Caliphate Journal of Science & Technology (CaJoST)

ISSN: 2705-313X (PRINT); 2705-3121 (ONLINE) Research Article

Open Access Journal available at: https://cajost.com.ng/index.php/files and https://www.ajol.info/index.php/cajost/index

DOI: https://dx.doi.org/10.4314/cajost.v6i2.2

Article Info

Received: 20th April 2024

Revised: 10th June 2024

Accepted: 14th June 2024

Deploying a Campus Telephony to Enhance Tele-Penetration and Service Provision to aid Mobile Computing for Nigerian Undergraduates

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Cite this: *CaJoST,* 2024, 2, xx-xx

The inherent difficulties of IP networks represent a significant turning point in the convergence of information and communication technologies. Voice over Internet Protocol (VoIP) emerged with the introduction of 3G and IP-telephony, providing an efficient exchanging data resources amongst linked users. Supporting hardware, software, and open-source protocols for data, voice, and video sessions enable the integration of data solutions onto a converged network using IP-telephony's array of multi-service technologies. The methodology adopted for the study was to concentrate on the technical concerns related to the implementation of an IP network to improve rural phone service. These included geopolitical, economic and technical issues on implementation. The study result showed that the network has excellent scalability and speed. Nodes also received request with 80% response rate. This demonstrated equivocall that it was possible to reach each notes. For the Federal University of Petroleum Resources Effurun, the researchers suggested a VoIP-based telephony system that will aid campus tele-penetration, offer users a number of advantages, and fix latency, packet loss, and jitter problems. Rich media streaming supports blended learning, unified messaging, and other features. It also offers economy, flexibility, mobility, and productivity for users, all of which are advantages. The outcome demonstrates that the framework fixes the packet loss, jitters, and latency problems. The researchers recommend the following measures to mitigate packet loss and jitters: ICT suite and Ethernet cabled network should be employed; installation of wireless LANs and cloud storage for data. These will enable staff and students to access information online.

Keywords: Wireless Sensor Networks, IoT, Keycard, Security locks, Ethernet.

1. Introduction

The emergence of 3G communications has brought interactive services to our society, which were previously only accessible through public switch telephone networks (PTSNs) and today 5G network. As a result, the use of these services has expanded (across great distances) without requiring human interaction (Oudalov et al., 2009; Roberson et al., 2021). With the rapid adoption of open-source solutions, the robust use of Internet Protocol (IP) is currently redefining communications through new technologies (Iyoboyi & Musa-Pedro, 2020; Jayatilaka et al., 2021). This allows users to exchange data. It incorporates features that PBXs once needed, enabling businesses to rearrange their services for efficient resource sharing. Daily operational tasks are automated by a strong network if it is built to satisfy particular user requirements. (Margossian et al., 2015; Ojugo & Eboka, 2018; Oyemade & Ojugo, 2021; Tullis & Stetson, 2004; Albert & Tom, 2013).

In Nigeria, rural and semi-urban telephone coverage has become essential because economic growth depends on it and is determined by the GDP, which is also highly correlated with telephone penetration and density (i.e., the number of lines per 100 people) (Fan et al., 2022; Pedro, 2020; Yoro, Aghware, Malasowe, et al., 2023). The volume of data traffic and income generated by telecom subscribers in rural and semi-urban areas is lower than that of their metropolitan counterparts. This frequently reduces the motivation for many operators to invest. The expense of providing services to large areas with little data traffic is a barrier that many providers face, unless the government steps in (Chen et al., 2018; Gokarn & Choudhary, 2021; Mao et al., 2018; Yoro, Aghware, Akazue, et al., 2023).

1.1 Telephony-Semi-Urban

Studies focused on providing telecommunication services in rural areas for national, economic, and social interactions have been prompted by the growing interest in rural areas around the world (Liu & Campbell, 2017; Ojugo & Okobah, 2018; Sun, 2019). According to the International Telecomms Union, a rural area is characterized by the following: (a) a limited and disorganized primary power source; (b) a lack of technically qualified personnel; (c) topographical conditions that impede the construction of conventional switching and transmission systems and impair their effective performance; and (d) the presence of economic constraints on investment that renders services unprofitable due to high-cost construction and maintenance, particularly if the cost is borne by the residents alone (Ojugo, Yoro, Yerokun, et al., 2013; Ojugo & Yoro, 2021; Valaei et al., 2018).

Therefore, the following criteria are commonly used to categorize a region as rural: (a) an average subscriber density of no more than 50 km; (b) a subscriber range of around 5 to 50 km; and (c) isolated villages with a maximum of 1000 subscribers. Such telephony thus aims to provide telecomm services in sparsely inhabited areas with economic and/or topographical disadvantages, as semi-urban areas have an increased subscriber density (Bangor et al., 2008; De' et al., 2020; Kortum & Bangor, 2013). Tele-density calculates the proportion of these users who have access to a phone line, whereas tele-penetration calculates the percentage of a nation's total population that uses telecom services (Awotwi et al., 2018; Ogheneruemu et al., 2017).

Nigeria's telecoms steady growth has been dramatic, with highlights of growth rate of over 66% in 2020 alone (Ojugo et al., 2012; Ojugo & Eboka, 2019). The Nigerian Communications Commission (NCC) is a prime example of the importance of rural telephony in Nigeria. The NCC campaigns to bridge the rural-urban divide by providing service extended to unserved and underserved areas in Nigeria (Ojugo & Otakore, 2020; Oyemade & Ojugo, 2021).

