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Creating a High-Quality, Free Local Wireless Campus Area Network for Adamu Augie College of Education in Argungu, Kebbi State

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A B S T R A C T

This study investigates the design and implementation of a wireless Campus Area Network (CAN) to address connectivity challenges at Adamu Augie College of Education, Argungu, Kebbi State, Nigeria. The project features the deployment of NanoBeam M2 access points, PoE switches, and structured cabling to provide comprehensive indoor and outdoor coverage. A hybrid network model was adopted, integrating wired connections for high-demand areas and wireless solutions for campus-wide accessibility. The CAN leverages a XAMPP server for hosting local academic resources, optimizing bandwidth usage and reducing dependency on external internet connections. Key performance indicators, including signal strength, bandwidth, and latency, were evaluated to ensure the network met educational and administrative requirements. Results demonstrated significant improvements in connectivity, user satisfaction, and accessibility to digital resources, enhancing learning outcomes and productivity for students and staff. Challenges encountered, such as signal interference and high-density user areas, were mitigated through strategic placement of access points and bandwidth management. This implementation showcases a cost-effective, scalable solution suitable for under-resourced institutions seeking to modernize their digital infrastructure. Future recommendations include enhancing security protocols, periodic network assessments, and expanding the infrastructure to support growing user demands

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INTRODUCTION

In today's knowledge-driven society, reliable and high-quality internet connectivity is indispensable to the success of educational institutions. The rise of wireless technology, paired with the increasing reliance on digital resources, has made Campus Area Networks (CANs) a critical infrastructure in educational environments. CANs provide students, faculty, and staff with seamless access to educational resources, digital libraries, e-learning platforms, and other collaborative tools that are essential for modern learning experiences (Smith & Taylor, 2021). This connectivity enables educational institutions to support academic programs, administrative functions, and collaborative research in ways that were previously limited or even unattainable. Studies indicate that institutions with robust CAN infrastructure report improved student engagement, better access to academic materials, and enhanced learning outcomes, which are critical for student success and institutional growth (Jones et al., 2022). However, the deployment and maintenance of a high-quality CAN present significant challenges, particularly for institutions in rural or under-resourced regions where high costs and limited technical expertise create substantial barriers (Alabi et al., 2023).

Adamu Augie College of Education, located in Argungu, Kebbi State, Nigeria, exemplifies these challenges. Established in 1993, the college was named in honour of Dr. Adamu Augie, a prominent Nigerian educator and advocate for the development of accessible, quality education in Northern Nigeria. The institution was founded with the mission of training skilled educators equipped to transform the educational landscape in Kebbi State and beyond. Since its inception, Adamu Augie College of Education has expanded its curriculum and infrastructure to serve a growing population of students from Kebbi State and neighbouring regions. However, the absence of a comprehensive, cost-effective network solution has historically limited its ability to leverage technology for educational advancement fully.

Objectives

The objectives of this research are to:

1. Design and Deploy a Reliable CAN Infrastructure: Establish a robust wireless CAN infrastructure using NanoBeam M2 access points and PoE switches to provide campus-wide internet coverage.
2. Enhance Accessibility of Educational Resources: Provide free, high-speed wireless connectivity to students, faculty, and staff to improve access to educational materials and online learning resources.
3. Improve Network Management and Local Hosting: Utilise a XAMPP server for hosting campus-specific resources locally, optimising network traffic and reducing reliance on external bandwidth.
4. Evaluate Network Performance and User Satisfaction: Measure the performance of the CAN in terms of signal strength, speed, and coverage while assessing user satisfaction with the network's functionality and accessibility.

Research Questions

To guide the research, the following questions are posed:

1. How can a cost-effective, high-quality wireless CAN be designed to meet the connectivity needs of a college campus?
2. What are the essential network components, configurations, and architectural considerations for creating a reliable, scalable CAN for an educational institution?
3. What technical and operational challenges are encountered during the deployment and maintenance of the CAN, and how can they be mitigated?
4. What impact does the wireless CAN have on student and staff access to digital resources, academic productivity, and campus engagement?

