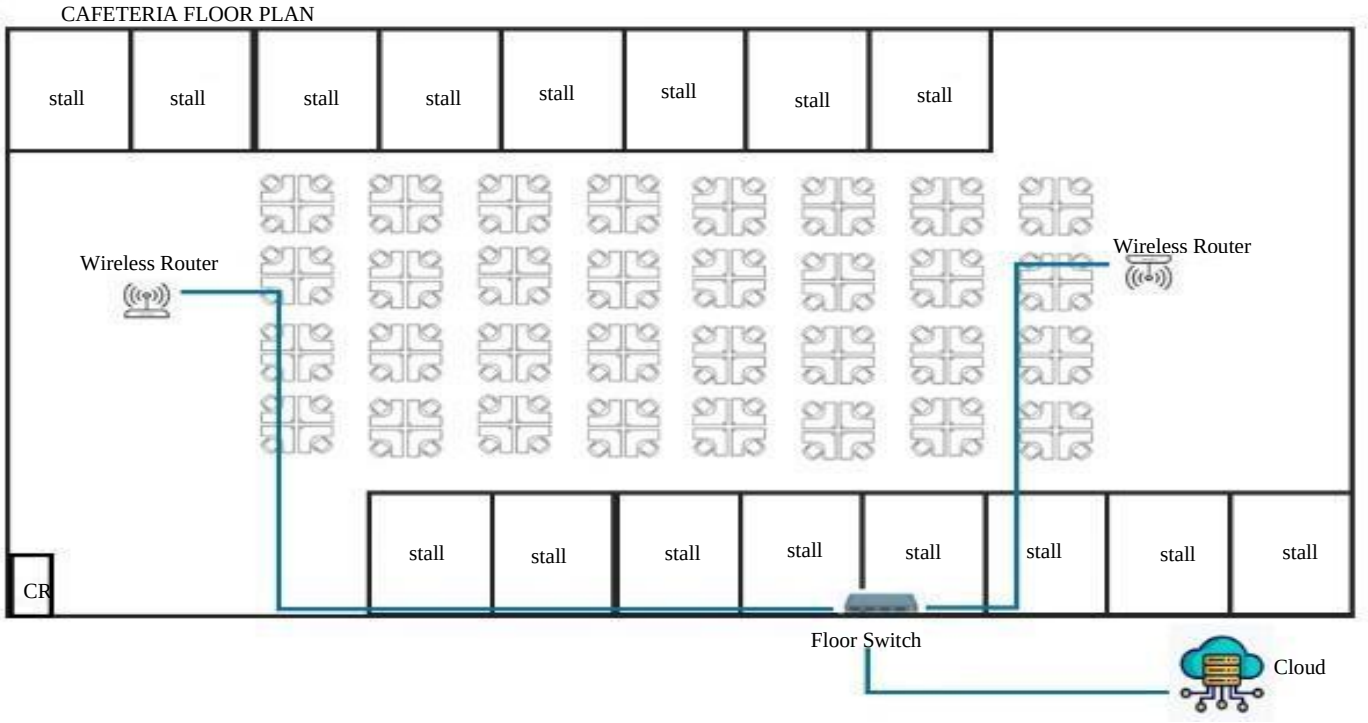

Fig. 15 Proposed logical design

4.3. Logical Design

The network infrastructure's logical architecture at the Bukidnon State University College of Technologies Annex B Campus has been carefully customized to meet the unique needs of its different buildings and amenities. The plan includes placing two wired Personal Computers (PCs) on each floor of the four buildings, each spanning three floors, ensuring seamless connectivity and effective data exchange for faculty, staff, and students. Additionally, two wireless routers are strategically placed on every floor of each building to meet the school's evolving technology requirements, providing continuous internet access and connectivity across the campus.

Moreover, the single-story motor pool, restaurant, and innovation hub each have two routers installed to address their specific networking needs effectively. This dual-router setup is crucial for maintaining stable and reliable network connections tailored to each area's technical demands. The network architecture aims to provide comprehensive coverage and uninterrupted connectivity by placing routers strategically in these designated zones, fostering an environment that supports collaborative learning, innovative research, and operational efficiency throughout the university.