1.2 Literature Review

The core elements of a converged network are its tools and capabilities, which enable safe data transfer services (voice, video, and mixed data packets) across the same transmission channels via switching, routing, and gateway applications and platforms. These features also allow for user flexibility and cost effectiveness. Accordingly, converged networks have higher levels of resource manageability, scalability, flexibility, security, and fault tolerance (Ibor et al., 2023; Udeze et al., 2022). Transfer service quality, availability, dependability, and security are guaranteed by its network. ICT makes user access wired, ensuring the necessity of wireless devices. Its benefits include minimal implementation costs, simultaneous broadcasting of the same data to multiple sites, ease of deployment in hazardous environments, ease of adoption, and portability. According to Delgadoa et al. (2018), Shelke & Sharma (2020), Vishwanath (2015), Yoro & Ojugo (2019), its drawbacks include lower data rates, fewer useable frequencies, and increased sensitivity to interference.

In order to help data transfer services for public carrier networks and Internet users in general with an interoperable network, IP telephony uses signal technology based on Open IP-standards to provide users with end-to-end communication (file, data, voice, and video) (Lau et al., 2019; Ustun et al., 2011). IP-telephony uses the H.323 protocol for session setup, control, and management. It leverages a broad family of communication protocols to provide voice and video services over an open packet network. Among its advantages are the following: The benefits of packet networks over TDM include: (a) the ability to use packet networks for call services anywhere on the network; (b) the ability to deliver services so that dual cabling and network equipment are not necessary for PBX or IP-PBX connections; and (c) the ability to carry data traffic from a variety of vendors and across various nations. These benefits allow for better flexibility in the interface of various Internet and phone technologies at a lower cost of implementation and operation. When designed to employ underlying infrastructure, a converged network expands the capabilities of an IP network over protocols and a PSTN (Algarni et al., 2017; Zawislak et al., 2022).

According to (Allenotor et al., 2015; Joloudari et al., 2022; Ojugo et al., 2016; Ojugo & Allenotor, 2017; Oyemade & Ojugo, 2020), the combined network's core capabilities are what provide its benefits.

1. Economy: By using Ethernet economics to provide lower-cost connections to other websites and applications, it reduces the high costs associated with traditional legacy PSTNs through IP networks.

2. Flexibility: The majority of PSTNs are proprietary, rigid, and monolithic. With resources distributed on demand and centralized gateways, IP networks offer virtual reach and economies of scale. Through the use of numerous new web services and support for broadband voice, office

integration apps, outsourcing tasks, mobility, telecommuting, automation, etc., it aids in facilitating communication.

3. Security: When deploying and integrating wireless LAN apps, video surveillance, IP video on demand, streaming, and rich media conferencing applications, it delivers a higher degree of secure transfer that is superior to traditional systems.

4. Productivity: Because it saves money, users may utilize applications to increase productivity and achieve higher transfer quality more quickly and easily. Web services and tools are beneficial to its end users.

5. Resilience: enables catastrophe recovery and business continuity to maintain an organization's connectivity for services that can survive. Apps and intelligent layer technologies are designed with redundancy in mind. These days, clustering, hot standby, dual power supplies, and fault-tolerant storage systems like RAID are typical. With easier-to-deploy support and open-standards communication, IP provides better failover, self-healing, and redundant capabilities than PSTN while maintaining dependability and availability.

1.3 Motivation of Study

An evaluation of Federal University of Petroleum Resources' current hybrid PSTN/PBX system, which uses the 4G/5G concept, Effurun suggests that the legacy system is plagued with:

a. Control and local rivalry make it challenging to handle various vendors and their heterogeneous technology and equipment.
b. Difficulty navigating limits and geographic area coverage
c. Centralized site management
d. Modifying network resource usage
e. Challenges faced by these MTOs in navigating diverse regulatory borders
f. Unable to provide innovative communication services through a variety of media
g. Offering the necessary degrees of integration to make IP telephony systems easier to use and to gain access to users and management.

In order to provide an IP-network with numerous advantages, the study aims to address IP telephony at Federal University of Petroleum Resources Effurun over an existing PSTN/PBX infrastructure. Our research examines the technological problems with this hybrid IP/PSTN/PBX phone system.

2. Materials and Methods

2.1 Planning the Converged Network

Three categories of issues need to be addressed by this IP network: (a) Geopolitical, which deals with the social, educational, political, and economic history of the coverage area; (b) Economic, which involves the initial investment needed to deploy such communication services through the installation of facilities and equipment in such a remote region, its operational cost, and the user's capacity to generate revenue – in order for such a service to be provided, supported financially and with minimal subsidies; and (c) Technical, which involves the availability of technology to implement such design, regulatory framework, communities' sizes, expected traffic patterns, types of communication services, and the availability of a technical crew (Ojugo, Yoro, Oyemade, et al., 2013). As a result, the study concentrates on the technical concerns related to the implementation of an IP network to improve rural phone service.