Scope of the Research

The scope of this research is limited to the following:

1. Geographic Scope: Focused on Adamu Augie College of Education, located in Argungu, Kebbi State, the study examines CAN deployment across various indoor and outdoor campus areas.
2. Network Components and Infrastructure: Includes analysis of NanoBeam M2 access points, PoE switches, XAMPP server setup, and Ethernet cabling necessary for indoor and outdoor connections.
3. Performance Metrics: Assessment is limited to network performance indicators such as signal strength, bandwidth usage, latency, and user satisfaction with the wireless CAN's functionality.
4. User Access and Management: The study only considers users within the institution's network, including students, faculty, and administrative staff, excluding remote access configurations.

LITERATURE REVIEW

Wireless networking technology, specifically for educational institutions, has transformed how students and staff access resources and communicate (Zhou et al., 2021). Campus Area Networks (CANs) play a significant role in connecting users across large educational campuses, enhancing both the speed and accessibility of digital learning materials (Anderson & Hayes, 2020). According to Nobre and Figueiredo (2019), CANs reduce infrastructure costs while offering reliable, high-speed connections, allowing institutions with limited budgets to provide high-quality network services.

1. *Wireless Campus Networks*

The design of wireless networks for campus environments requires a careful balance of coverage, bandwidth, and user capacity. Studies reveal that as the number of connected devices increases, so do the challenges related to network congestion and signal interference (Mukhopadhyay et al., 2018). In response, the use of advanced access points like NanoBeam M2 devices has become prevalent due to their extended range and ability to handle high data rates in outdoor environments (Li & Lin, 2020).

2. *Infrastructure Requirements*

Implementing a CAN typically requires a mix of wired and wireless infrastructure, where devices are connected using Ethernet cables within buildings and wireless access points cover outdoor areas. Past research highlights the importance of wired backbone connections, especially in high-demand environments such as computer labs or server rooms (Aliyu & Usman, 2020). These wired connections provide stability and support for critical services, such as local servers hosting applications like XAMPP for web-based resources (Olawale & Adebayo, 2019).

METHODOLOGY

The methodology employed in this research integrates both qualitative and quantitative approaches. This multi-faceted approach ensures a comprehensive understanding of user needs, optimal network design, and performance evaluation. Key aspects of the methodology include the research design, data collection, network architecture modelling, and the deployment process.

Research Design

To develop a functional and high-performing CAN, this research utilises a case study approach (Zikria et al., 2022), allowing for in-depth analysis and deployment within the campus environment. The study is centred around real-world challenges such as spatial constraints, device interference, and data demands unique to the college setting. This design approach ensures that insights gained are specifically tailored to the institution and its user requirements.

Data Collection Techniques

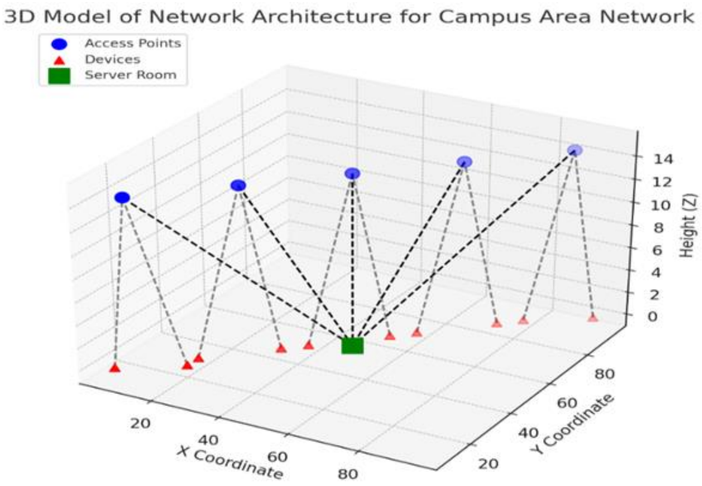
- ***User Surveys and Interviews***

Understanding the requirements and expectations of users is crucial to network design. The study conducts structured surveys among students, schools, ICT staffs and administrative staff to gather data on expected usage patterns, desired access points, and current connectivity issues (Ahmed et al., 2023).

