

Exploring the Status and Challenges of ICT Network Services and Broadband Utilization in Revolutionizing Nigerian Universities



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ABSTRACT: The development of university education through ICT resources is highly essential while the issues of accessibility and challenges to network services remain some of the serious concerns facing Higher Education Institutions (HEIs) in Nigeria. This study carried out from January 15 – April 21, 2023 investigated the status of ICT infrastructure for 25 HEIs across the six geopolitical zones in Nigeria in terms of bandwidth, hosting of network resources, and power solutions. This study adopts a descriptive observational design, with purposive sampling using online questionnaires with open ended and close ended questions. The research data were analysed leveraging descriptive, comparative, Analysis of Variance and the coefficient of determination. These metrics help assess the statistical significance and goodness-of-fit of the models, exploring the relationship between bandwidth and institutional characteristics. The average bandwidth available per student was 0.038 Mbps, less than the international benchmark; 35% of the institutions depended on expensive generators for power backup. Institutions with lower student populations have bandwidth constraints, compounded by the limitation of technical expertise and reliance on third-party ICT managers. Recommendations include increasing bandwidth, using renewable energy, and enhancing internal ICT skills through training. Addressing these issues will help Nigerian universities close the digital divide and improve global competitiveness. The study has shown the critical need for coordinated policies and sustainable investments in creating a transformative educational environment.

KEYWORDS: Bandwidth Subscription, Broadband penetration, Broadband utilization, ICT, Network Services, Higher Education Institutions, ICT in education

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I. INTRODUCTION

The incorporation of Information and Communication Technology (ICT) in higher education has become a key factor in enhancing global competitiveness and fostering innovation within the knowledge economy. Institutions of higher learning around the globe are progressively utilising ICT to revolutionize their teaching, learning, and research methodologies (Egoeze, Misra, & Colomo-Palacios, 2014). Nigeria, like many developing countries, faces several challenges with regards to network services accessibility in its educational institutions. The growth of ICT within the Higher Educational Institutions (HEIs) in Nigeria faces obstacles due to systemic issues such as insufficient broadband capacity, inconsistent power supply, and a lack of internal technical skills (Akomolafe, 2008; Ogunode, Babayo, Jegede, & Musa, 2021). The rapid advancement of technology has led to an increase in the demand for reliable and efficient network services (Philip Achimugu, 2010), which is crucial for effective and efficient operation of educational institutions. Previous researches focused on internet connectivity in both public and private institutions in Nigeria affirms germane issues premised on inadequate funding due to high

connectivity cost (Akinlolu A.O., 2018; Datukun Kalamba Aristarkus, 2018), inefficient high-speed internet broadband access and inadequate bandwidth (Aderemi A. Atayero, 2019), poor internet service delivery and infrastructure (Osuwagwu O.E., 2013), inadequate technical expertise, and poor policies.

For Nigerian universities, the challenges surrounding ICT and broadband utilization are not only technological but also rooted in socioeconomic and policy-based factors. Reliable broadband access is essential for online learning, digital research tools, and virtual collaboration platforms that support modern education. Despite the efforts made by the government and private organizations to improve network infrastructure and services, with the recent intervention of the Nigeria Communication Commission (NCC) at upgrading broadband penetration in selected Higher Education Institutions (HEIs), accessibility to network services in Nigerian institutions remains a significant challenge. Hence, many institutions still face issues like inadequate infrastructure, limited financial resources, and disparities in access to technology among students and staff (Adewale, 2022), (Ajayi, 2020). Many HEIs still lack basic internet connectivity, and even where internet access is available, the quality of service is often poor, inadequate and subscription model is very low as compared to the Staff and Student population. These challenges slow down

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the progress of educational transformation through ICT. This lack of access to reliable network services has implications for the quality of education in Nigerian institutions leveraging on advancement in technology for teaching, learning and research. It affects the ability of students and lecturers to access educational resources, collaborate with peers and colleagues, and stay up-to-date with the latest information in their fields.

This research became expedient considering the ongoing discussions about the impact of Information and Communication Technology (ICT) in reshaping educational settings. While previous studies have documented the presence of these infrastructural issues (Akomolafe, 2008) and underscored their detrimental effects on education (Egoeze *et al.*, 2014), there still exists a significant gap in comprehending how these infrastructural shortcomings relate to different institutional characteristics. For example, a comprehensive analysis of bandwidth distribution with the size of the student body is necessary to offer a more nuanced insight into the issue. Hence, this paper investigates the status and challenges Nigerian universities encounter regarding ICT network services, including hosting of resources, broadband availability, adequacy of power backup and institutional ICT staff capacity building with a particular emphasis on how these issues impact the overarching goal of transforming higher education. It offers insights into how the challenges identified can be addressed to foster a more inclusive and technologically advanced education system.

This research thoroughly assesses the current state of ICT network services and broadband usage in universities across Nigeria, aiming to generate an evaluation that will guide both institutional strategies and national policy. The study specifically utilizes a descriptive observational design, alongside comparative analyses, ANOVA, and the coefficient of determination (R^2), to investigate the correlation between bandwidth allocation and the characteristics of institutions. This methodology is expected to provide practical insights for enhancing ICT infrastructure, improving internal technical skills through focused training initiatives, and encouraging sustainable investments in renewable energy solutions.

A. GLOBAL PERSPECTIVE ON ICT AND BROADBAND IN HEIs.

Recent research highlights the importance of ICT infrastructure and high-speed broadband access for achieving high standards in teaching, research, and administration in higher education institutions globally. Researchers worldwide contend that the COVID-19 pandemic hastened the digital transformation in higher education, making strong broadband connectivity essential for the implementation of online and blended learning (Al-Omouh, Tarhini, & Qudah, 2021). In developed countries, significant investments in ICT have resulted in network systems that facilitate massive open online courses (MOOCs), virtual labs, and smart campuses. For example, studies conducted in Europe and North America indicates that, integrating ICT systems, featuring gigabit-level broadband and cloud computing, have greatly improved educational delivery and institutional competitiveness (Popenici & Kerr, 2020). Although there have been

advancements, difficulties persist even in developed environments, especially in guaranteeing fair access and promoting digital literacy among faculty and students. Research has indicated that while investing in infrastructure is crucial, additional initiatives such as ongoing professional training and user assistance are vital to fully leverage the advantages of broadband connectivity in higher education institutions (Agarwal, Gautham, & Singh, 2020).

B. SUB-SAHARAN AFRICA: BROADBAND AND ICT IN HIGHER EDUCATION

In the past few years, the ICT landscape in higher education across Sub-Saharan Africa has significantly changed; however, the region still encounters considerable difficulties. A study conducted by Maseko and Mlambo in 2021 emphasizes that numerous African higher education institutions (HEIs) still face challenges related to insufficient broadband connectivity, which is worsened by inconsistent power supply and limited funding (Maseko & Mlambo, 2021). Even though various national and regional programs have been launched to address the digital divide like the African Union's Agenda 2063, the actual implementation at the institutional level remains inconsistent. Recent findings suggest that while some prominent institutions in nations such as South Africa and Kenya have succeeded in enhancing their ICT infrastructure, most institutions in the region continue to deal with slow internet speeds and expensive connectivity (Chigona & Chigona, 2020). These infrastructural challenges are further intensified by a lack of digital literacy and a deficit of skilled ICT personnel, which together impede the comprehensive integration of digital technologies in teaching and learning activities.

II. CONCEPTUAL FRAMEWORK

The provision of network services in Nigerian institutions has been a topic of interest due to its impact on education and the economy. Research have been focused on internet usage through a case study model of a questionnaire for students (undergraduate and postgraduate) and lecturers, in order to access the level of adoption and utilization (Jagboro, 2003) (Anyira, 2011), and faculty members' utilization (Aduwa-Ogiegbaen S. E., 2005). Without de-emphasising the prominence of social media and the online activities of students with internet access (Awolaye, 2008), the focus is recommended on the quality of the internet access provided in terms of the level of penetration, the challenge of erratic power supply and the capacity of the infrastructure. According to (Agboje O., 2017), infrastructure deficit and inadequate funding is a major bottleneck to broadband penetration, a prominent precursor to quality internet service required in Nigerian Universities for teaching, learning and research. Expanded research on three (3) Nigerian Universities by (Ani, 2010), further affirms the prominence of internet access and its use for learning and research.

Hence, the framework for this research serves to guide the visual and theoretical understanding of the key constructs and their relationships within the context of universities in

Nigeria. It synthesizes the elements of ICT infrastructure, digital divide, and technology acceptance models in an attempt to explain aspects that may influence ICT utilization and, subsequently, educational transformation.

A. ICT INFRASTRUCTURE AND NETWORK SERVICES

The availability and quality of infrastructure, such as electricity, fibre optic cables, and network equipment, affect the accessibility of network services in Nigerian institutions (Akinlolu A.O., 2018). The inability of the services to be complemented with adequate infrastructure is one of the major problems identified relating to the use of ICT network services in Nigerian universities. Indeed, most institutions are poorly connected to the internet due to low bandwidth, and have inadequate hardware and software resources. Such infrastructural deficiencies restrict the manner in which students and faculty use online resources for research and e-learning. Unless and until the institutions are equipped with adequate ICT infrastructure, it would not be possible to maintain and sustain the utility of the digital tools and services toward which higher education is gradually shifting. Adewale, Sanni, and Salami 2022 expressed that this acts as one of the main barriers in Nigerian universities, where most of them depend on obsolete equipment and unstable networks.

B. DIGITAL DIVIDE, COST OF ACCESS AND BROADBAND UTILIZATION

The term digital divide refers to the inequality in accessing ICT tools and services on the part of students, staff, and institutions. The factors being identified with solemnity that create digital divide encompass the socio-economic background, geographical location, and institutional budget allocations. The level of funding allocated to network services in Nigerian institutions can limit the availability and quality of network services. Lack of funding can result in outdated equipment, limited bandwidth, and inadequate maintenance (Osugwu O.E., 2013).

The disparity in funding model for HEIs is a prominent challenge. This potentially reduces the chances of students from poor backgrounds and institutions in rural areas exposing themselves to digital tools in education, and it widens existing gaps in education. According to Olumide & Yusuf, 2023, this enhances inequity in education. Furthermore, there is a continuation of digital divide issues in Nigerian universities, since students in urban regions or those from well-enacted families can have easy access to computers while students from rural areas cannot.

Meanwhile, it is the extent to which access to and quality of broadband for Internet services are available at universities that impacts its utilization. Sufficient bandwidth, along with uninterrupted connections, is necessary for web-based learning, research, and collaboration. In many instances, students and institutions strive hard to afford an adequate broadband service; hence, for this economic reason, access to valuable educational resources is restricted. This is compounded by the very low percentage allocation to education in the Nigerian budget, which has actually limited

the potential of institutions to invest in a solid solution for ICT. Excellent broadband practice is essential in enabling Staff, students and researchers to take advantage of full educational resources, engage in virtual learning, and conduct various research activities. According to Olumide and Yusuf (2023), inadequate broadband diffusion and unreliable access to the Internet hinder universities from fully implementing an e-learning system and collaboration tools digitally.

C. POLICY AND INSTITUTIONAL SUPPORT

All these deployment and utilization factors are shaped by policies put in place by both the government and individual institutions. Such policies include ICT policies, broadband expansion strategies, and institutional investments in technologies. Government policies and regulations can affect the accessibility and quality of network services. Policies that promote competition and investment in network infrastructure can result in improved services, while restrictive policies can limit the availability of services. Robust policy frameworks are consequently quite essential in building robust infrastructures for ICT and ensuring sustainable access to broadband services (Oke, 2021).