In summary, the logical design emphasizes tailored wired and wireless networking solutions designed to meet each building and facility's unique operational and educational requirements. This approach significantly contributes to the Bukidnon State University College of Technologies Annex B Campus's growth and success by enabling seamless data transmission and communication. It also promotes a dynamic and innovative learning environment, encouraging technological exploration and academic excellence.

Table 3. Network cost of ownership

TCO Components	Cost
One time installation costs, hardware and labor for deployment	57,500,000
Operating Expense per year	11,000,000
Total Capital and Operating Expenditures for the First Year of Implementation	68,500,000

4.4. Network Cost Ownership

Table 3 offers a comprehensive view of the financial considerations related to network implementation, focusing on the Total Cost of Ownership (TCO) components that encompass various cost factors associated with owning and running the network. The initial investment required for setting up the network infrastructure, covering expenses like hardware procurement and labor costs, totals 57.5 million. Furthermore, the annual recurring expenses for network maintenance and operations are projected at 11 million. Consequently, the combined capital and operating expenditures for the inaugural year of implementation reach 68.5 million.

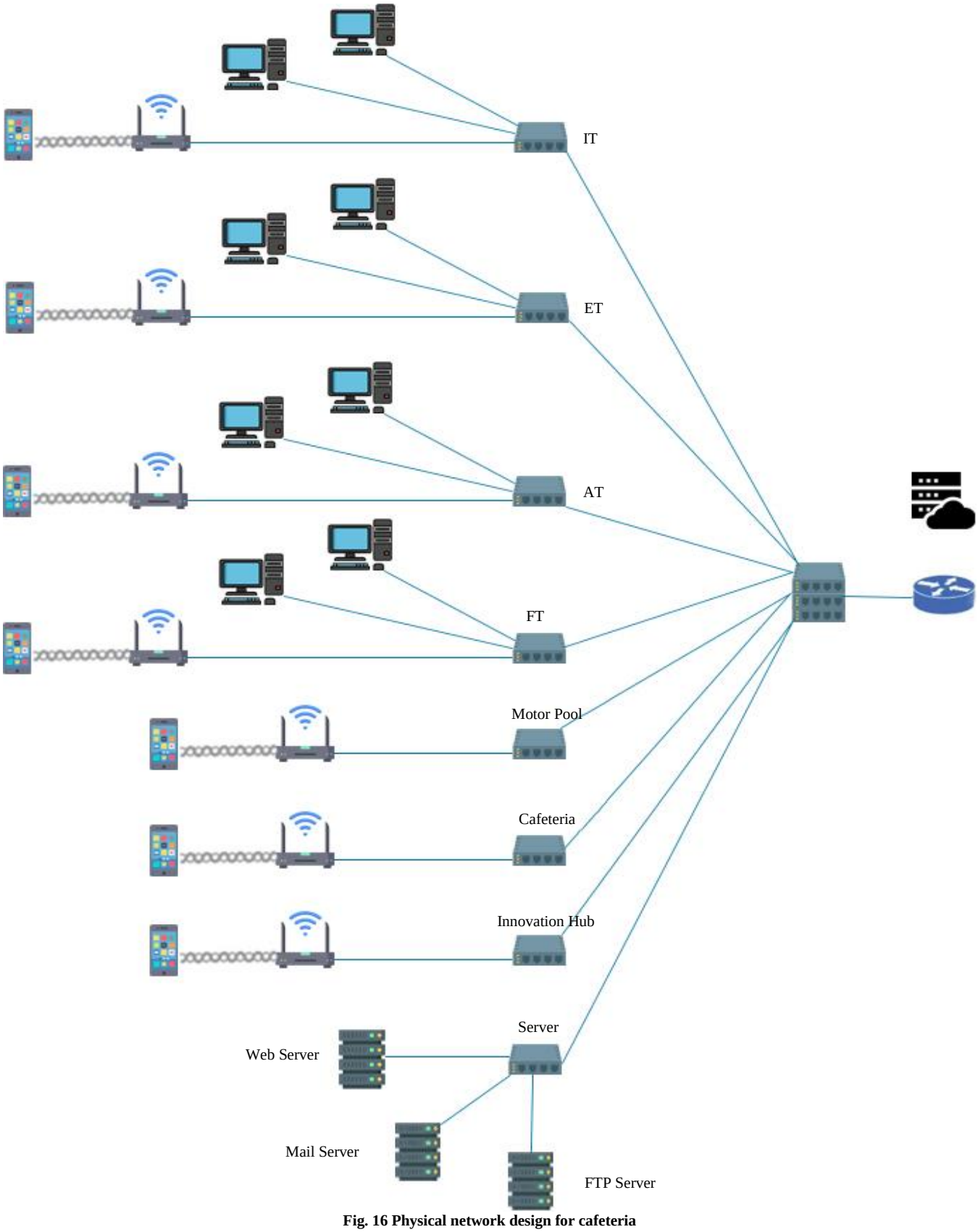

Fig. 16 Physical network design for cafeteria

4.5. Implementation

The objective of this study is to develop an optimized Network Design tailored explicitly for the Bukidnon State University College of Technologies Annex B Campus, enabling smooth and effective data transmission across all campus buildings. The proposed network design will prioritize meeting the diverse technological needs and operational demands of the campus facilities. The phased approach to network activities outlined in Table 1 follows a structured deployment strategy.

Additionally, Table 2 provides a breakdown of anticipated capital expenditures, covering network equipment, storage, computer specifications, subscriptions, communications, administration support, and training costs. The network configuration will be streamlined to minimize complexity, ensuring stable and trouble-free operations. It is recommended that the administrative team adhere to the one-year planning and implementation timeline outlined in the project for successful integration.

4.5.1. Implementation Challenges and Solutions

The potential obstacles that could arise during the deployment of the proposed network design for Bukidnon State University's College of Technologies Hub. It would discuss challenges such as:

