Public Wi-Fi Set-Up to Complement Existing Campus Internet Access Provided by the University of Ghana

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***Abstract*—Public Wi-Fi can be found in public places such as airports, coffee shops, University campuses, etc. The ease with which people can access the internet using public Wi-Fi is comparatively the preferred internet access technology and provides comfort to many of its users. The major issues that characterize the public Wi-Fi networks at the University of Ghana especially the School of Engineering Sciences are slow internet speeds, low bandwidth, and weak Wi-Fi signals. Wi-Fi accessibility during peak hours for serious academic work has always been a problem. There is therefore the need to provide improved wireless communication technology with improved internet speeds, higher bandwidths, and stronger signals to complement the Wi-Fi services provided by the University of Ghana. To achieve this, a Wi-Fi network was implemented to provide an alternative to the existing campus Wi-Fi. This was done using fiber optics backhaul, two Altai super Wi-Fi access points (antennas), and a Mikrotik 8 port router. The results showed a significant improvement in performance as compared to the Wi-Fi services provided by the University in terms of strength, signal bandwidth, upload, and download speeds respectively. This will help students and lecturers at the University to conduct their research work smoothly without any disruptions.**

***Index Terms*—Wi-Fi, Fiber presence, Optical Network Terminal, CAT 6 Cable, and User ID**

I. Introduction

A public network is a type of network whereby anyone in the range of the network has access and connection to the internet [1]. Public Wi-Fi networks are mostly found in airports, University campuses, coffee shops, etc., and are used for research work, entertainment, business, and general social communication. Though largely convenient, many public Wi-Fi networks are marred by numerous security threats, low efficiency, and unreliability [2]. Data from the World Bank indicates that globally, the number of internet users increased from 413 million in the year 2000 to 3.4 billion in 2016 [3]. The demand for internet access has increased as the world is getting more connected. Despite the gains in accessibility, there remains a large section of the population without access to the internet [4]. Due to its relevance in today's world, many researchers have looked into public Wi-Fi networks and have tried to suggest several ways of managing and setting up such networks with improved security, efficiency, cost, and reliability [5]. Setting up a public Wi-Fi network might cost up to $1500 or more on average and this is quite a challenge for lower-to-middle-income countries like Ghana in their quest to make internet access more affordable [6], [7].

In early 1998, the University of Ghana reached full internet connectivity in all its computer laboratories, further advancing the opportunities available to the academic community. Due to the significant growth in student population over the years, the University had to re-structure its internet network to allow for wireless access to the network so that any student with his or her laptop or mobile phone could access the network without having to be in the computer laboratory. Despite the massive improvement in internet connectivity and access across the university's campuses, there still exist several challenges with the University's Wi-Fi network. These challenges include low internet speeds, limited Bandwidth, reduced throughput at peak hours, and outdated equipment which are unable to meet the increasing number of users. This is evident during peak hours when students have to keep refreshing and waiting to simply access a particular website. These challenges make the use of the network by students on campus very difficult and unreliable. Our project is aimed at implementing a public Wi-Fi set-up to complement existing campus internet access provided by the University of Ghana. This project will be modeled and replicated all over the campus of the University of Ghana, becoming a benchmark for other tertiary institutions and organizations in Ghana [8]-[11]. The project is divided into 5 major sections. In section I, we address internet connectivity at the University of Ghana, the state of the existing Wi-Fi network in the university, and the current global state of public Wi-Fi networks and some of its challenges. section II deals with a thorough research analysis of the project field proposed

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technology, and architecture for Wi-Fi setup, their advantages, and why they were reviewed to justify this research. section III describes the architectural overview, the components used in the design implementation, and the design process of the public Wi-Fi setup. section IV will focus on the physical and software design implementation of the network, results obtained from simulations and actual implementations, and the discussion and comparison of the results. section V is the conclusion part of the paper. It highlights the key accomplishment of the work and possible recommendations for further work to enhance the performance of the system.

II. REVIEW OF RELATED WORK

Much research has been conducted on public Wi-Fi to provide the best ways of setting up public Wi-Fi networks. In doing this, some considered the network architecture, security risks, cost, wireless communication technologies, and general improvement in performance. Mardiana Mohamad Noor et al. (2013) discussed the current threats in wireless networks stating sniffing, Man-In-The-Middle (MITM), Rogue Access Points (RAP), Denial of Services (DoS), and social engineering as the most significant and persistent attacks. This paper was, however, theory-based and offered no practical countermeasure to the threats and attacks it highlighted [12]. Ullah et al. (2012) emphasized the importance of knowing the numerous wireless network technologies available and upon their research found that IEEE 802.11 (Wi-Fi) was the best wireless technology to provide internet access to public places as compared to the likes of 4G, 3G, and LTE technologies due its cost to performance ratio. Despite the clear results obtained from his research, the research approach was largely theoretical and involved no practical comparison of the technologies [13]. Sheth, S. