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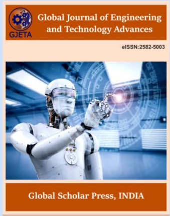

(RESEARCH ARTICLE)

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Performance analysis of wireless fidelity network within the university campuses: a case study of Nigerian university

Olusayo Adekunle Ajeigbe *, Johnson Gbadebo Adenle and Opeyemi Ogunsanya

Department of Electrical and Electronics Engineering, Faculty of Engineering, Ajayi Crowther University, Oyo, Nigeria.

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Abstract

This study evaluates the Wireless Fidelity infrastructure at a typical Nigerian University Campus taking Ajayi Crowther University as a case study, and focusing on key performance indicators such as signal strength, channel usage, and network speed across various campus locations. The analysis revealed significant disparities in signal strength, ranging from -50 dBm in the Chief Wole Olanipekun lecture room to -65 dBm in faculty buildings, and identified interference in the 2.4 GHz band as a major issue in high-density areas. Network speeds varied, with averages of 50 Mbps in lecture halls and up to 120 Mbps in administrative offices. While the current network meets basic connectivity needs, critical improvements are needed, including upgrading to IEEE 802.11ac access points, optimizing channel allocation, and increasing access point density in high-traffic zones. These enhancements aim to boost the network's reliability and performance, though the study faced challenges with fluctuating traffic and environmental factors affecting signal consistency.

Keywords: Wireless fidelity; University campus; Performance analysis; Network; Traffic zones

1. Introduction

In the past few decades engineering and technology has transformed significantly, but so too networking using various mechanisms. However, despite these developments, access to quality and best performing network still continue to be an international priority in the engineering industry. Wireless Fidelity (Wi-Fi) has become an indispensable technology woven into the fabric of our daily lives. Its wide range of applications continues to grow, and its deployment is expected to surge in the near future due to several key advantages, particularly its cost-effectiveness in both installation and maintenance [1, 2]. When it comes to technology in our daily lives, the significance of wireless connectivity or communication cannot be ignored. It has evolved into being essential for reliable and efficient data transfer [3. 4]. Gone are the days of cumbersome wired connections that limit mobility and hinder productivity [5]. Wi-Fi is a **ubiquitous technology** that allows electronic devices to exchange data over a computer network without the constraints of physical cables providing several advantages using radio waves [6]. Wi-Fi networks are widely used, which is evidence to it been developed always. Wi-Fi networks serves as the standard options for local buildings including schools, offices, airports, colleges and universities [7]. The IEEE 802.11 family series of standards introduced in the 1990s, specifies the technologies and procedures needed for establishing wireless connections between devices, is the building block of Wi-Fi networks. Over time, these standards have changed, with each new generation bringing improved performance and efficiency [8]. The choice of Wi-Fi standard depends on various factors, including the desired speed, range, and compatibility with existing devices. Wi-Fi networks have become a necessity in today's world because they give our gadgets wireless connectivity, which allows us to share files, access the internet, and converse with people without difficulty [5, 9]. It provides a wireless portal to the digital world and also grown to be the cornerstone of seamless communication in the complex web of modern connections. In essence, a Wi-Fi network is a local area network (LAN) that connects devices wirelessly through the use of Wi-Fi technology. It is important because it frees users from the

* Corresponding author: Olusayo Adekunle Ajeigbe

limitations of physical cords and offers an adaptable and effective connection method. Wi-Fi is used in areas other than business and personal, such as the Internet of Things (IoT) [10]. Wi-Fi networks provide smooth communication between smart devices, which include wearable technology (which represents another realm of Wi-Fi-integrated IoT applications. Smartwatches, fitness trackers, and health monitoring devices often utilize Wi-Fi connectivity to sync data with smartphones or cloud platforms) and thermostats, creating a linked environment that improves automation and data transmission. While the integration of Wi-Fi with IoT devices offers unparalleled convenience and connectivity, it also poses challenges related to network security, data privacy, and the potential for network congestion [11, 12]. The way we live, work, and play has been completely transformed by the revolutionary technology known as Wi-Fi. Wi-Fi is a rapidly evolving technology with new Wi-Fi standards are constantly being developed to provide faster speeds, greater capacity, and improved security. It is a fundamental component of the contemporary world, and its significance will only increase going forward.