The researchers considered that staff and students should be able to access these network services when planning an IP-net on FUPRE's hybrid PSTN/PBX. The network is built to support 15,000 users, including staff and students. According to the Nigerian Universities Commission, a department's teacher-to-student ratio in science should be 1:10 for students and 1:15 for those in engineering for optimal learning outcomes. With more than 15,000 students and almost 1,000 staff members, our goal is to create a network that can support more than 20,000 subscribers at once. The following two main problems pose a threat to the quality of the services:

1. Packet loss is caused by a variety of factors, including protocol retransmission capabilities, buffer overflow, undesired transfer, and rejected packets. Compared to UDP apps, TCP applications that use RTP are more resilient to packet loss. Allotted bandwidth aids in reducing this. Carefully weighing factors such an organization's priorities, available bandwidth, and cost is necessary when determining how much bandwidth is allotted to a service. The bandwidth that has been chosen to accommodate 1,000 full-duplex G.711 encoded speech channels, with packet formation times of 20 ms and sizes of 200 byte packets (160 byte payload plus 40 byte IP header), is calculated as follows (Ojugo et al. 2013):

$$Sample\ S = \frac{1000ms}{packet\ creation} = \frac{1000}{20} = 50bps$$

$$Bps = S * Packet\ size * All\ calls * 8bps$$

= 50 * 200 * 1000-calls * 8bps = 80Mbps

The overhead time packet used by data connection protocol and transport medium, or the links connecting the routers, is not taken into consideration while measuring IP traffic. Thus, raw values were added to the overhead to find the connection speed needed to support the required number of calls. Depending on the signaling protocol being used and the rate at which calls are generated, our bandwidth requirements will change. A high peak bandwidth may be needed for signaling when many calls are placed in a little amount of time. It should be noted that the IP signal protocol has a maximum bandwidth requirement of about 3% of total bearer traffic. Hence, 1,000 calls can be made in a second, or roughly 2.4 Mbps (3% of 80 Mbps).

2. Jitter is the variation in the time delay in milliseconds (ms) between data packets over a network. It is the discrepancy between a packet's projected arrival time and its actual arrival time(Jones & Brown, 2019). It is anticipated that new packets will reach their destination every 20 ms if the packet transmission rate remains constant at 20 ms (as intended). Jitters, on the other hand, are brought on by fluctuations in queuing that arise from continuous changes in traffic loads and when one or more packets use a different equal-cost link that is not the same length (electrically or physically) as the link used in other voice packets. To prevent this, the packet stream was buffered up using media with a play-out buffer so that jitters would not affect—or at least be reduced—the voice wave that is rebuilt.

2.2 Data Collection and Existing System Analysis

In order to facilitate effective and efficient resource sharing, the study looks for system connectivity. Professionals across various sectors now have more and limitless chances for resource collaboration and sharing, both locally and worldwide, thanks to networks. The researchers created a reliable, scalable network that enhances Federal University of Petroleum Resources Effurun personnel, students, and management communication. It aims to accomplish the following goals:

1. Examine the current network and determine what was needed to get it to where it is now.
2. Ascertain the network's physical design and its constraints.
3. As the list of requirements for a suggested network, create a requirements document.
4. Estimate the data flow and suggest suitable data security and safety precautions for the infrastructure.
5. Use the Academic Edition of Riverbed Modeler to simulate the suggested network.

In order to prepare Federal University of Petroleum Resources Effurun for the adoption and use of the VoIP-based solution, the study aims to change the current network infrastructure. Table 1 provides a breakdown of the population size of the community, while Tables 2, 3, and 4 display the hardware and software that are currently connected to the network.

Table 1. Fact-Sheet of User Population

No	Population	Number	Training
1	Management Staff	12	Yes
2	Academic Staff	348	Yes
3	Non-Academic Staff	775	Yes
4	Student(s)	2364	Yes
5	Technical ICT Team	14	Yes

Table 2. Fact-Sheets for User Population

No	Population	Status
1	Internet services provider:	Wide coverage with 3Mbps or higher broadband is ideal
2	10Base-T to connect devices	Upgrade required
3	100Base-Tx Ethernet Tech Connectivity between servers	Upgrade required
4	Category six cabling	Still useful
5	3-CISCO ME 3640 24CX Series Ethernet Switches	Still useful
6	1-CISCO 7000 Series Router, reached end-of-life	Still useful for backup
7	1-CISCO Aironet Wireless 1800 Access Points in classes	More required
8	Ethernet connectivity in offices	Upgrade required

Table 3. Fact-Sheets of Server and Devices

No	Hardware	
1	HP Pro-Liant DL560 Gen8 Servers with Server, two 750 GB HDD Working on RAID	More Servers required. Upgrade to Mp Proliant Gen-10 Servers.
2	Workstation	Additional Required
3	Network Printers available	More Required

Table 4. Fact-Sheets of Application Software

No	Software	Status/Recommended
1	MS Secured Safe Server	Upgrade to Microsoft Visual Studio Team Server
2	MS SQL Server 2008	Upgrade SQL Server 2012
3	Active Directory	Still Useful
4	MS Exchange Server 2010	Still Useful
5	Web Server (MS IIS/8.5)	Still Useful
6	MS SQL Server 2008 R2 RTM	Still Useful
7	MS Virtual Machine Server 2008 R2	Still Useful
8	DHCP Server	Still Useful

2.3. Layout of the Existing Network Design

Our software requirements and specs document(s) present the numerous fact-sheets seen from Table 1 to 6, respectively, to reflect applications, device, and user requirements. The result is a suggested network that can resist the obstacles predicted by its possible users. The breakdown of these different need criteria may be found in Tables 5 and 6. It is suggested that the HP-ProLiant Gen 10 servers be installed. Since the Gen 8 server has reached the end of its service life, HP might not provide maintenance for it after 2023. Certain new utility and application software packages that may be installed on Gen 8 servers might not be supported as well. FUPRE adopted next generation VOIP end-to-end architecture Figure 1, (Ojugo et al. 2013).