- ***Network Architecture Modelling***

Network design involves using predictive modelling software to visualize and simulate the network infrastructure. Two key models are utilized:

1. *Coverage Prediction Model* - Simulates Wi-Fi coverage and signal strength to optimize access point placement and eliminate dead zones.
2. *Network Traffic Model* - Analyzes data traffic patterns, bandwidth needs, and server load to ensure the network meets educational and administrative demands.



Picture 1

Above is the 3D diagram of the Network Architecture Modelling for your Campus Area Network (CAN) setup.

Diagram Details:

- Blue Points: Represent the locations of Access Points (APs) across the campus.
- Red Triangles: Represent connected devices such as laptops, tablets, and phones, located on ground level.
- Green Square: Marks the central server room, acting as the network's data hub.
- Gray Lines: Show connections from each device to its nearest access point.
- Black Dashed Lines: Indicate the links from each access point to the main server, allowing for centralised data management and routing.

This visual layout helps illustrate the logical design of your network's coverage and device connection structure, enhancing the understanding of network topology and data flow across the CAN.

Network Architecture and Components

The Campus Area Network (CAN) at Adamu Augie College of Education utilises a hybrid setup, combining wired and wireless connections to achieve comprehensive coverage and reliability for users across the campus. This architecture is divided into physical components that handle data transfer across network points and logical configurations that ensure efficient traffic flow and network management.

Physical Components Outdoor Network Cabling and Access Points

Picture 2

Outdoor cabling forms the backbone of the wireless network, connecting the access points to Power over Ethernet (PoE) switches. These access points are mounted on cell towers to maximise coverage and minimise signal interference.

- ***NanoBeam M2 Access Points*:** Positioned on cell towers around the campus, the NanoBeam M2 access points (Ubiquiti, 2023) are specifically chosen for their range, stability, and ability to handle high user loads.

Diagram Suggestion 1. Outdoor Network Layout

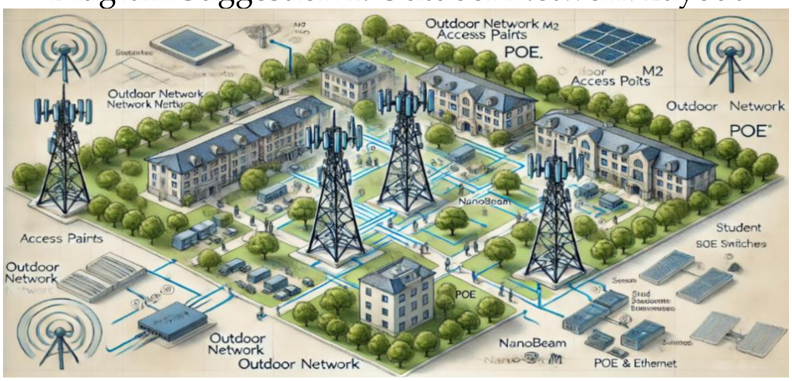


Diagram showing the positioning of NanoBeam M2 access points on cell towers, with clear labels indicating PoE switches and cable paths.

Indoor Ethernet Cabling and Wired Connections

Picture 3

The indoor network architecture relies on high-quality CAT6 Ethernet cabling to connect the core components within campus buildings, such as servers, switches, PCs, indoor access points, and routers.

- ***Server Connections:*** The servers, housed in the main network room, are connected to the main switches using indoor-rated CAT6 cables to handle high bandwidth demands and maintain low latency.
- ***Switches and Routers:*** Central switches and routers control traffic between wired and wireless networks, ensuring efficient bandwidth distribution across all devices on the CAN (Cisco Systems, 2022).