2. Materials and Methods

This section delineates the procedures for evaluating Wi-Fi network performance at Ajayi Crowther University, emphasizing the collection, processing, and analysis of data pertaining to Wi-Fi signal strength and overall network efficacy throughout the campus. The methodology entails dividing the institution into clusters, determining optimal hours for analysis, and assessing the effectiveness of the "ACU_AP" Wi-Fi network inside each cluster. Data is compiled into a dataset, thereafter analyzed and visualized to get insights regarding network behavior. To guarantee precision, assessments are performed under stable power conditions, average signal strength is computed for different building zones, and performance evaluations are produced for each cluster, including variables such as high-rise structures. The research design is non-experimental, quantitative, and employs a sampling method to assess network performance at designated intervals. The site survey and selection procedure entails the identification of several campus locations, emphasizing lecture halls, administrative offices, and faculty buildings. Measurement locations are chosen based on user population, closeness to access points, structural obstructions, sources of interference, and environmental conditions.

2.1. Data collection and analysis

The inSSIDer Wi-Fi analysis tool is utilized for data collecting in Wi-Fi performance analysis, measuring signal strength (RSSI), network speed, and channel interference. A laptop equipped with inSSIDer software, a GPS device for accurate location tracking, and a digital campus map are utilized to assess signal strength at designated spots over a duration of 2–3 minutes, capturing average values. Supplementary parameters, including channel utilization and maximum channel velocity, are documented. Data points, comprising measurement point ID, GPS coordinates, date, time, RSSI (in dBm), channel utilized, and observations, are methodically recorded in a spreadsheet. Heatmaps are subsequently produced to illustrate the spread of signal strength throughout the campus. The gathered data undergoes an extensive analytical procedure that includes data cleansing to rectify abnormalities and guarantee precision. The data is evaluated utilizing statistical and analytical tools to reveal patterns, trends, and correlations. Signal intensity data is represented using Python-based Folium heatmaps, speed data is scrutinized to pinpoint areas of inadequate performance, and channel usage data is assessed to find interference and overlapping networks. Furthermore, qualitative study of non-numeric data offers contextual insights, augmenting the comprehensive understanding of the network's functioning.

2.2. Python Modules

A module in programming denotes a self-contained unit that encapsulates a set of related functions, classes, and variables, facilitating orderly and modular development. Modules are structured to encapsulate functionality and enhance reusability, hence facilitating code maintenance and improving readability by deconstructing complicated software systems into manageable components. Python modules operate in a comparable manner. They are reusable code segments that offer features for integration into your projects. Python enables the importation of pertinent modules into your application to achieve specific objectives. This modular methodology enhances code organization, facilitates reusability, and streamlines intricate programming jobs.

3. Results and Discussion

3.1. Evaluation of network efficacy

Clusters A through J denote distinct campus sites, each assessed separately for Wi-Fi network performance based on the provided data. Cluster A comprises the T.Y. Danjuma Library, Cluster B encompasses the Faculty of Engineering, Social Sciences, and Management Sciences, whereas Cluster C includes the Faculty of Communication and Media Studies, Common Lecture Room, Faculty of Religious Studies, St. Andrews Chapel, Book Shop, and Faculty of Humanities. Cluster D pertains to the Vice Chancellor's Office, Cluster E encompasses the University Health Center and Registry, and Cluster F addresses the Bursary, Student Affairs, and Works Department. Cluster G comprises the University Auditorium and the Florence Ajimobi ICT building, whilst Cluster H encompasses the Faculty of Natural Sciences. Cluster I comprises the Chief Wole Olanipekun Lecture Room, Student Common Room, Faculty of Education, Physics and Biology Laboratories, and Department of Radiography. Cluster J concentrates on the Faculty of Law. The study will be performed on a per-cluster basis, assessing critical performance indicators including signal strength, network speed, coverage, and interference to discern patterns, identify anomalies, and comprehend the factors influencing total Wi-Fi network performance within each cluster.