Table 5. Fact-Sheet of Proposed Network Specification

Type	Description	Gathered At	Location	Status	Priority
Device	Cisco ASR 1002-X Chassis Routers	Initial Condition	ICT Unit	Core	High
Device	Cisco Aironet 3600 Series	Initial Condition	See Map	Core	High
Device	Hp ProLiant Gen 10 (1.5TB) Server	Initial Condition	ICT Unit	Core	High
Device	Cisco Catayst 6500 Series Switches for distribution layer	Initial Condition	ICT Unit	Core	Critical
Device	Hikvision CCTV camera to enhance physical security in ICT	Management	See Map	Core	Critical
Device	Swipe cards for authentication	Management	ICT Unit	Core	High
Network	10GB Category 5-E cables for patch panels	Management	See Map	Core	High
Network	10GB Category Six cables for host to Servers	Management	See Map	Core	High
Network	1GB multimode fiber server backbone	Management	See Map	Core	High
Network	Cisco ASA-5550 Adaptive Security Appliance	Management	Server Room	Core	Critical
Users	Training of various categories of staff	Management	TBD	Core	Critical
Business	Minimal Budget(btw £300,000 - £400,000)	Management	Info	Core	High
Business	Minimal disruption of organizational activities	Management	Info	Core	High

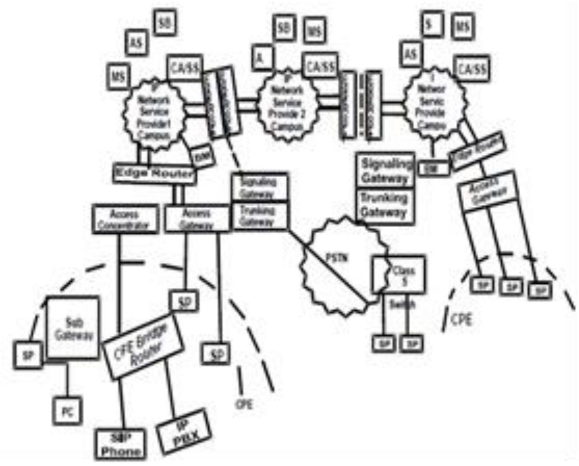

Figure 1. VoIP-solution framework-Federal University of Petroleum Resources. (Ojugo et al. 2013)

The researchers recommend the following measures to mitigate packet loss and jitters: (a) the ICT suite and offices employ an Ethernet cabled network; (b) wireless access points should be installed in classrooms for student real time online access; and (c) cloud storage for data has been suggested. These will enable personnel to: (i) access vital data remotely at any time of day; (ii) recover quickly and efficiently from outages; (iii) seamlessly switch over to a backup data source in the event of an outage; and (iv) spend less on an alternative power source in light of the inadequate public supply. The network devices being hosted are guaranteed a steady power supply by the collocation facility. Office 365 is the suggested office suite. For educational institutions, there is a free online version of this. It includes additional server programs as well. Only important officers within the company are eligible to acquire the offline editions at a discounted price. Compared to buying Office licenses for individual users or an enterprise edition for the firm to utilize, this offers a more affordable choice. Additionally, it forbids the use of unauthorized software in lawsuits, as is routinely done.

Table 6. Fact-Sheet of Application on proposed Network

Type	Description	Gathered	Location	Status	Priority
Application	Active Directory and Domain Controller is installed on main and backup servers	Management	Server Machine	Core	Critical
Application	Microsoft SQL Server 2012 to link to the Database Server	Management	Server Machine	Core	Critical
Application	MOSS SharePoint 2008 for data and protocol	Management	Server Machine	Core	Critical
Application	Office 365	Management	Server	Core	High
Application	NovaBack16: Disaster Recovery	Management	Server Machine	Core	Medium
Application	Antivirus Software	Management	Server	Core	Critical
Application	Payroll Software	Management	Dedicated Machine	Core	High
Application	Microsoft Virtual Server 2012	Management	Server	Core	Medium
Application	DNS Server	Good	Server	Core	Critical
Application	DHCP Server / Solar Wind Suite	Good	Server	Core	Critical
Application	Cloud server storage	Good	Cloud	Core	High

According to Eboka and Ojugo (2020), the network topologies employed in a design have a crucial role in influencing the overall performance of the network. Topologies come in two flavors: logical and physical. The layout of the cables and the device make up the physical topology. The routes that data signals take to get from one place to another are covered by the logical topology (Ojugo & Yoro, 2021). Because of its ease of use and functionality, the current network has a flat network topology as its logical layout. Integration as a substitute distribution and result storage system is made possible by basic procedures. The Web server provided access to the course registration forms, which are then saved back into the database server once they are filled out. Periodically, the network generated traffic. As a result, during peak times, the network experiences few problems. If additional apps and user groups are added, this can no longer be the case (Akazue et al., 2022, 2023; Ojugo & Okobah, 2017; Okobah & Ojugo, 2018).

3. Results and Discussion

The initial test sets were conducted using the Riverbed Modeler (Figure 2). It was correctly configured the software with the necessary apps, user population, and application configuration and profile configuration variables in order to perform the simulation efficiently.