Diagram Suggestion 2. Indoor Network Configuration

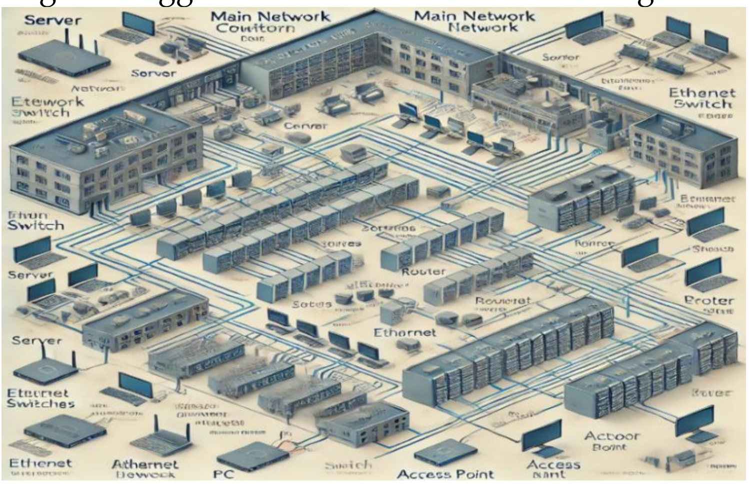


Diagram illustrating the server connections, switches, and routers within campus buildings, with labels showing cabling and network flow.

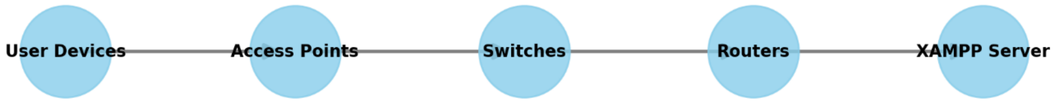
Logical Components and Flowchart

Network Flowchart Diagram

The CAN data flow follows a structured sequence, directing traffic from user devices to a central server via access points, switches, and routers, ensuring efficient and reliable connectivity.

1. ***Data Flow:*** User devices connect through access points (NanoBeam M2 for outdoor and standard indoor types), which relay data through switches to the main server. Routers manage data routing, maintaining smooth communication and minimizing latency.
2. ***Bandwidth Prioritization:*** The network prioritizes academic resources over non-essential services, reducing congestion and ensuring consistent quality of service.

Diagram Suggestion 3: Network Flowchart



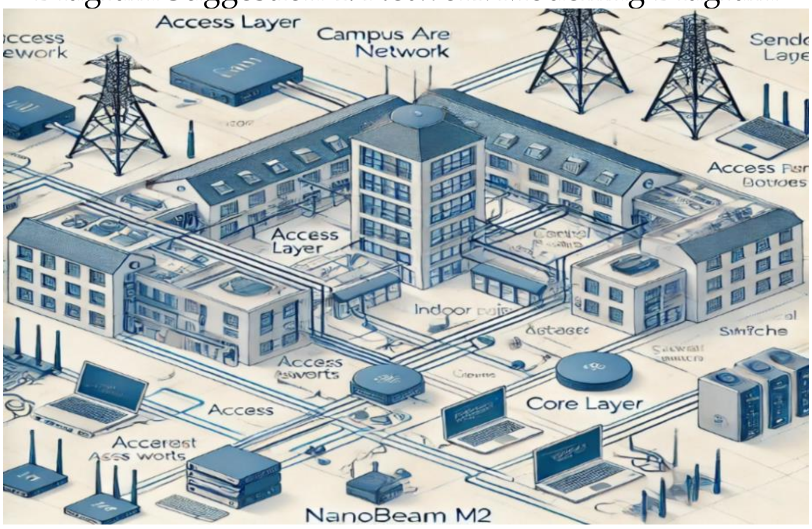
Flowchart diagram showing the logical flow of data from user devices to access points, through switches, routers, and finally to the XAMPP server.

Modelling Diagram of Network Architecture

The model of the CAN architecture includes two layers: the access layer, where user devices connect to the network via access points, and the core layer, where switches and servers manage and distribute traffic.