Figure 1a Signal heatmap at Danjuma Library

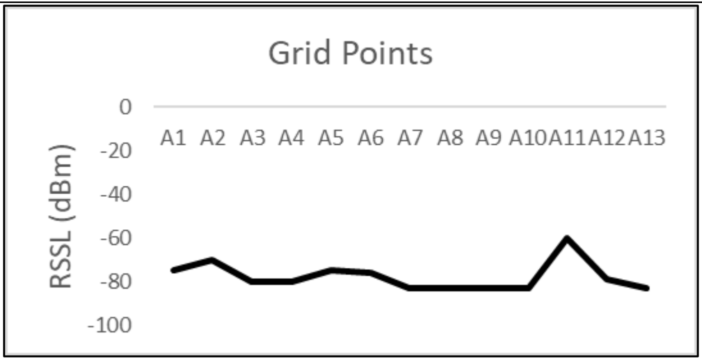


Figure 1b Signal intensity at Danjuma Library

Figure 1 illustrates the signal intensity data in Cluster A, emphasizing Wi-Fi coverage surrounding the University Library, with signal intensities varying from -60dBm to -83dBm. The research indicates that optimal signal intensity was exclusively detected at point A11, however the overall performance within the cluster is subpar. The heatmap and associated graph depict a feeble "ACU_AP" signal strength within the cluster, with a maximum attainable speed of 300 Mbps and a channel width of 40 MHz. The library, a multi-story edifice, exhibits a signal intensity variation of -5dBm to -10dBm across its floors. Due to its function as a tranquil reading area, users may encounter inadequate connectivity, highlighting the necessity for network enhancements.

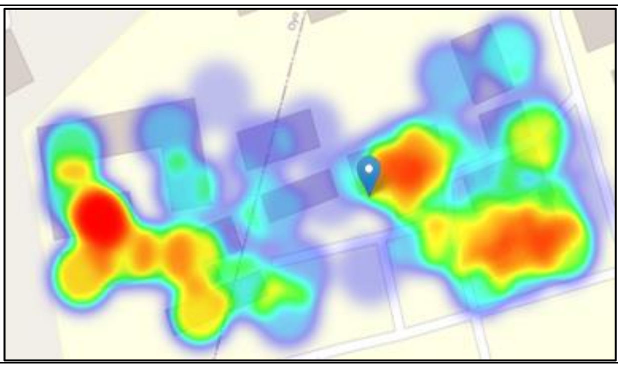


Figure 2a Signal strength heatmap at Faculty Engineering Social Sciences and Management Sciences

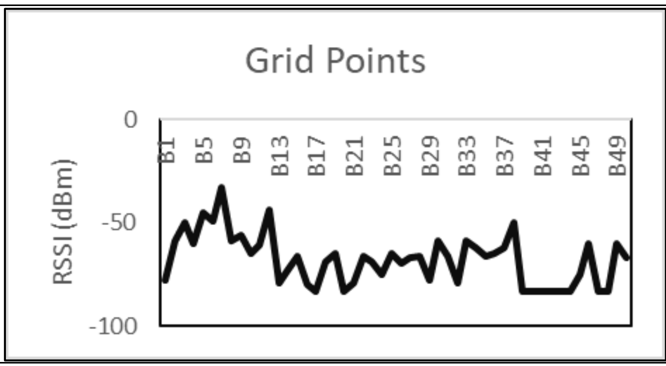
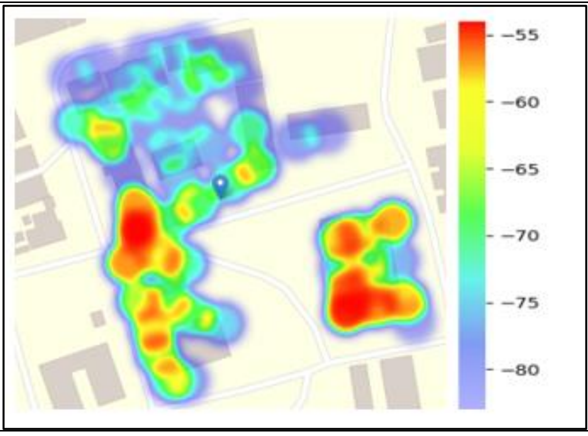
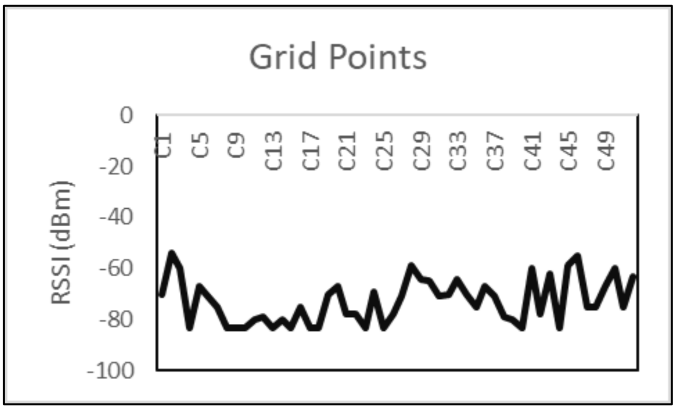