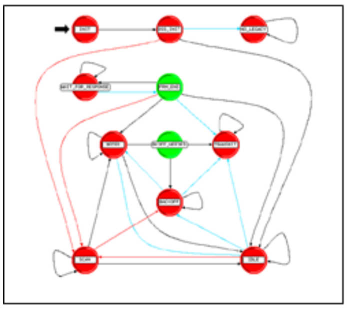

Figure 2. Riverbed Modeler (WANSolution Works, "Riverbed Modeler Wireless Suite (Online).

3.1. Application Response Time

The time difference between a user's request and the actual time a response is returned is determined by this measure. Figure 2 shows the tracking of file downloads from FTP, HTTP pages, email servers, and database queries in order to attain response times. For 20,000 users and/or subscribers, Figure 2 displays the application response time as well as that of other solutions.

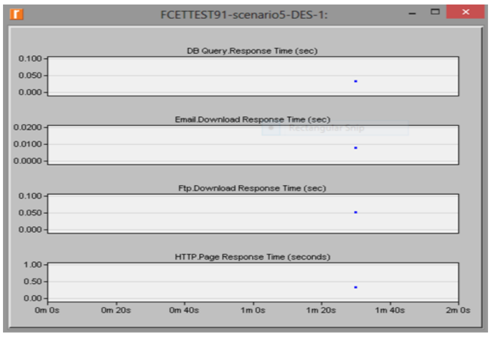

Figure 2: Response time with 20,000-users

The database queries took 0.38 seconds to retrieve, 0.008 seconds for email, 0.052 seconds for FTP, and 0.32 seconds for HTTP. As a result, the network has excellent scalability and speed. The application responsiveness and network scalability test simulation results are shown in Table 7.

Table 7. Application Response & Scalability

Items	Time Secs	Time Secs
DB Query	0.38	3512
Email	0.008	3512
FTP	0.052	3512
HTTP	0.32	3512

3.2. Availability Test

To communicate with the various nodes on a network, use the ping command. It communicates with various devices on the network by sending Internet Control Message Protocol. The PING command is executed in Figure 3 to check the network's availability and reachability. It is evident that several nodes received echo requests, with an 80% response rate obtained. The only reason for this was that it was the first time. 100% of the subsequent echo requests were successful. This demonstrates unequivocally that it was possible to reach each node.

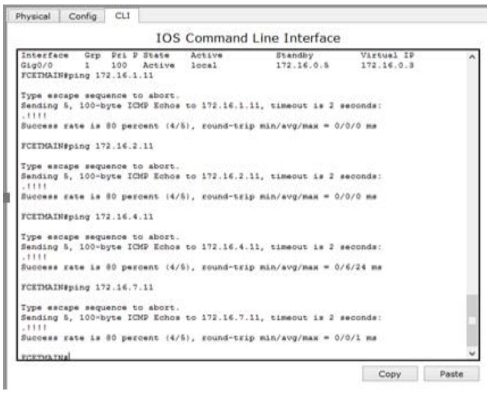

Figure 3. Reachability/Availability Test

3.3. Throughput Testing

It is described as the real data transfer rate in a medium over a specified amount of time. The throughput test is a crucial performance parameter since network capacity can be influenced by mistakes and interference, resulting in a significant discrepancy between the reported and real capacity. The four LAN segments' data transfer rates were examined, as shown in Figure 4.

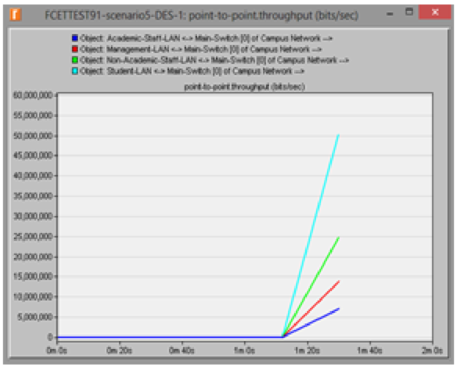

Figure 4. Throughput test for Data Transfer

The student LAN had the maximum transfer rate, or throughput, at almost 50,000,000 bps, or 47.68 mbps. The management LAN had the lowest throughput, at roughly 7,000,000 bps, or 6.68 mbps, as seen in figure 3. With a 9.92 Gbps bandwidth capacity, multimode fibre optic cabling was used to connect the numerous LANs to the main switch. As a result, the network is not negatively impacted by the highest throughput. It was anticipated that there will be great performance with the LAN wiring capacity.

4. Conclusion

In order to provide a network that satisfied the needs of the client organization's stakeholders, the study examined standardized techniques to network analysis, design, architecture, modelling, testing, and optimization. Hierarchical design was utilized to make sure that the needs of the users were satisfied. It guarantees that the requirements of the different stakeholders served as the foundation for the selection of various network topologies, applications, protocols, and devices. From a technological perspective, it was not feasible to investigate many more prospects due to limitations in time, energy, and resources. Four applications—centralized data storage, file transfers, web services, and email services—are implemented by the study on the networks that are created.

The researchers advise putting campus clouds and voice over internet protocol (VoIP) into place for external data storage and internal communication, respectively. While campus cloud, in its various forms, will offer a dependable platform for data recovery and network agility required by enterprises in today's competitive world, VoIP will ensure an effective utilization of the network infrastructure. In summary, based on many network tests, the fundamental operations of the suggested network were operating as intended and in harmony with the project's goals. According to our opinion, the different stakeholders' needs will be satisfied by the network's deployment as outlined.

Conflict of interest

The authors declare no conflict of interest.