D. TECHNICAL EXPERTISE, TECHNOLOGY ACCEPTANCE, SECURITY OF INFRASTRUCTURE AND CAPACITY BUILDING

The availability of technical expertise to install, maintain, and troubleshoot network services affects the quality and accessibility of the services. A lack of technical expertise can result in delays in resolving issues and inadequate support for users. The importance of this construct lies in the willingness of university staff and students to adopt new technologies. It involves digital literacy of the population, perceived usefulness of the technology, and available training programs for the same. However, even with excellent infrastructures and broadband access, it is the digital literacy and resistance to change that makes the faculty and students avoid the use of ICT. Agbolade and Omisore (2021) argue that, in most of Nigeria's universities, the reluctance on the part of staff and students to fully embrace ICT is entrenched in the lack of adequate technical skills, lack of training, and concerns about the reliability of such systems. The security of network services is critical to the accessibility, confidence reposed, and utilization of the services. A lack of security measures can result in unauthorized access, data breaches, and other security threats that can compromise the availability and integrity of the services.

III. RESEARCH METHODOLOGY

The study employed a descriptive research design for the purposes of data collection from the HEIs in Nigeria through quantitative methods of online questionnaire administered through institutional Google form, from January – April, 2023. This design, therefore, represent a snapshot regarding the state of ICT infrastructure and broadband access and challenges

thereof of HEIs in Nigeria as captured from Directors of ICTs (DICTs). The present study targets the findings at the higher education institutional level in different geopolitical zones of Nigeria

A. SAMPLING STRATEGY

The study adopted a stratified sampling technique that will make its sample representative of a good number of HEIs in Nigeria's six geopolitical zones. The link to questionnaires were posted on the virtual platform, Google form for DICT of HEIs in Nigeria, to ensure response by target institutions, direct communication and follow up was done with the DICT. A total of 25 representative institutions responded which represent various classes of government-owned institutions. The sample size used reflects about 27th percentile of all government-owned HEIs in the country and thus provides insight into both well-established and smaller institutions. This stratified approach ensures that the findings represent comprehensive insight into regional variations, as well as into institutional diversity in relation to their student population, infrastructure, and ICT services.

B. INSTRUMENTS OF DATA COLLECTION

The primary data collection instrument is an online questionnaire addressed to institutional ICT directors. The questionnaire was divided into sections, which capture data such as:

Demographics: Institutional size comprised of number of students and staff.

Internet Infrastructure: Subscription type and size of internet bandwidth, data centres, network operating centre, cloud hosting versus institutional websites hosted locally.

ICT Capabilities: The functionality of institutional portals, Learning Management Systems, server availability.

Power Infrastructure: Sources of electricity supply, including solar, inverter, generator; reliability of power backup systems and implications thereof for ICT operations.

ICT Personnel: Internal ICT staff and third-party ICT organizations involvement in network infrastructure, website, and LMS management.

C. QUESTIONNAIRE DEVELOPMENT

The questionnaire design was a critical methodological component aimed at developing both qualitative and quantitative data for the evaluation of the institutional ICT infrastructure. The instrument was structured into two main segments of close-ended questions for standardised data collection and open-ended questions to elicit further conversations targeted at qualitative insights. The closed-ended questions which include:

- ❖ Bandwidth size (Mbps or Gbps) for the scale of internet provision and an assessment of the institutional digital readiness.

- ❖ Number of enrolled students in order to provide context the demands for institutional ICT coverage and scalability.
- ❖ Hosting of services either offsite or onsite.

A couple of open-ended questions to complement the quantitative data were included to capture challenges and qualitative responses to ICT management practices. The research was implemented through institutional email platform through Google form. The digital deployment was selected for its scalability, ease of use, cost efficiency and automatic digital aggregation features. A sample of the online questionnaire deployed is attached- Appendix 1

D. DATA COLLECTION PROCEDURE

Data collection was done within 3 months (15th January – 21st April, 2023) through the online questionnaire instrument. A pre-survey email was addressed to the ICT managers of the various institutions, explaining the purpose of the study, the measures taken concerning the confidentiality of the provided information, and the link to the questionnaire. The institutions were allowed four weeks to fill in the questionnaires, thereafter reminders were sent to the non-respondents. Institutional data anonymity and confidentiality were guaranteed, hence, data were analysed and reported only in aggregate form.

E. VALIDITY AND RELIABILITY

The questionnaire was screened by ICT experts at higher education institutions to assist in providing adequate comprehensiveness regarding questions on the scope of ICT challenges and infrastructure. Two ICT managers from different departments within the same institution will be asked to fill out a questionnaire if appropriate. Addressing non-response bias, measures were taken to minimise the threat of not obtaining responses, particularly from some of the HEIs, considered as a very real risk.

The bias of not desirous of revealing the state of the ICT infrastructure for research was imminent. To minimize this, some follow-up reminders were sent; nevertheless, the research is conscious to note that some institutions may not be well represented as not all challenges are encapsulated in the phenomenon under study for incomplete data submission. The data inaccuracies may occur in that it is self-reporting. Efforts were made to cross-check key points of data (e.g., bandwidth size, LMS functionality) with publicly available institutional information.

F. DATA ANALYSIS

Data was analysed using descriptive statistics and inferential statistics

Descriptive Analysis: Frequency distribution, means, and percentages were employed in describing internet bandwidth

availability, involvement of ICT staff, student population, and backup power systems.

Comparative Analysis: Comparison of bandwidth availability was done across institutions, based on sizes, that is, population of students to establish the comparison of bandwidth availability. Differences in institutions with lower student populations below 20,000 were pointed out against institutions with higher student populations. From the data, an inferential analysis was made using Anova regression analysis to determine whether the relationship existed between the size of the institution (by population) and bandwidth per student.