Figure 2b Signal strength intensity at Faculty of Engineering Social Sciences and Management Sciences

Figure 2 illustrates the signal intensity, depicting Wi-Fi coverage within the cluster and assessing the distribution and consistency of signal strength across different building types. Signal levels vary from -44dBm to -83dBm, with optimal strength recorded at point B7, indicating overall average performance. The heatmap demonstrates adequate coverage in most regions; however, several pathways exhibit poor connectivity to the "ACU_AP" Wi-Fi. The highest speed for each access point is 300 Mbps, with a cluster comprising 8–10 access points, including 2–3 utilizing a 20 MHz channel width, which can accommodate around 200 people. During peak usage, the network's performance may deteriorate due to heightened user load or bandwidth requirements.



(a)



(b)

Figure 3 Faculty of Communication and Media Studies, Common Lecture Room, Faculty of Religious Studies, St. Andrews Chapel, Book Shop, and Faculty of Humanities: (a) signal heatmap, (b) signal intensity

Figure 3 illustrates the Wi-Fi coverage within the cluster, assessing the distribution and consistency of signal strength across multiple buildings. Signal levels vary from -54dBm to -83dBm, with the optimal signal detected at point C2; nonetheless, the overall performance remains subpar. Although certain regions exhibit strong signal strength, the general lecture room area suffers from weak signals, complicating mobile device connectivity. Regions with inadequate signal experience a maximum speed of 130 Mbps, markedly inferior to the 300 Mbps available in areas with superior coverage. The cluster encounters difficulties in efficiently distributing users among access points during peak demand, with only areas of strong signal capable of supporting greater user density. The cluster can accommodate approximately 100–150 users concurrently, with channel widths of 20 MHz for certain access points.

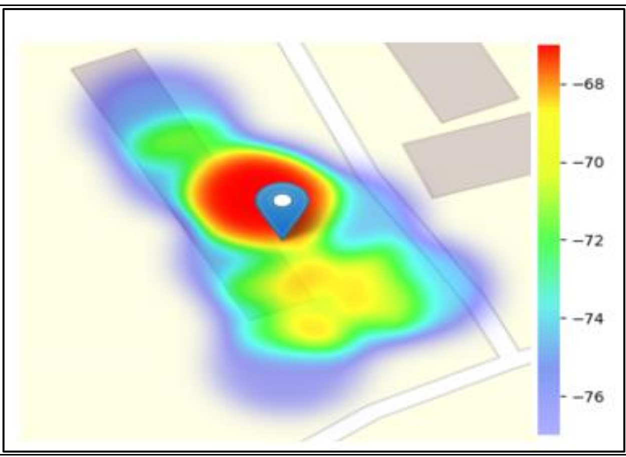


Figure 4a Signal heatmap at Vice Chancellor’s Office

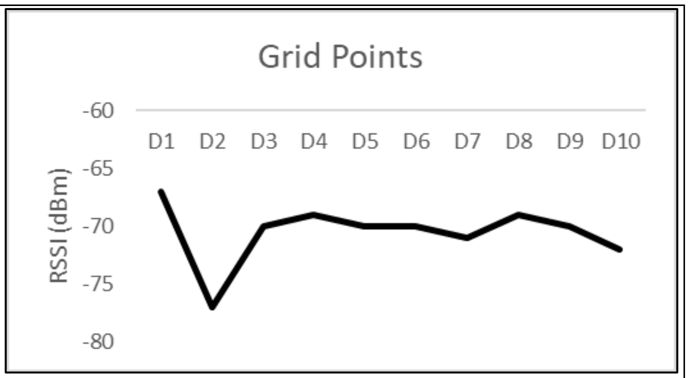


Figure 4b Signal intensity Vice Chancellor’s Office

Figure 4 illustrates the Wi-Fi coverage within the cluster, emphasizing the dispersion and constancy of signal intensity. The signal strengths near the university vice chancellor’s office vary from -67dBm to -77dBm, with the optimal strength seen at point D1, reflecting an overall average performance. The heatmap additionally records signals from adjacent Cluster E, characterized by a channel width of 40 MHz and a maximum speed of 300 Mbps, underscoring potential overlap and impact on coverage.