Budgetary Constraints: The initial capital and operational expenditures for the network infrastructure are significant, with an estimated total of 68.5 million PHP for the first year. This chapter could explore strategies for phasing the implementation over multiple budget cycles, seeking government or private funding, and prioritizing essential infrastructure in the initial stages.

Technological Limitations: While the network design incorporates advanced technologies, limitations such as compatibility with existing systems, vendor lock-in, or outdated infrastructure could present challenges. Solutions could include deploying interim technologies to bridge gaps, backwards-compatible equipment, or strategic partnerships with technology providers.

User Adoption Issues: Faculty, staff, and students may face difficulties in adjusting to new network systems or utilizing new tools like e-learning platforms and administrative systems. This chapter could propose comprehensive training programs, user-friendly interfaces, and ongoing technical support to facilitate smooth adoption.

Security and Privacy Concerns: Implementing new cybersecurity measures may raise concerns about privacy and data protection. This section could cover how to balance these issues by employing encryption, secure access protocols, and conducting regular security audits to address any vulnerabilities without compromising user trust.

5. Future-Proofing the Network

Addressing how the proposed network design anticipates future technological advancements and prepares Bukidnon State University for long-term growth. Key topics could include:

Scalability: The network design is built with scalability in mind, using VLAN segmentation, dynamic routing, and flexible IP addressing to accommodate increased user numbers and data traffic.This section could explore in detail how the network will handle future expansions, such as adding new buildings or incorporating new departments into the infrastructure.

Integration with Emerging Technologies: The chapter could examine the ability of the network to integrate with evolving technologies such as IoT devices, AI-powered systems, and cloud-based applications. For example, the inclusion of dual routers in each building ensures that the network will be able to support the growing demand for wireless connectivity.

Adapting to Changing Security Threats: As cyber threats evolve, the network's layered security approach—including firewalls, IDS, VPNs, and encryption—ensures it remains resilient to new forms of attacks. This chapter could further delve into plans for regular security updates, network monitoring tools, and machine learning-based security systems to address zero-day vulnerabilities and Advanced Persistent Threats (APTs).