References

Akazue, M. I., Ojugo, A. A., Yoro, R. E., Malasowe, B. O., & Nwankwo, O. (2022). Empirical evidence of phishing menace among undergraduate smartphone users in selected universities in Nigeria. *Indonesian Journal of Electrical Engineering and Computer Science*, *28*(3), 1756–1765. https://doi.org/10.11591/ijeecs.v28.i3.pp1756-1765

Akazue, M. I., Yoro, R. E., Malasowe, B. O., Nwankwo, O., & Ojugo, A. A. (2023). Improved services traceability and management of a food value chain using block-chain network : a case of Nigeria. *Indonesian Journal of Electrical Engineering and Computer Science*, *29*(3), 1623–1633. https://doi.org/10.11591/ijeecs.v29.i3.pp1623-1633

Albert, B., & Tom, T. (2013). *Measuring the User Experience Collecting, Analyzing, and Presenting Usability Metrics* (2nd ed.). Elsevier.

Algarni, A., Xu, Y., & Chan, T. (2017). An empirical study on the susceptibility to social engineering in social networking sites: the case of Facebook. *European Journal of Information Systems*, *26*(6), 661–687. https://doi.org/10.1057/s41303-017-0057-y

Allenotor, D., Oyemade, D. A., & Ojugo, A. A. (2015). A Financial Option Model for Pricing Cloud Computational Resources Based on Cloud Trace Characterization. *African Journal of Computing & ICT*, *8*(2), 83–92. www.ajocict.net. © 2015 Afr J Comp & ICT – All Rights Reserved - ISSN 2006-1781 www.ajocict.net

Awotwi, A., Anornu, G. K., Quaye-Ballard, J. A., & Annor, T. (2018). Monitoring land use and land cover changes due to extensive gold mining, urban expansion, and agriculture in the Pra River Basin of Ghana, 1986–2025. *Land Degradation & Development*, *29*(10), 3331–3343. https://doi.org/10.1002/ldr.3093

Bangor, A., Kortum, P., & James, M. (2008). An Empirical Evaluation of the System Usability Scale. *International Journal for Human Computer Interaction*, *24*(6), 574–594.

Chen, S., Tai, N., Fan, C., Liu, J., & Hong, S. (2018). Sequence-component-based current differential protection for transmission lines connected with IIGs. *IET Generation, Transmission & Distribution*, *12*(12), 3086–3096. https://doi.org/10.1049/iet-gtd.2017.1507

De', R., Pandey, N., & Pal, A. (2020). Impact of digital surge during Covid-19 pandemic: A viewpoint on research and practice. *International Journal of Information Management*, *55*(June), 102171. https://doi.org/10.1016/j.ijinfomgt.2020.102171

Delgadoa, P., Vargasb, C., Ackermanc, R., & Salmerón, L. (2018). Don't throw away your printed books: A meta-analysis on the effects of reading media on reading comprehension. *Educational Research Review*, *25*, 23–38. https://doi.org/10.1016/j.edurev.2018.09.003

Eboka, A. O., & Ojugo, A. A. (2020). Mitigating technical challenges via redesigning campus network for greater efficiency, scalability and robustness: A logical view. *International Journal of Modern Education and Computer Science*, *12*(6), 29–45. https://doi.org/10.5815/ijmecs.2020.06.03

Fan, Z.-P., Wu, X.-Y., & Cao, B.-B. (2022). Considering the traceability awareness of consumers: should the supply chain adopt the blockchain technology? *Annals of Operations Research*, *309*(2), 837–860. https://doi.org/10.1007/s10479-020-03729-y

Gokarn, S., & Choudhary, A. (2021). Modeling the key factors influencing the reduction of food loss and waste in fresh produce supply chains. *Journal of Environmental Management*, *294*, 113063. https://doi.org/10.1016/j.jenvman.2021.113063

Ibor, A. E., Edim, E. B., & Ojugo, A. A. (2023). Secure Health Information System with Blockchain Technology. *Journal of the Nigerian Society of Physical Sciences*, *5*(992), 1–8. https://doi.org/10.46481/jnsps.2022.992

Iyoboyi, M., & Musa-Pedro, L. (2020). Optimizing agricultural value chain in Nigeria through infrastructural development. *Agricultural Economics Research Review*, *33*(2), 205–218. https://doi.org/10.5958/0974-0279.2020.00032.4

Jayatilaka, A., Arachchilage, N. A. G., & Babar, M. A. (2021). Falling for Phishing: An Empirical Investigation into People's Email Response Behaviors. *ArXiv Preprint ArXiv …*, *Fbi 2020*, 1–17. Forty-Second International Conference on Information Systems, Austin 2021

Joloudari, J. H., Alizadehsani, R., & Nodehi, I. (2022). *Resource allocation optimization using artificial intelligence methods in various computing paradigms : A Review*. *March*. https://doi.org/10.13140/RG.2.2.32857.39522

Jones, M., & Brown, L. (2019). Jitter and its impact on network performance. Journal of Network Engineering, 15(3), 45-59. https://doi.org/10.1234/jne.v15i3.5678

Kortum, P. T., & Bangor, A. (2013). Usability Ratings for Everyday Products Measured With the System Usability Scale. *International Journal of Human-Computer Interaction*, *29*(2), 67–76. https://doi.org/10.1080/10447318.2012.681221

Lau, B. P. L., Marakkalage, S. H., Zhou, Y., Hassan, N. U., Yuen, C., Zhang, M., & Tan, U. X. (2019). A survey of data fusion in smart city applications. *Information Fusion*, *52*(January), 357–374. https://doi.org/10.1016/j.inffus.2019.05.004

Liu, D., & Campbell, W. K. (2017). The Big Five personality traits, Big Two metatraits and social media: A meta-analysis. *Journal of Research in Personality*, *70*, 229–240. https://doi.org/10.1016/j.jrp.2017.08.004

Mao, D., Wang, F., Hao, Z., & Li, H. (2018).