Power Supply and Sufficiency of ICT: This study investigates the relationship between the reliability of power supply and the level of sufficiency of ICT resources to establish if institutions with better power infrastructures indeed face less challenge in the delivery of services.

The matrix of HEIs that responded was spread across the six geopolitical zones of Nigeria. This is aimed at ensuring accurate data is supplied from first-hand managers of the IT infrastructures of HEIs in Nigeria. This would make the inferences made from the data to be likely valid as the situation in other institutions across the country. Key challenges identified through the analysis of data collected relate to bandwidth, which is less than adequate; power supply problems; and the capacity of the human resources is still very limited. It provides recommendations based on identified gaps for increasing broadband internet penetration, optimizing the use of current power solutions, and creating an enabling environment for effective management of the ICT infrastructure within HEIs.

G. REGRESSION ANALYSIS

We implemented an ANOVA (Analysis of Variance) and computed the coefficient of determination (R^2). These metrics help assess the statistical significance and goodness-of-fit of the models. The calculation of the P-value, F-value, and R-squared value for the regression models is presented. A simple linear regression model (via ordinary least squares), was implemented using Equation (1):

$$Y = \beta_0 + \beta_1 X + \varepsilon \quad (1)$$

The equation 1 specifies the linear relationship between the independent variable X, internet bandwidth and the dependent variable Y. β_0 represents the intercept, β_1 the slope, and ε the error. In order to test the linearity of the relationship between X and Y, null hypothesis $H_0 : \beta_1 = 0$ was introduced. Rejecting H_0 indicates that X significantly contributes to the prediction of Y.

Test Statistic (t-value) in Equation (2) measures the standard errors when the estimated slope is away from zero. A higher

absolute t-value suggests that the slope is significantly different from zero

$$t = \frac{\hat{\beta}_1}{SE(\hat{\beta}_1)} \quad (2)$$

$\hat{\beta}_1$ is the estimated slope
 $SE(\hat{\beta}_1)$ is the standard error of $\hat{\beta}_1$.

The P-value is used to determine the statistical significance of the slope coefficient in a simple linear regression model. Having tested the null hypothesis $H_0 : \beta_1 = 0$ against the alternative hypothesis $H_0 : \beta_1 \neq 0$, a key step is the testing the t-statistic for the estimated slope $\hat{\beta}$ as captured in Equation (2).

The cumulative distribution function $T_{cdf}(|t|, n - 2)$ is the cumulative distribution probability of obtaining a t-value less than or equal to $|t|$ in a student's t-distribution with $n - 2$ degrees of freedom. This distribution account for the sample size and the fact that two parameters (β_0 and β_1) have been estimated.

Hence, the p-value is calculated based on the t-distribution with $n - 2$ degree of freedom is represented in Equation (3):

$$P - value = 2 \times (1 - T_{cdf}(|t|, n - 2)) \quad (3)$$

In the context of hypothesis testing considering the model, the F-statistic is introduced to test the null hypothesis, that all the regression coefficients are equal to zero. Although the t-test is used to assess the significance of the individual coefficients, the F-test provides opportunity of measuring the overall model fit. A statistically significant F-test indicates that the model provides a better fit. The Regression Sum of Squares SSR, which measures the amount of variability of the regression model comparing the predicted values of \hat{Y}_i to the overall mean \bar{Y} is captured in Equation (4). The Error Sum of Squares SSE captures the unexplained variability (residual error) through the measurement of the differences between the observed values Y_i and the predicted values \hat{Y}_i as shown in Equation (5).

$$SSR = \sum_{i=1}^n (\hat{Y}_i - \bar{Y})^2 \quad (4)$$

$$SSE = \sum_{i=1}^n (Y_i - \hat{Y}_i)^2 \quad (5)$$

Having calculated the SSR and SSE, the df_{reg} degrees of freedom for regression and df_{err} degree of freedom of error account for the number of predictors in the model, which is 1 for linear regression and $n - 2$ in simple linear regression respectively, the n represent the number of observations, F-value is calculated using Equation (6) as represented below.

$$df_{reg} = 1 \text{ (for simple linear regression)}$$

$$df_{err} = n - 2$$

$$F = \frac{MSR}{MSE} = \frac{SSR/df_{reg}}{SSE/df_{err}} \quad (6)$$

A large F-value indicates that the model explains a substantial amount of the variability in the dependent variable relative to the error variance, which is significant in explaining Y. Meanwhile, a small F-value implies the model does not explain the variability than what is expected by chance, implying the model may not be statistically significant.

For the determination of the total variability in the independent variable Y, SST (Total Sum of Squares) is calculated as a baseline to evaluate how much of the variability is explained by the model. SST is calculated with equation (7).

$$SST = \sum_{i=1}^n (Y_i - \hat{Y}_i)^2 \quad (7)$$

The coefficient of determination (R^2) indicates the proportion of the variance in Y that is explained by X. The R^2 is calculated using Equation (8).

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \quad (8)$$

An R^2 value close to 1 indicates that the model explains most of the variability in the dependent variable.

The standard deviation s, measuring the dispersion of the independent variable X was calculated. This is fundamental for calculating the standard error of the estimated slope. The standard deviation s is calculated in Equation (9).

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2} \quad (9)$$

where

X_i are the individual data points

\bar{X} is the sample mean

n is the number of observations

H. ETHICAL CONSIDERATIONS

Informed consent, confidentiality, and voluntariness have been taken into consideration during the research. Informing them of the objective of the study and ensuring that their identity would remain anonymous. The research examined the germane issues raised in literatures reviewed to extrapolate the currency of their relevance as it affects accessibility, adoption and utilization.