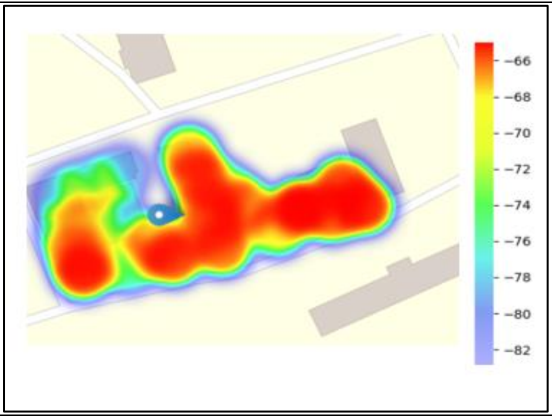


Figure 5a Signal heatmap at Health Center, Registry

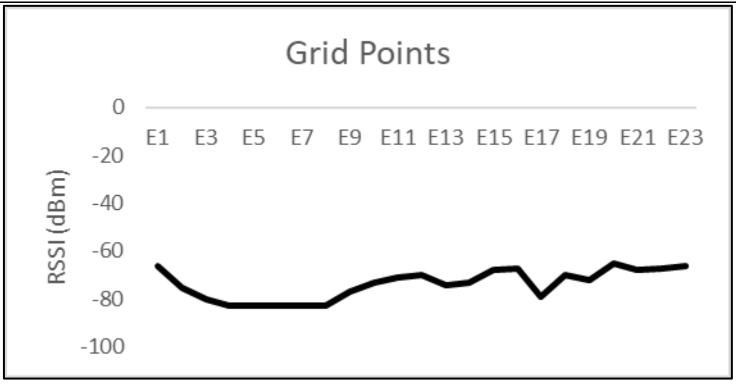


Figure 5b Signal strength at Health Center and Registry

Figure 5 illustrates the Wi-Fi coverage within the cluster, evaluating the distribution and consistency of signal strength across buildings. Signal levels vary from -66dBm to -83dBm, indicating predominantly inadequate coverage in the region. Although the majority of access points function at a 40 MHz channel width and a speed of 300 Mbps, those operating at a 20 MHz channel width and 130 Mbps speed prevail in some regions, adversely affecting overall performance. Figure 4.10 illustrates that point E20 exhibits the optimal signal strength, signifying a moderate enhancement in performance. Nonetheless, interference from overlapping access points, probably caused by a nearby cluster utilizing the same channel and linking to the primary point-to-point access point, exacerbates connection issues within the cluster.

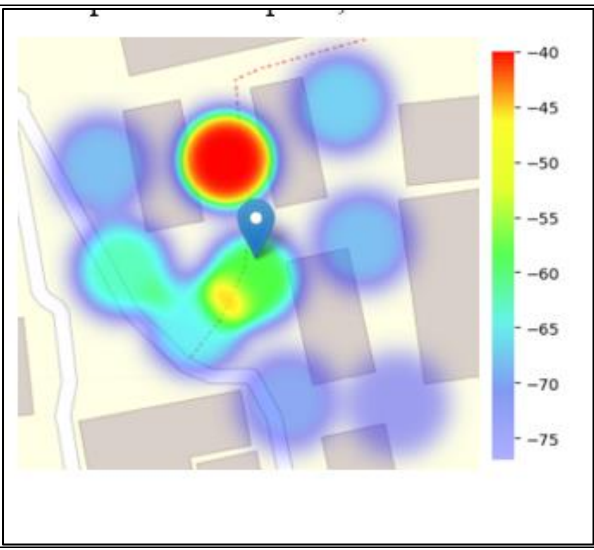


Figure 6a Bursary, Student Affairs and Works Dept.