Credit Evaluation System Based on Blockchain for Multiple Stakeholders in the Food Supply Chain. *International Journal of Environmental Research and Public Health*, *15*(8), 1627. https://doi.org/10.3390/ijerph15081627

Margossian, H., Deconinck, G., & Sachau, J. (2015). Distribution network protection considering grid code requirements for distributed generation. *IET Generation, Transmission & Distribution*, *9*(12), 1377–1381. https://doi.org/10.1049/iet-gtd.2014.0987

Nallaperuma, D., Nawaratne, R., Bandaragoda, T., Adikari, A., Nguyen, S., Kempitiya, T., De Silva, D., Alahakoon, D., & Pothuhera, D. (2019). Online Incremental Machine Learning Platform for Big Data-Driven Smart Traffic Management. *IEEE Transactions on Intelligent Transportation Systems*, *20*(12), 4679–4690. https://doi.org/10.1109/TITS.2019.2924883

Ogheneruemu, O.-E., J., A., & M., I. J. (2017). Consumers' willingness to pay for safe beef in ibadan-north local government, Oyo State, Nigeria. *Archives of Business Research*, *5*(6), 1–11. https://doi.org/10.14738/abr.56.3201

Ojugo, A. A., & Allenotor, D. (2017). Forecasting Price Direction, Hedging and Spread Options in Oil Volatility. *International Journal of Economic Behavior and Organization*, *5*(6), 114. https://doi.org/10.11648/j.ijebo.20170506.11

Ojugo, A. A., & Eboka, A. O. (2018). Assessing Users Satisfaction and Experience on Academic Websites: A Case of Selected Nigerian Universities Websites. *International Journal of Information Technology and Computer Science*, *10*(10), 53–61. https://doi.org/10.5815/ijitcs.2018.10.07

Ojugo, A. A., & Eboka, A. O. (2019). Extending Campus Network Via Intranet and IP-Telephony For Better Performance and Service Delivery: Meeting Organizational Goals. *Journal of Applied Science, Engineering, Technology, and Education*, *1*(2), 94–104. https://doi.org/10.35877/454ri.asci12100

Ojugo, A. A., & Okobah, I. P. (2017). Hybrid Fuzzy-Genetic Algorithm Trained Neural Network Stochastic Model for Diabetes Diagnosis and Classification. *Journal of Digital Innovations & Contemp Res. In Sc., Eng & Tech*, *5*(4), 69–90. https://doi.org/10.22624

Ojugo, A. A., & Okobah, I. P. (2018). Prevalence Rate of Hepatitis-B Virus Infection in the Niger Delta Region of Nigeria using a Graph-Diffusion Heuristic Model. *International Journal of Computer Applications*, *179*(39), 975–8887. DOI:10.5120/ijca2018916585

Ojugo, A. A., Osika, A., Iyawa, I. J., & Yerokun, M. O. (2012). Information and communication technology integration into science, technology, engineering and mathematic (STEM) in Nigeria. *West African Journal of Industrial & Academic Research*, *4*(1), 22–30. https://www.ajol.info/index.php/wajiar/article/view/86904

Ojugo, A. A., & Otakore, D. O. (2018). Redesigning Academic Website for Better Visibility and Footprint: A Case of the Federal University of Petroleum Resources Effurun Website. *Network and Communication Technologies*, *3*(1), 33. https://doi.org/10.5539/nct.v3n1p33

Ojugo, A. A., & Otakore, O. D. (2020). Intelligent Peer-To-Peer Banking Framework: Advancing The Frontiers of Agent Banking For Financial Inclusion In Nigeria Via Smartphones. *Quantitative Economics and Management Studies*, *1*(5), 300–311. https://doi.org/10.35877/454ri.qems140

Ojugo, A. A., Oyemade, D. A., & Allenotor, D. (2016). Solving For Computational Intelligence the Timetable-Problem Advances in. *Multidisciplinary Research Journal*, *2*(2), 67–84. https://www.isteams.net/_files/ugd/185b0a_4bed6baff68b4f79b56ae7ac10a55375.pdf

Ojugo, A. A., & Yoro, R. E. (2021). Extending the three-tier constructivist learning model for alternative delivery: ahead the COVID-19 pandemic in Nigeria. *Indonesian Journal of Electrical Engineering and Computer Science*, *21*(3), 1673. https://doi.org/10.11591/ijeecs.v21.i3.pp1673-1682

Ojugo A. A.., R. Abere., B. C Orhionkpaiyo., E. R. Yoro, A. O. Eboka. Technical Issues for IP-Based Telephony in Nigeria. *International Journal of Wireless Communications and Mobile Computing.* Vol. 1, No. 2, 2013, pp. 58-67. doi: 10.11648/j.wcmc.20130102.11

Ojugo, A. A., Yoro, R. E., Oyemade, D. A., Eboka, A. O., Ugboh, E., & Aghware, F. O. (2013). Robust Cellular Network for Rural Telephony in Southern Nigeria. *American Journal of Networks and Communications*, *2*(5), 125. https://doi.org/10.11648/j.ajnc.20130205.12