IV. RESULT AND DISCUSSION

Twenty-five (25) institutions from the six geopolitical zones were included in the study- figure 1. Thirteen 13 (52%) of the institutions were in the north and 12 (48%) in the southern part of the country. Northwest and Southwest had 6 (46%) and

7(54%), the highest respondents from their regions. This represents a fairly equitable spread of the research matrix across the north and south of Nigeria. Hence, the representation shows the transferability of recommendations from the research to other higher education institutions in Nigeria.

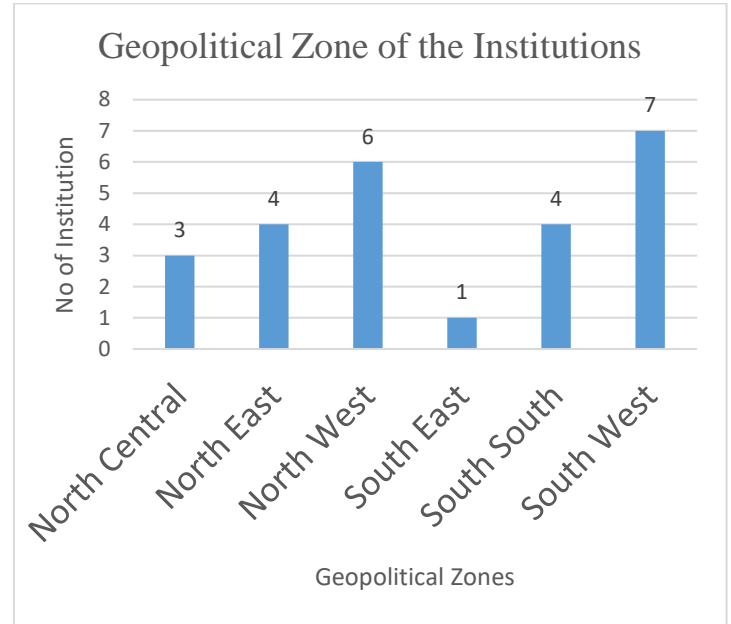


Figure 1: Geopolitical zones of in participating Nigerian Higher Educational Institutions

The average undergraduate population was 23,829 with a range from 3,000 to 90,000. The student population of the higher education institutions was less than 10,000 in 5 (20%), 10,000-30,000 in 14 (56%) and greater than 30,000 in 5 (20%). 12(48%) of the institutions had less than 2,000 academic staff, 4 had more than 5,000 staff as shown in figure 2. The staff strength as captured in figure 3 has a spread of less than 1000 to more than 5000.

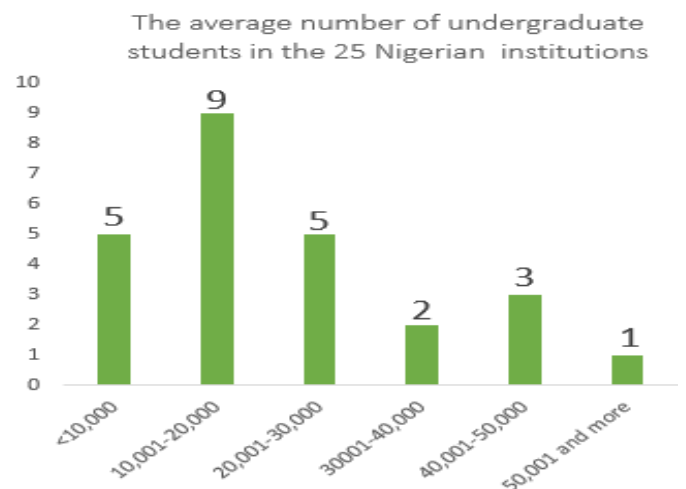


Figure 2: Average number of undergraduate enrolments in participating Nigerian Higher Educational Institutions.

The mean student population across institutions is 31,250 with large spread, SD = 20,678.6, with institutions ranging from small to very large institutions. The mean size of staff is 4,160 but with some institutions having very low numbers, the standard deviation is 2,880. This therefore shows that institutions have differing sizes, which would have implications for their ICT needs and scale of services that are implemented.

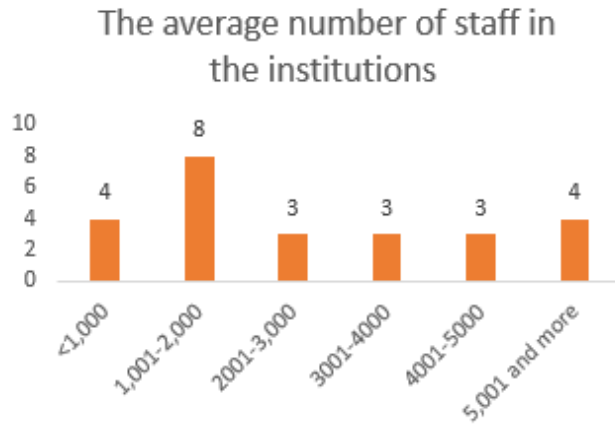


Figure 3: Average number of staff in participating Nigerian Higher Educational Institutions.

A. INTERNET BANDWIDTH SUBSCRIPTION

Internet bandwidth subscription was STM-1(155 Mbps) or lower and in almost a half of the institutions, only about a quarter had up to 2 Gbps bandwidth subscription. In addition, the bandwidth available to institutions with populations less than 20,000 was less than half in those institutions with higher population. This is without the consideration of utilization by staff and other resources hosted by the institution.

The average bandwidth available to students in the Nigerian institutions was 0.038 Mbps, and its degree of dispersion is high. This reflects the fact that some institutions provide as little as 0.015 Mbps per student, extremely low for current university needs, while others provide up to 0.060 Mbps per student, a more adequate amount. The low bandwidth utilization is a challenge to universities with plans to support extensive ICT services such as Learning Management Systems, online research databases, and cloud-hosted applications. This evidenced the abysmally low bandwidth subscription by HEIs and its impact on the availability of quality internet access for staff and students. This has attendant impact on teaching, learning and research.