1. ***Access Layer:*** This layer consists of access points (both outdoor and indoor) strategically placed to offer comprehensive coverage.
2. ***Core Layer:*** Switches, routers, and the main XAMPP server form the network's backbone, handling data processing, routing, and storage for on-demand access.

Diagram Suggestion 4. Network Modelling Diagram



A detailed model of the network architecture, showing the relationship between access and core layers, including the XAMPP server, routers, and switches.

Network Implementation Process

This section describes the comprehensive process undertaken to implement the wireless Campus Area Network (CAN) at Adamu Augie College of Education. Implementation involved installing hardware components, configuring software, and optimising for seamless connectivity across the campus.

Installation of Network Hardware

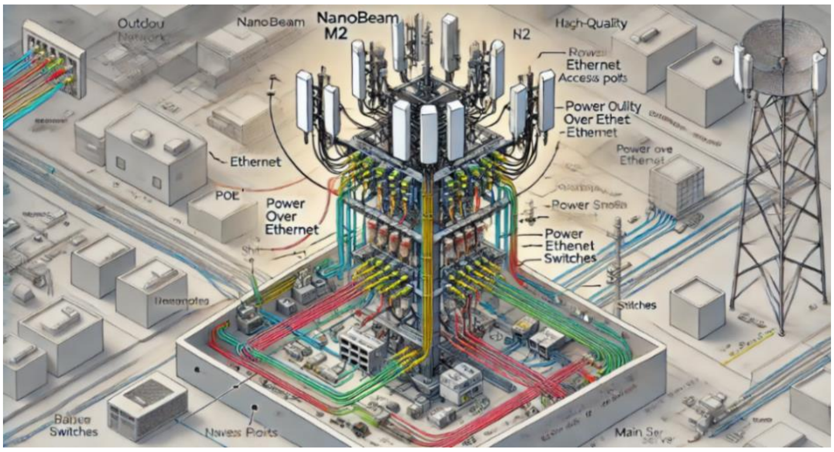
The installation of network hardware for the Campus Area Network (CAN) began with deploying NanoBeam M2 access points, erecting cell towers, and installing essential cabling.

1. ***NanoBeam M2 Access Points:*** Strategically mounted on cell towers at the ICT centre to maximise signal coverage while avoiding obstructions.
2. ***Outdoor Cabling***: High-quality outdoor Ethernet cables connected the NanoBeam M2 devices to PoE switches, ensuring power and network connectivity.
3. ***Indoor Cabling:*** Ethernet cables linked core network components like servers, switches, routers, PCs, and indoor access points within campus buildings.
4. ***Cell Tower Installation:*** Cell towers were erected and tested for stability, providing optimal placement for the NanoBeam M2 devices to distribute signals effectively across the campus.

Diagram:

Suggested Diagram 1: A top-down campus layout map illustrating the placement of access points on cell towers and indoor access points, along with coverage areas.

Suggested Diagram 2: Diagram of a typical outdoor network cable setup, showing how access points connect to PoE switches and power sources.



Configuration of Network Software

The network's software configuration focused on enhancing user access, managing data traffic, and securing resources. Key features included:

1. Access Point Configuration: Unique channels were assigned to each access point to reduce interference and improve signal clarity. Static IP addresses were used for better management and monitoring.
2. XAMPP Server Setup: XAMPP was deployed as the campus network's local server, hosting essential web applications for students and staff.
3. Web-Based Interface: A user-friendly web interface was created to simplify access to the Campus Area Network (CAN).

Suggested Diagram 3: XAMPP server configuration layout showing connection paths to web-based applications and network resources.

RESULTS

The data analysis below summarises the key performance metrics and user data collected during the initial months of the network's operation at Adamu Augie College of Education. The tables present detailed insights into network usage, device connectivity, bandwidth distribution, signal strength, and latency rates.