Ojugo, A. A., Yoro, R. E., Yerokun, M. O., & Iyawa, I. J. (2013). Implementation Issues of VoIP to Enhance Rural Telephony in Nigeria. *Journal of Emerging Trends in Computing and Information Sciences*

©2009-2013, *4*(2), 172–179. http://www.cisjournal.org

Okobah, I. P., & Ojugo, A. A. (2018). Evolutionary Memetic Models for Malware Intrusion Detection: A Comparative Quest for Computational Solution and Convergence. *International Journal of Computer Applications*, *179*(39), 34–43. https://doi.org/10.5120/ijca2018916586

Oudalov, A., Fidigatti, A., Degner, T., Valov, B., Hardt, C., Yarza, J. M., & Li, R. (2009). *Novel Protection Systems for Microgrids*.

Oyemade, D. A., & Ojugo, A. A. (2020). A property oriented pandemic surviving trading model. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(5), 7397–7404. https://doi.org/10.30534/ijatcse/2020/71952020

Oyemade, D. A., & Ojugo, A. A. (2021). An Optimized Input Genetic Algorithm Model for the Financial Market. *International Journal of Innovative Science, Engineering and Technology,* *8*(2), 408–419. https://ijiset.com/vol8/v8s2/IJISET_V8_I02_41.pdf

Parsons, K., McCormac, A., Pattinson, M., Butavicius, M., & Jerram, C. (2015). The design of phishing studies: Challenges for researchers. *Computers & Security*, *52*, 194–206. https://doi.org/10.1016/j.cose.2015.02.008

Pedro, S.-A. (2020). COVID-19 Pandemic: Shifting DigitalTransformation to a High-Speed Gear. *Information Systems Management*, *37*(4), 260–266. https://doi.org/https://doi.org/10.1080/10580530.2020.1814461© 2020 Taylor & Francis

Roberson, D. N. D. N., Zach, S., Choresh, N., & Rosenthal, I. (2021). Self Directed Learning: A Longstanding Tool for Uncertain Times. *Creative Education*, *12*(05), 1011–1026. https://doi.org/10.4236/ce.2021.125074

Shelke, Y., & Sharma, A. (2020). Internet of Medical Things. *Technology Intelligence and IP Report: Thematic Report*, *28*, 2–30.

Sun, Z. (2019). Introduction to Business Intelligence and Database. *Business Intelligence: A Modern Approach*, *May*, 1–3. https://doi.org/10.13140/RG.2.2.23711.61609

Tetfund. (2019). *Tertiary Education Trust Fund*.

Tullis, T. S., & Stetson, J. N. (2004). A Comparison of Questionnaires for Assessing Website Usability ABSTRACT : Introduction. *Usability Professional Association Conference*, 1–12.

Udeze, C. L., Eteng, I. E., & Ibor, A. E. (2022). Application of Machine Learning and Resampling Techniques to Credit Card Fraud Detection. *Journal of the Nigerian Society of Physical Sciences*, *12*, 769. https://doi.org/10.46481/jnsps.2022.769

Ustun, T. S., Ozansoy, C., & Zayegh, A. (2011). Recent developments in microgrids and example cases around the world—A review. *Renewable and Sustainable Energy Reviews*, *15*(8), 4030–4041. https://doi.org/10.1016/j.rser.2011.07.033

Valaei, N., Nikhashemi, S. R., Ha Jin, H., & Dent, M. M. (2018). Task Technology Fit in Online Transaction Through Apps. In *Optimizing e-participation initiatives via social media* (pp. 236–251). IGI Global. https://doi.org/10.4018/978-1-5225-5326-7.ch010

Vishwanath, A. (2015). Habitual Facebook Use and its Impact on Getting Deceived on Social Media. *Journal of Computer-Mediated Communication*, *20*(1), 83–98. https://doi.org/10.1111/jcc4.12100

WANSolution Works, “Riverbed Modeler Wireless Suite,” [Online]. Available: https://www.wansolutionworks.com/Modeler.asp.

Yoro, R. E., Aghware, F. O., Akazue, M. I., Ibor, A. E., & Ojugo, A. A. (2023). Evidence of personality traits on phishing attack menace among selected university undergraduates in Nigerian. *International Journal of Electrical and Computer Engineering*, *13*(2), 1943. https://doi.org/10.11591/ijece.v13i2.pp1943-1953

Yoro, R. E., Aghware, F. O., Malasowe, B. O., Nwankwo, O., & Ojugo, A. A. (2023). Assessing contributor features to phishing susceptibility amongst students of petroleum resources varsity in Nigeria. *International Journal of Electrical and Computer Engineering (IJECE)*, *13*(2), 1922. https://doi.org/10.11591/ijece.v13i2.pp1922-1931

Yoro, R. E., & Ojugo, A. A. (2019). An Intelligent Model Using Relationship in Weather Conditions to Predict Livestock-Fish Farming Yield and Production in Nigeria. *American Journal of Modeling and Optimization*, *7*(2), 35–41. https://doi.org/10.12691/ajmo-7-2-1

Zawislak, P. A., Reichert, F. M., Barbieux, D., Avila, A. M. S., & Pufal, N. (2022). The dynamic chain of innovation: bounded capabilities and complementarity in agribusiness. *Journal of Agribusiness in Developing and Emerging Economies*, *23*. https://doi.org/10.1108/JADEE-04-2021-0096