Meanwhile, there were 3 institutions with no bandwidth subscriptions.

Two simple linear regression models were deployed consisting of model 1: Internet bandwidth (X) predicting average student enrolment (Y1) and model 2: Internet bandwidth (X) predicting average bandwidth per student (Y2).

Table 1: Range of internet bandwidth subscription by participating Nigerian Higher Educational Institutions.

Internet Bandwidth	No of Institutions	% Percent	Average of Student Enrolment	Average Bandwidth /student
≤ STM-1	10	45.5	8,750	0.015
STM-2 - STM 4	5	22.7	17,406	0.024
1 Gbps	2	9.1	23,667	0.051
2 Gbps	5	22.7	35,800	0.060

Table 2: Internet bandwidth (X) and average student enrolment (Y) in Nigerian Higher Educational Institutions (Model 1)

Internet Bandwidth (X)	Average of Student Enrolment (Y)
≤ STM-1	8,750
STM-2 -STM 4	17,406
1 Gbps	23,667
2 Gbps	35,800

Table 3: Internet bandwidth (X) and average bandwidth/student (Y) in Nigerian Higher Educational Institutions (Model 2)

Internet Bandwidth (X)	Average Bandwidth /student (Y)
≤ STM-1	0.015
STM-2 -STM 4	0.024
1 Gbps	0.051
2 Gbps	0.060

Table 4: Internet Bandwidth (X) Predicting Student Enrolment (Y1) (Model 1).

Statistics	Value	Interpretation
P-value	0.0083	Statistically significant at p < 0.05, indicating a very low probability that the observed association between internet bandwidth and outcomes is due to chance.
F-value	118.65	A high F-value suggests that the model explains a significant amount of variance relative to the residual

		variance, confirming strong overall model fit.			being lower than that of Model 1.
R-Squared	0.9834	Indicates that 98.34% of the variance in student enrolment is explained by internet bandwidth, implying an excellent model fit.	R-Squared	0.9529	Approximately 95.29% of the variation in bandwidth per student is explained by the variation in internet bandwidth.
Standard Deviation (Bandwidth per Student)	11,379.42	Reflects the spread of the observed student enrolment values, providing context on the variability around the predicted values.	Standard Deviation (Bandwidth per Student)	0.0214	Reflects a relatively low spread in the bandwidth per student values, suggesting consistency in the measurements.

P-value = 0.0083 (Significant at $p < 0.05$). This indicates that the slope is statistically significant ($p < 0.05$), meaning there is a very low probability that the observed association is due to chance. This implies that the relationship between internet bandwidth and the outcomes (student enrolment and bandwidth per student) is statistically significant. This supports the notion that internet bandwidth is an important factor in these educational metrics as captured in Table 4.

F-value = 118.65 (High, indicating a strong model). A high F-value indicates that the model explains a significant amount of the variance in student enrolment relative to the residual variance. The high F-statistics supports the idea that the model as a whole is significant, meaning the predictor (bandwidth) explains a significant amount of the variance in the outcomes.

R-squared = 0.9834 (98.34% of variance in student enrolment is explained by internet bandwidth). The R-squared values being above 95% suggest that the simple linear regression (with our coding) fits the data extremely well. This implies that 98.34% of the variation in student enrolment is explained by the bandwidth variable. With such a small dataset, a near-perfect fit can occur if the relationship is nearly linear.

Standard Deviation (of Y): Approximately 11,379.42

This is the sample standard deviation of student enrolment values, computed using the unbiased estimator ($ddof=1$).

Table 5: Internet Bandwidth (X) Predicting Bandwidth per Student (Y2) (Model 2).

Statistics	Value	Interpretation
P-value	0.0238	Statistically significant at the 5% level; the slope is significantly different from zero.
F-value	40.50	Indicates strong overall model significance despite

The low P-values (< 0.05) confirms that the relationships in both model 1 and 2 captured in tables 4 and 5 are statistically significant, which confirms the strong evidence against null hypothesis. This confirms the predictor, internet bandwidth is statistically significantly related to the outcome, bandwidth per student. The results affirms that there is a significant relationship in that increasing internet bandwidth is strongly associated with both higher student enrolment and improved bandwidth per student.

The F-value of 40.50 further validates the model as statistically significant, suggesting a robust exploratory power in the context of regression analysis. This strengthened the credibility of the role of the predictor in the model.

With an impressive R^2 value of 0.9529, this suggests that over 95% of the variation in bandwidth per student can be explained by the variation in internet bandwidth. This affirms the strong fit of the model that internet bandwidth is a prominent determinant

The average bandwidth per student testifies that most of the institutions are ill-equipped in terms of mean bandwidth demand needed for effective digital transformation. The larger the institution, or analytically, the more students, the more challenged it will be unless a significant investment is made in enhancing ICT infrastructure. Smaller institutions with low bandwidth are still at a disadvantage in terms of access to, management, and maintenance of robust ICT networks.

B. HOSTING AND MANAGEMENT OF NETWORK INFRASTRUCTURES

Institutions often need to host and manage certain services such as portals, websites, Learning Management Systems (LMS), and other applications meant for students and staff use. The hosting in HEIs and the management is presented in Table 6.