6. Impact Assessment

This chapter will assess the anticipated impact of the proposed network design on teaching, learning, and administrative processes at Bukidnon State University. It would focus on:

Teaching and Learning Improvements: The network's ability to support virtual learning platforms, e-learning resources, and research collaboration will be evaluated. Metrics such as the number of users accessing online resources, feedback from faculty and students, and improvements in research output could be analyzed to assess the benefits of the new infrastructure.

Administrative Efficiency: By streamlining data sharing, communication, and record-keeping processes, the network is expected to boost administrative productivity. This chapter could suggest tracking key performance indicators (KPIs) such as time saved on administrative tasks, reductions in data loss, and improvements in cross-departmental collaboration.

Ongoing Assessment Methodologies: This section could outline the methods used to evaluate the network's effectiveness continuously after implementation. Suggested methods might include user satisfaction surveys, network

performance monitoring tools (e.g., for latency, downtime, and throughput), and regular security audits to ensure that the infrastructure is functioning optimally and meeting the university's evolving needs.

7. Empirical Evidence

To substantiate the theoretical claims regarding the performance, reliability, and security of the proposed network design, empirical evidence from real-world case studies and benchmarks can be presented. This section will utilize data from similar network implementations in academic institutions to reinforce the relevance of the design for Bukidnon State University's College of Technologies Hub.

7.1. Performance Metrics

Performance is a critical metric in evaluating the success of a network infrastructure, particularly in academic settings where high data transmission rates and minimal latency are essential for both teaching and administrative tasks. The empirical evidence gathered from various sources highlights the following Key Performance Indicators (KPIs):

Data Transmission Speed: Studies such as Ruaya and Buladaco [1] reported improvements in data transmission speeds by 30-40% after implementing VLAN-based network architectures in educational settings. VLANs effectively reduce network congestion, ensuring faster access to learning materials, research databases, and administrative portals.

Network Uptime and Availability: Empirical data from the researcher demonstrated that automated network management systems implemented in campus networks resulted in 99.9% uptime, ensuring that teaching and learning processes were uninterrupted. Similar uptime rates are expected with the proposed design, as dynamic routing protocols and dual-router configurations across buildings will enhance fault tolerance and minimize downtimes.

Bandwidth Utilization: Studies that benchmark university networks have shown that a combination of dynamic routing and load balancing can increase bandwidth utilization efficiency by 20-25% [5]. The design for Bukidnon State University aims to replicate these results by employing dynamic routing protocols such as OSPF to optimize bandwidth allocation, especially during peak usage periods.

7.2. Reliability

The reliability of a campus network is critical to ensure continuous access to resources for students, faculty, and administrative staff. Empirical evidence from similar academic environments confirms the benefits of resilient and redundant network design:

Fault Tolerance: Network redundancy, as illustrated in case studies from Yuhong et al. [5], can dramatically reduce service interruptions. Their implementation of redundant connections across campus buildings resulted in a 15% reduction in network failures. The dual-router setup in Bukidnon State University's design will similarly provide multiple paths for data transmission, ensuring continued service even in the event of a router failure.

System Stability: A stable network requires constant monitoring and proactive maintenance. Evidence from previous campus networks shows that employing network monitoring tools can detect up to 85% of potential faults before they escalate into critical issues [9]. The proposed network for Bukidnon State University includes continuous monitoring solutions that will enable real-time detection and rectification of anomalies, ensuring high system reliability.

7.3. Security Effectiveness

Security is one of the most pressing concerns for university networks, given the sensitivity of academic and administrative data. Several studies provide empirical evidence on the effectiveness of advanced security measures implemented in similar networks:

Intrusion Prevention and Detection Systems (IDS/IPS): Case studies from Singh et al. [4] demonstrated that university networks equipped with IDS/IPS systems experienced a 60% reduction in successful cyber-attacks. The proposed network for Bukidnon State University will incorporate such systems to monitor and block unauthorized access attempts in real-time, providing a significant security boost.

Data Encryption and VPN Usage: In a review of secure campus networks, Yuhong et al. [5] reported that data encryption and secure VPN access prevented 90% of Man-in-the-Middle (MITM) attacks. The proposed design will employ strong encryption standards (e.g., SSL/TLS) and secure VPNs, ensuring the confidentiality of academic and administrative data during transmission.