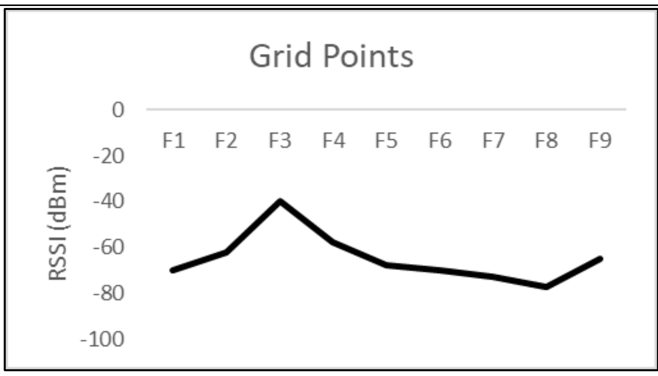
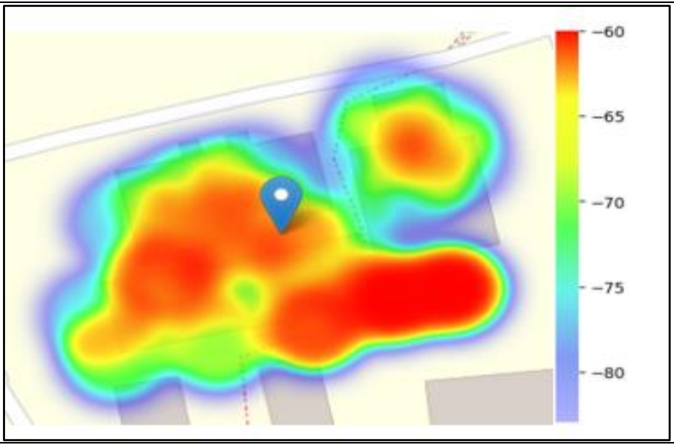


Figure 6b Bursary, Student Affairs and Works Dept

Figure 6 illustrates the Wi-Fi coverage within the cluster, assessing the distribution and consistency of signal strength across buildings. Signal levels vary from -40dBm to -77dBm, with optimal performance recorded at point B7, reflecting average overall efficacy. The "ACU_AP" Wi-Fi coverage is significantly inadequate in this cluster, encompassing administrative sectors such as student affairs, the bursary, and works departments. Notwithstanding the weak signals, the access points in this region accommodate capacities ranging from 270 Mbps to 300 Mbps with a 40 MHz channel width, allowing them to manage elevated traffic loads despite subpar signal strength.



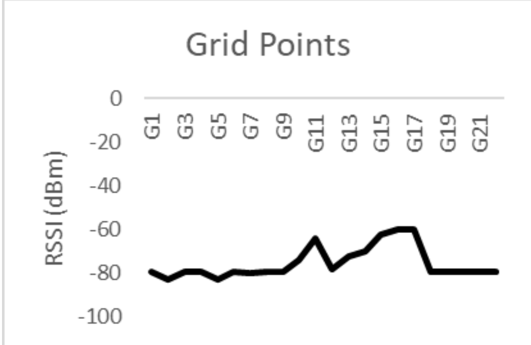
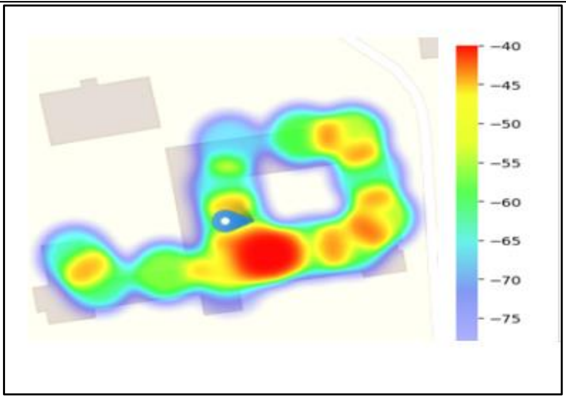


Figure 7a Signal heatmap at University Auditorium, ICT

Figure 7b Signal strength at University Auditorium, ICT

Figure 7 illustrates the generated signal intensity and visualizes coverage areas inside the cluster. The coverage was assessed regarding signal intensity dispersion and uniformity across various building types. Signal strength within and surrounding each building in this cluster varies from -64dBm to -83dBm. The graph indicates that the optimal signal strength was recorded exclusively at point G17, while the overall performance is moderately satisfactory. This graph depicts the Wi-Fi signal strength in dBm at different locations as indicated. This area comprises a lecture room and the ICT department of the campus, to which all access points are connected. This region experiences significant channel interference owing to the diverse channels employed for point-to-multipoint connections across multiple campus clusters. Notwithstanding this difficulty, the maximum speed attainable on access points at this site is 300 Mbps, with a channel width of 40 MHz. Only channels 1 and 8 are utilized here. Channel 1 experiences interference and extends from CLUSTER F.