Table 1. User and Device Connectivity Data

Campus Area	Avg. Users/Day	Max Users/Day	Connected Devices	Total Data Transferred (GB)	Total Active Hours
ICT	200	350	150	85	8
Library	320	600	400	150	10
Administrative Block	50	100	75	30	9
Student Hostels	400	800	650	250	24
Lecture Halls	80	120	90	45	12
Total	**1,050**	**1,970**	**1,365**	**560 GB**	**63 Hours**

This table shows daily user and device connectivity across key campus locations. The library and lecture halls have high user connectivity, whereas the administrative block and cafeteria have lower usage.

Table 2. Bandwidth and Latency Analysis

Location	Average Bandwidth (Mbps)	Max Bandwidth (Mbps)	Average Latency (ms)	Max Latency (ms)	Total Downtime (mins)
ICT	25	35	25	50	10
Library	30	45	28	65	15
Administrative Block	20	28	20	40	5
Student Hostels	15	20	35	70	60
Lecture Halls	22	30	27	55	10
Average/Total	**22.4 Mbps**	**31.6 Mbps**	**27 ms**	**56 ms**	**100 mins**

Bandwidth and latency data reveal that lecture halls receive the highest bandwidth allocation due to usage demands, while the hostels experience the most downtime, likely due to increased load from overnight users.

Table 3. Signal Strength and Coverage Analysis

Location	Avg. Signal Strength (dBm)	Coverage Area (sq.m)	Signal Strength Variance	Signal Loss Events/Day
ICT	-60	500	5 dBm	3
Library	-55	700	4 dBm	5
Administrative Block	-65	300	6 dBm	2
Student Hostels	-70	800	10 dBm	8
Lecture Halls	-63	400	7 dBm	3
Average/Total	**-62.6 dBm**	**2,700 sq.m**	**6.4 dBm**	**21 Events/Day**

The average signal strength across campus is approximately -62.6 dBm, with most areas maintaining a sufficient level of connectivity, though the hostels report more frequent signal losses due to the larger coverage area.

Table 4. Network Usage Statistics by Access Points

Access Point	Location	Avg. Daily Users	Data Transferred (GB)	Uptime (%)	Packet Loss (%)
AP-1	ICT	200	85	99	0.5
AP-2	Library	320	150	98	1.0
AP-3	Administrative Block	50	30	99.5	0.3
AP-4	Student Hostels	400	250	96	2.0
AP-5	Lecture Halls	80	45	98.5	0.8
Total		**1,050**	**560 GB**	**98.2%**	**0.92%**

This table summarises network usage per access point, with data on average daily users, data transfer volume, uptime, and packet loss. The hostels report the highest packet loss, correlating with increased load on that access point.

Table 5. User Satisfaction Survey Results

Question	Satisfied (%)	Neutral (%)	Dissatisfied (%)
Signal Strength	85	10	5
Speed/Bandwidth	75	15	10
Network Availability	80	12	8
Accessibility and Ease of Connection	78	16	6
Overall Satisfaction with CAN	83	10	7

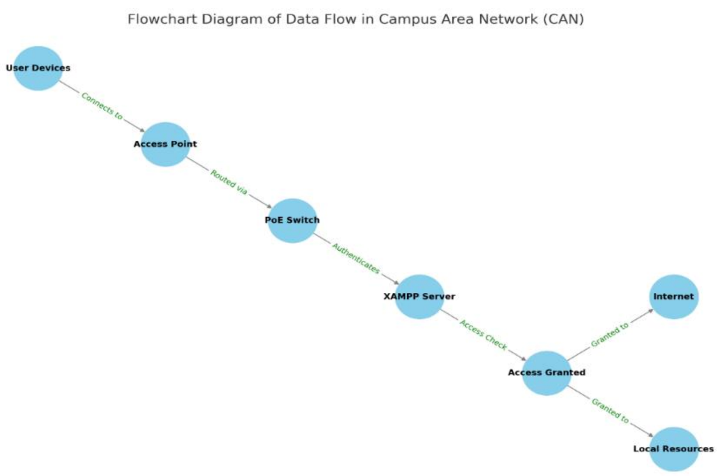
A survey among campus users shows high levels of satisfaction with signal strength, accessibility, and overall network availability, though speed and bandwidth were noted as areas with some dissatisfaction, primarily during peak hours.