Table 6: Hosting and Management of Resources

ICT Resources	Hosting of ICT Resources				Management of ICT Resources	
	On-campus hosting		Cloud hosting		Management of web resources (LMS, Website, and Portals)	Freq (%)
	Yes (%)	No (%)	Yes (%)	No (%)		
Website	13 (52)	12 (48)	16 (64)	9 (36)	ICT staff only	12 (48)
Portals	17 (68)	8 (32)	17 (68)	8 (32)	ICT staff with international 3rd party	1 (4)
LMS	11 (44)	14 (56)	14 (56)	11 (44)	ICT staff with local/national 3rd party	10 (40)
Other Resources	15 (60)	10 (40)	12 (48)	13 (52)	Third party only	2(8)

on-campus which is hybrid in some instances. Portals hosting on the cloud and on-site were each done by about 2/3 of the institution. Cloud hosting, for instance, is considered a good indicator of technological adoption, with 64% of the institutions using it. However, only about 52% of websites and 68% of portals are hosted on-campus, meaning some institutions still struggle with full integration of on-site and cloud services.

Learning management system was available at 14(56%) institutions and are mostly hosted on the cloud. Other ICT applications were hosted by 15(60%) institutions and mostly hosted on site with 12(48%) having additional on cloud hosting.

In 11 (44%) of the institutions, in addition to the university ICT staff, third party ICT organizations were involved in routine management of their website, portals and LMS. These comprises of HEIs that has committed resources to the training of her ICT staff. With 44% of institutions reliance on third-party management of ICT resources, depicts an indication of lack of in-house technical capacity, hence, affecting the quality and consistency of network services. The reliance on external ICT managers also points to the likelihood of a skills gap within Nigerian universities ICT staff. The scaling up of network services faces greater difficulties in smaller and less-well-endowed institutions.

C. AVAILABILITY OF POWER BACKUP FOR NETWORK INFRASTRUCTURE

All the institutions utilise public grid primarily for electricity supply. Two (8%) of the institutions rely only on the public grid without other power backup solutions.

In the other 17 (68%) institutions, a combination of other electrical power back-ups including inverters, solar, and generators were introduced as captured in figure 4. Inverter is the commonest power backup, though only 5 (22%) Nigerian higher education institutions use solar with inverters while about a third still require generators.

Although 92% of the institutions have a backup resource, a disturbing representation of 35% are still dependent on generators, which involves high financial and operational costs. Only about 22% use more viable alternatives like solar power. This means there is still potential for improvement in adapting renewable energy sources. Others, about 8%, fully depend on the public power grid, therefore, are prone to power cuts that can bring discontinuation in network services and ICT operations.

Availability of Power backup for Network infrastructures

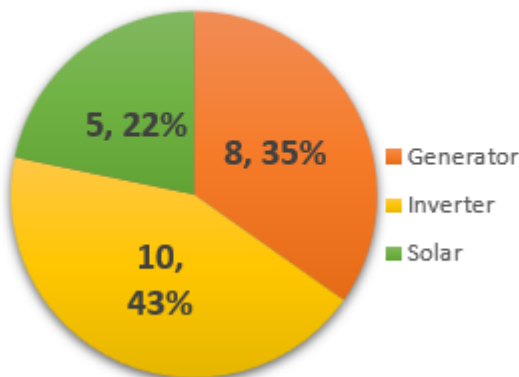


Figure 4: Availability of Power backup for Network infrastructures

The hosting and management of ICT resources, a technology backbone for HEIs necessitated the research on the modalities adopted. Only 4 (16%) hosted all their applications on-campus and have no resources hosted on cloud. More HEIs, 13 (52%) and 17 (68%) hosted websites and Portals On-campus respectively, with the services predominantly managed by only the ICT staff 12(48%) within the institutions. Cloud hosting with a frequency of 16(64%) was commonly employed by the HEIs, where about a half host their websites

IV. DISCUSSION, RECOMMENDATION AND FUTURE DIRECTION

The hosting of ICT resources, a vital prerequisite for service delivery in academic community as shown in the research, leveraged hybrid on-campus and cloud hosting by Nigerian higher educational institutions. HEIs should be particularly targeted for government or private sector support to enhance their information and communication technology

infrastructure. They could especially benefit from shared infrastructure models, such as regional data centres.

There is a significant departure to predominant cloud hosting of services and sole third-party management of web resources, making HEIs at the risk of data lock-in and the susceptibility of Institutions held to ransom by aggrieved third party. A trend that could have been effectively stemmed by deliberate investment in building international standard ICT man power that will host, drive and effectively manage resources locally. These affirms the need for HEIs to invest in developing internal ICT teams so that they do not have to rely heavily on third-party providers. This will ensure greater control over the ICT operations and quicker response times to issues arising. This reiterates the need to develop training programs and alliances with technology firms so that ICT staff have the necessary knowledge base needed to manage modern ICT infrastructure. Without discountenancing the supportive role of third-party hosting providers, premium importance should be placed on the deliberate training of ICT staff. Staff development with the right skills especially in Network infrastructure, server administration, cloud services management, and security.

The population of enrolled students and staff as collated, effectively captured highly and lowly populated institutions. The analysis of models 1 and 2 shows that there is some significant relationship between internet bandwidth, student enrolment and bandwidth per student. Meanwhile, this suggests that other factors may contribute more substantially to variations in student enrolment and bandwidth utilization in Nigerian universities. The results could be further validated with a larger dataset considering more universities in Nigeria. Hence, further analysis with a larger sample size might provide more conclusive insights.