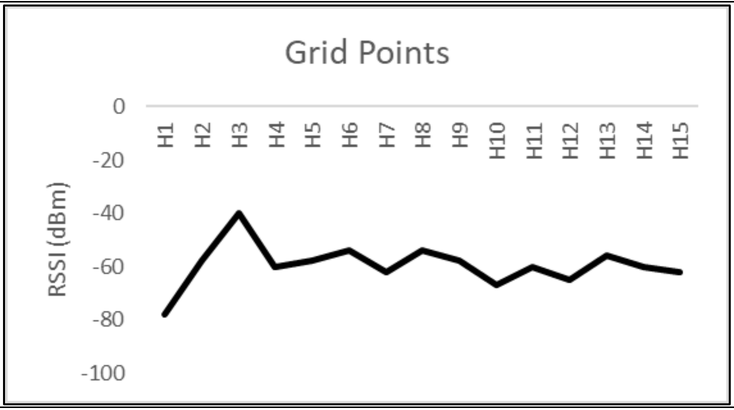


Figure 8a Signal heatmap at Faculty of Natural Sciences

Figure 8b Signal strength Faculty of Natural Sciences

Figure 8 illustrates the produced signal intensity and visualizes the Wi-Fi coverage within the Faculty of Natural Science building, assessing the distribution and consistency of signal strength across various areas. Signal intensity varies from -40dBm to -78dBm, with optimal performance seen at point H3. The multi-story skyscraper features 4 to 7 access points, providing a throughput of 300 Mbps and a channel width of 40 MHz. The signal strength is more robust at the entry and maintains relative consistency across the floors due to access points positioned outside the hallways. Notwithstanding sufficient coverage, the existing access points may falter in accommodating the building's elevated user density during peak periods.

Figure 9a Chief Wole Olanipekun Lecture Room, Student Common Room, Faculty of Education, Physics and Biology Laboratories, and Dept. of Radiography

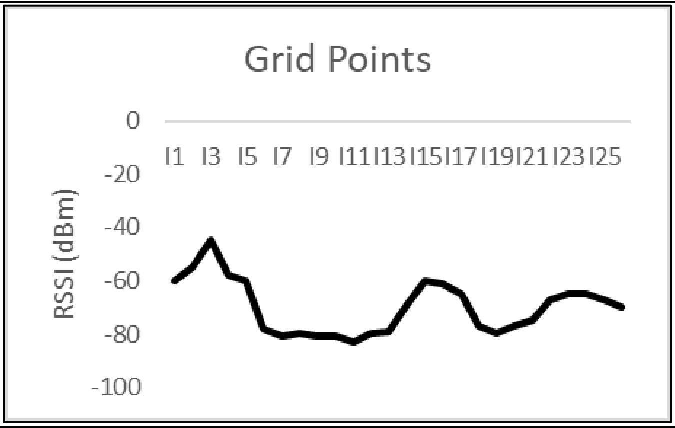


Figure 9a Chief Wole Olanipekun Lecture Room, Student Common Room, Faculty of Education, Physics and Biology Laboratories, and Dept. of Radiography

Figure 9 illustrates the produced signal strength, depicting Wi-Fi coverage over multiple buildings within the cluster, with signal strength varying from -40dBm to -78dBm. The graph indicates that the optimal signal strength occurred at point I3; however, the total performance remains subpar. The coverage encompasses the Chief Wole Olanipekun Lecture Room, Physics Laboratory, Radiology Department, Common Room, and Faculty of Education. The Chief Wole Olanipekun Lecture Room provides robust signal strength with optimal performance (40 MHz channel width, 300 Mbps speed, accommodating 240-300 people), but other locations, notably the Faculty of Education, suffer from inadequate performance and weak signal strength. During periods of high user density, only the access points within the lecture room can efficiently manage the heightened traffic.