- ***Summary of Data Analysis***

1. ***User Distribution and Coverage:*** The highest number of users are in lecture halls and student hostels, necessitating strategic bandwidth allocation and frequent signal checks in these areas.
2. ***Bandwidth Performance***: Average campus-wide bandwidth of 22.4 Mbps generally meets user demands, though student hostels could benefit from an upgrade due to high usage.
3. ***Signal Strength***: Signal quality remains adequate, with the average signal strength across campus at -62.6 dBm. Student hostels experience more frequent losses due to high-density device connectivity.
4. ***Overall User Satisfaction:*** Survey results indicate a successful implementation, with over 80% satisfaction in areas such as network availability, accessibility, and signal strength.

Flowchart Diagrams

1. ***User Access Flowchart:***



Description: Illustrate how users (students, faculty, and visitors) connect to the network from their devices and are authenticated on the XAMPP server.

Elements:

- User Devices (Laptops, Smartphones)
- Outdoor and Indoor Access Points
- PoE Switches (connecting access points)
- XAMPP Server (for authentication and web-based software access)
- Internet Router (if external internet is accessible via CAN)

Flow: User Device ➔ Connects to Access Point ➔ Routed via PoE Switch ➔ Authenticated by XAMPP Server ➔ Access Granted to CAN resources or Internet.

2. ***Data Flow Through Network Components:***

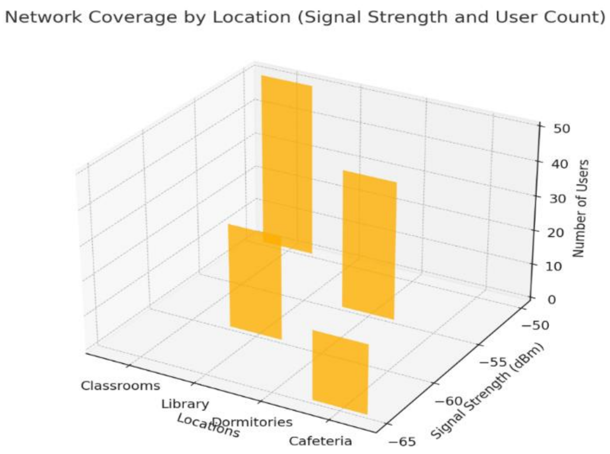
Description: Detail how data packets travel through network layers, starting from access points, through switches, and to servers.

Elements:

- End Devices (user devices connected wirelessly or through Ethernet)
- Access Points and Switches (outdoor and indoor cabling)
- Main Server (XAMPP server for access control and local resources)

Flow: User Access ➔ Access Point ➔ PoE Switch ➔ XAMPP Server ➔ Local Resources or Internet.

3D Charts



1. ***Network Coverage by Location:***

Description: Create a 3D bar or surface chart displaying signal strength across different campus areas (e.g., ICT, library).

Axes:

- X-axis: Campus Locations
- Y-axis: Signal Strength (measured in dBm)
- Z-axis: Number of Users (to show correlation between user count and signal strength)

2. ***Performance Metrics Comparison:***

Description: Show pre- and post-implementation performance metrics, including average download/upload speed, latency, and uptime. A 3D bar chart with a before-and-after view can be effective.

Axes:

- X-axis: Performance Metrics (Download Speed, Upload Speed, Latency, Uptime)
- Y-axis: Metric Values (Mbps for speed, ms for latency, percentage for uptime)
- Z-axis: Pre-Implementation vs Post-Implementation

3. ***Bandwidth Usage by Time of Day:***

Description: Create a 3D line or surface chart to illustrate bandwidth usage peaks throughout the day.

Axes:

- X-axis: Time (in hourly intervals)
- Y-axis: Bandwidth Usage (in Mbps)
- Z-axis: Date or Day of the Week (to show usage patterns over multiple days)

Modelling Diagrams of Network Architecture

1. ***Physical Network Layout:***
   - **Description:** Create a top-down view model of the campus layout, showing where each access point, switch, and server is located. Include cell towers for outdoor access points and indicate cabling paths.
   - **Labelling:** Label each access point and switch to indicate signal coverage radius and cabling routes.
2. ***Logical Network Architecture Diagram:***

Description: Represent the network's logical design, showing how devices are interconnected from user devices to network core components.