However, the research provided a plausible reference in HEIs in Nigeria emphasizing that, the bandwidth penetration at HEIs is abysmally low considering the student and staff population. The research evidenced the deficit in bandwidth subscription of HEIs with respect to enrolled student and staff strength. The advent of COVID -19 and the redefinition of teaching, learning and research affirmed the premium importance of leveraging technology. Coincidentally, the backbone of internet infrastructure deployment is the availability of equitable bandwidth subscription. With the average bandwidth available to students pegged at 0.038 Mbps (38 Kbps), considering the bandwidth intensive applications deployed for learning, the research affirmed the inadequacy of bandwidth subscription by HEIs. An application such as Zoom, requires a minimum of 600 Kbps full duplex link for 1:1 video calling for uninterrupted lecture delivery through the platform and 1 Mbps for group video calls without countenancing screen sharing. The facilities for Internet access in Nigerian Universities are yet to be significantly enhanced toward supporting modern university education. Indeed, an ideal target broadband would

have to be at least 1 Mbps per student for reasonably smooth operation of LMS, research activities, and video conferencing. This further affirms the urgent need to scale up bandwidth subscription, and the adoption of the minimum of two service providers to effectively manage disruption to services due to occasional down time associated with fibre cuts whenever it occurs. National policies should ensure equity in the distribution of broadband across institutions. Funding mechanisms should be established to prevent the likelihood of smaller universities being left behind in developing ICT infrastructure.

The rising cost of energy fuels places premium on the need for the comprehensive adoption of renewable energy including windmills, and solar powered inverters as a sustainable and clean energy alternative for HEIs. The needs assessment and energy audits need to be done by the institutions to understand their power needs and what inefficiencies are occurring. This streamlining of energy will take some of the burdens off the backup systems, which in turn will add years to the life cycle of the equipment. For instance, universities can change their old networking equipment with energy efficient lower power consuming alternatives. Institutions should utilize renewable energy, such as, solar power, so that the supply of power could become more reliable and stable. Solar systems complimented with inverters offers a much cleaner and more reliable source of energy compared to using generators. Generators could be seriously hampered by fuel shortages, high cost of purchase and maintenance. The incentives provided by the government should be aligned with and directed towards institutions in ways that would grant them substantial funding in developing green energy solutions.

The government, in collaboration with companies in the private sector, should establish funding opportunities or public-private partnerships to support institutions in their movement toward renewable energy solutions. Subsidies for solar panels or low-interest loans could incentivize more universities to adopt sustainable power systems. The seamless integration of the green energy initiative with the public power provision places HEIs at a vantage position of hosting services onsite and sufficiently manage the challenge of resources availability. The hybrid deployment in addition to the public grid will ensure adequate power needs of institutions are met.

We hereby recommend that HEIs should focus on:

1. Increased Bandwidth: Network infrastructure should be upgraded to support higher speeds and more reliable connections for online learning and research.
2. Scalable Network Solutions: The network systems should be scalable to seamlessly handle growth in data usage, especially for increasing numbers of remote learners.
3. ICT Infrastructure Investment: Deliberate efforts should be focused on investment on more reliable and cost-effective

broadband services, power solutions (green energy) to address connectivity challenges and power outages.

4. Upgraded Learning Management Systems (LMS): Improve or develop advanced, user-friendly LMS platforms for better interaction and content delivery.

5. Human Capacity Development: Needs based training approach should be adopted for the capacity development of staff for robust and effective management of ICT infrastructure.

F. CONCLUSION

This research investigated the current status of Information and Communication Technology (ICT) network services and broadband access and management of network resources within Nigerian universities. The study reveals that while significant progress has been made in digital infrastructure across higher education institutions, notable disparities exist among tertiary institutions in bandwidth penetration and utilisation as well as in the management of the available resources.

The current ICT and broadband initiatives have laid a foundation for enhancing academic delivery, and research productivity. However, to fully harness these benefits, it is imperative that stakeholders, with emphasis on the administrator of the institutions and government, should place priority on investment in ICT network services, broadband subscription, and capacity building of ICT staff. With the statistical results in models 1 and 2 based on the data provided by the HEIs, it affirms the importance of proactive technological integration of robust internet infrastructure in educational settings. As the digital learning environment expands, provision of adequate internet bandwidth to keep pace with increasing number of enrolled students and digital demand is critical.

If these areas are improved, it will successfully transform the educational landscape of HEIs in Nigeria and adequately place them on a pedestal to compete on equal footing in the global academic arena while offering higher quality education to their students. These issues are thus very fundamental to the sustained transformation of higher education in Nigeria.

AUTHOR CONTRIBUTIONS

Dupe S. Ademola-Popoola: Conceptualization of idea, questionnaire development and Validation, and Writing **J. A. Adesina** Writing – Original draft, analysis, calculation, interpretation of results, review & editing.

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Appendix 1

This form seeks to find the Status and capacity of our resources and hosting of network resources. Confidentiality of information supplied is guaranteed.

Email Address

1. WhatsApp Telephone number(for follow up communication)
2. Name of institution
3. Geopolitical Zone of institution

- 1 NC-North Central
- 2 NE-North East
- 3 NW-North West
- 4 SE-South East
- 5 SS-South South
- 6 SW-South West

4. What is the number of students in your institution?
5. What is the number of staff in your institution?
6. Do you currently host any network website/portals/LMS on site in your university? [Website], [Portals], [LMS], [Others]

Yes No

- 1 Website
- 2 Portals
- 3 LMS
- 4 Others (Please specify)

7. Do you currently host any network website/portals/LMS on the cloud? [Website], [Portals], [LMS], [Others]

Yes No

- 1 Website
- 2 Portals
- 3 LMS
- 4 Others (Please specify)

8. If you use a cloud platform, which one e.g. Amazon web services, Go Daddy, Digital Ocean etc do you use and for which of your resources?
9. How much internet bandwidth do you subscribe to annually?
10. What challenges do you have with hosting your resources onsite locally in your institution if you do?
11. Other than the Electricity grid use, what is the availability of Power backup for Network infrastructures?

Yes No

- 1 Generator
- 2 Solar
- 3 Inverter
- 4 None

12. Who manages your web resources-LMS/Website/Portals?

In- House Staff International 3rd Party web services organizations Local 3rd party service Organizations

- 1 Website
- 2 Portals
- 3 LMS
- 4 Others (Please specify)

Please provide any free comments that may enhance deployment and hosting of a University's web/network resources.

Thank you