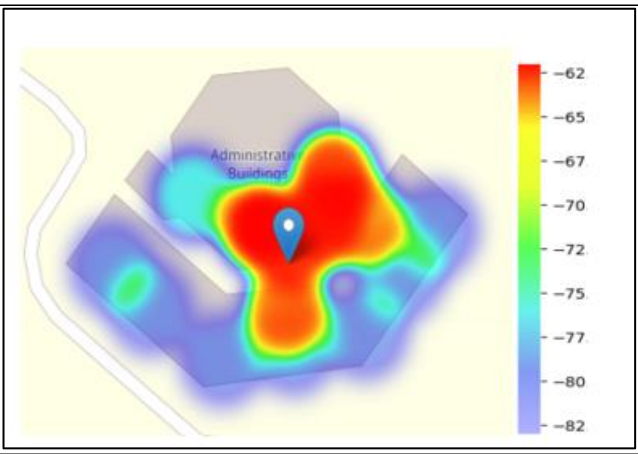


Figure 10a Signal heatmap at Faculty of Law

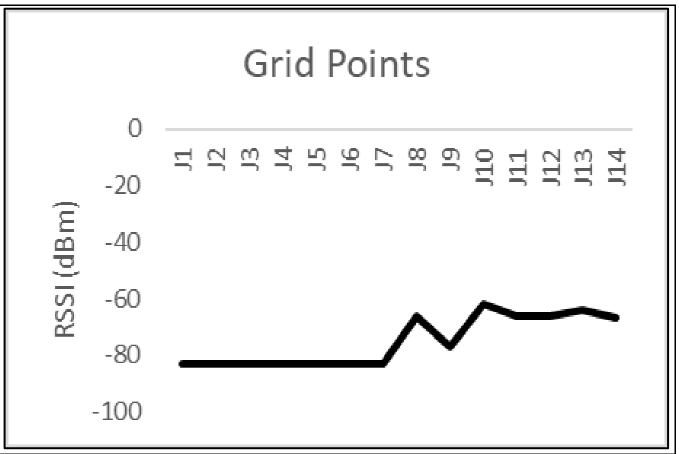


Figure 10b Signal strength at Faculty of Law

Figure 10 illustrates the Wi-Fi coverage within the cluster, evaluating the distribution and uniformity of signal strength. Signal levels vary from -62dBm to -83dBm, with the optimal signal observed at point J10, reflecting generally satisfactory performance. The building's design, characterized by a central hall encircled by a multi-story configuration, results in signal discrepancies owing to interference. Channel 4, functioning at 300 Mbps with a 40 MHz bandwidth, offers optimal coverage within the cluster; nonetheless, the overall performance remains subpar despite the increased channel width. The cluster can accommodate between 40 to 80 users concurrently for optimal connectivity.

4. Conclusion

Analyzing Wi-Fi network performance is essential in educational institutions such as Ajayi Crowther University, where dependable internet connectivity underpins academic and administrative functions. This study assesses the campus Wi-Fi infrastructure, pinpoints areas for enhancement, and provides practical recommendations to increase network performance. The study offers a comprehensive evaluation of various building types, including lecture halls, administrative offices, and faculty buildings, by analyzing key performance characteristics such as signal strength, channel utilization, and network speed. A full site assessment was conducted to rigorously gather and evaluate data on access points, signal strength, channel interference, and speed using both quantitative and qualitative methodologies to comprehend network behavior under diverse scenarios. The results indicate substantial fluctuations in signal intensity, varying from -50 dBm in the Chief Wole Olanipekun lecture room to -65 dBm in academic buildings, with channel interference in the 2.4 GHz band impairing performance in densely populated regions. Network speeds averaged 50 Mbps in lecture halls and reached up to 120 Mbps in administrative offices. The existing network fulfills fundamental connectivity requirements; nevertheless, significant performance improvements are essential.

Recommendation

To improve Wi-Fi performance throughout Ajayi Crowther University, some essential recommendations are suggested. Prioritizing the upgrade to newer Wi-Fi protocols, such as IEEE 802.11ac (Wi-Fi 5) or IEEE 802.11ax (Wi-Fi 6), is essential for enhancing speed and dependability. Enhancing access point density in high-traffic areas, optimizing channel allocation, and executing load balancing will mitigate interference and maximize bandwidth utilization. Consistent firmware upgrades for access points will guarantee the implementation of the most recent security patches, performance improvements, and bug corrections. Furthermore, delivering extensive training for IT personnel would furnish them with the requisite skills to proficiently administer and resolve issues within the enhanced infrastructure. Recognizing the difficulties posed by variable network traffic and environmental influences on signal strength data, resolving these issues would enhance the accuracy and dependability of the network.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they do not have any conflict of interest.

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