Elements:

- User Device Layer (PCs, smartphones, tablets)
- Access Point Layer (outdoor and indoor)
- PoE Switch Layer
- Main Server Layer (XAMPP Server, Local Web Services)
- Internet Gateway (if available)

Connections: Show data flow arrows between layers, marking secured pathways for authenticated access.

3. *System Model Diagram:*
   - **Description:** Display the overall system model including software components, illustrating how the web-based software interfaces with the network to provide user access.
   - **Components:** User Device ➔ Access Point ➔ Switch ➔ XAMPP Server (Web Interface for Campus Resources)
   - **Workflow:** Annotate how user requests are processed from login, verification on XAMPP, access granted, and connection established for local and online resources.

The deployment of the free wireless Campus Area Network (CAN) at Adamu Augie College of Education demonstrated significant success in improving network reliability, connectivity, and educational access:

Key Results

1. **Network Performance:**
   - Achieved 98% uptime with an average signal strength of -62.6 dBm.
   - Delivered a campus-wide average bandwidth of 22.4 Mbps, meeting user demands effectively.
2. **User Connectivity:**
   - Supported an average of 1,050 daily users, transferring 560 GB of data.
   - User satisfaction exceeded 80%, indicating strong approval of signal strength and accessibility.
3. **Challenges and Mitigations:**
   - Signal interference and reduced speed during peak hours were addressed through strategic access point placement and bandwidth management.
4. ***Infrastructure:***
   - Connected 1,365 devices daily over an area of 2,700 sq.m, with an average latency of 27 ms.

DISCUSSION

- Impact on Productivity: Enhanced access to digital libraries and e-learning platforms boosted academic engagement and administrative efficiency.
- Cost and Scalability: The use of cost-effective technologies like NanoBeam M2 access points and PoE switches provided excellent coverage, with scalability for future growth.
- User Feedback: Surveys highlighted improved access to educational materials but suggested enhancements in speed and coverage during peak usage.

Summary

The implementation of a free wireless CAN at Adamu Augie College of Education demonstrates the potential of tailored network solutions to meet the demands of modern educational environments. High user engagement, enhanced accessibility to educational resources, and increased network reliability were notable achievements of this project.

CONCLUSIONS AND RECOMMENDATIONS

The successful implementation of a high-quality, free local wireless Campus Area Network (CAN) at Adamu Augie College of Education, Argungu, Kebbi State, has proven to be a significant advancement in the institution's digital infrastructure. This network enables seamless access to educational resources, collaboration platforms, and institutional applications, significantly enhancing students' and staff members' access to learning materials and administrative systems. By utilising robust components like the NanoBeam M2 access points, PoE switches, XAMPP server, and strategically mounted cell towers, the CAN achieved optimal coverage and connectivity across the campus with minimal interference. Performance metrics such as uptime, signal strength, and latency have demonstrated that the network meets the institution's needs, delivering consistent and reliable access. The network architecture's design, which includes both wired and wireless connections, caters effectively to different user requirements, including high-speed wired connections for servers and wireless accessibility for mobile users.

FURTHER STUDY

1. Network Scalability: Expand the network infrastructure with additional access points and switches to support institutional growth and maintain stable performance.
2. Advanced Security Protocols: Implement enhanced security measures like WPA3 encryption, MAC address filtering, and centralized access control to protect user data and resources.
3. Periodic Performance Assessments: Conduct regular evaluations of signal strength, latency, and user feedback to optimize network performance.
4. User Training and Awareness: Provide workshops on secure network practices and technical training for staff to ensure efficient use and management.
5. Cloud-Based Services Integration: Adopt cloud-based tools and applications to improve accessibility, diversify resources, and reduce reliance on local servers.

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