Regular Security Audits: Continuous auditing has proven effective in maintaining network security. Institutions that performed regular security audits experienced a 25% reduction in vulnerabilities over time [6]. The network design includes regular audit protocols to ensure ongoing protection against emerging cyber threats.

7.4. User Experience and Satisfaction

Lastly, user feedback and satisfaction are important metrics that can serve as qualitative empirical evidence of the network's effectiveness. Several surveys and studies conducted post-implementation in other institutions have shown that:

Improved User Satisfaction: Surveys conducted in universities that adopted similar network designs revealed a 75% increase in user satisfaction with network speed and accessibility, particularly in areas such as accessing e-learning platforms and administrative portals [2]. The proposed

network for Bukidnon State University is expected to yield similar improvements in user satisfaction, particularly through enhanced wireless connectivity and reduced downtimes.

Ease of Adoption: Feedback from IT staff and end-users at other institutions highlighted the importance of user-friendly network management interfaces and effective training sessions. Reports from researcher indicated that IT staff were able to manage new networks with 30% greater efficiency following comprehensive training on the network architecture.

8. Conclusion and Recommendations

8.1. Conclusion

In conclusion, the introduction of a Wide Local Area Network at the Bukidnon State University College of Technologies Annex B Campus is set to enhance network management and fortify the security of the computer network infrastructure. This endeavor is expected to establish a resilient and effective operational setting for the institution, representing a notable stride in technological progress and network dependability. The proposed network design for Bukidnon State University College of Technologies Hub offers several key findings. It is highly scalable and adaptable, ensuring future technological advancements and growing demands are met while supporting both academic and administrative functions. Enhanced security is a major focus, with layered protections such as firewalls, Intrusion Detection Systems (IDS), encryption, and secure VPNs significantly reducing vulnerabilities.

The design also improves performance and reliability through VLAN segmentation, dynamic routing, and redundant network paths, leading to faster data transmission and minimized congestion. Additionally, the network is expected to support academic innovation by integrating virtual learning platforms and research databases, fostering a more conducive environment for teaching and research. Future research can explore how emerging technologies like AI, IoT, and 5G could further enhance the network's capabilities. Longitudinal studies assessing the impact of the network on academic outcomes, such as student performance and faculty research output, would provide valuable insights. Additionally, advancements in AI-driven cybersecurity could be explored to stay ahead of emerging threats, while studies on optimizing energy efficiency and cost-effective scaling strategies would contribute to making the network more sustainable in the long term. By addressing these areas, future research can further strengthen the effectiveness, security, and adaptability of network infrastructures in academic institutions.

8.2. Recommendations

Based on the findings and objectives outlined in this study, several key recommendations can be proposed to enhance the network integration project at the Bukidnon State University College of Technologies Annex B Campus. Firstly, conducting regular assessments and audits is crucial to promptly identifying and addressing potential weaknesses in the network architecture. This proactive approach helps in maintaining network security and efficiency. Secondly, establishing a comprehensive training program is essential. This program should educate faculty, staff, and students on network security best practices, fostering a culture of responsibility and vigilance among all stakeholders. Well-informed users are crucial in mitigating security risks and ensuring smooth network operations. Additionally, collaboration with industry professionals and experts is vital. This collaboration helps us stay updated with the latest advancements in network architecture and security. It ensures the implementation of cutting-edge solutions that align with the institution's evolving needs and industry standards. By implementing these recommendations, the network integration project can be further enhanced, leading to a more secure, efficient, and future-ready network infrastructure at Bukidnon State University College of Technologies Annex B Campus. Prioritizing scalability and flexibility in the network design is crucial. It enables the seamless integration of emerging technologies and allows for future campus expansions without sacrificing network security and performance. Additionally, fostering a collaborative mindset among various departments and stakeholders is essential. This collaborative approach enhances communication and coordination, ensuring a smooth transition during the implementation phase. These recommendations collectively aim to enhance the effectiveness, resilience, and security of the network infrastructure. They also contribute to driving forward the university's technical advancement and upholding high academic standards at the Bukidnon State University College of Technologies Annex B Campus.

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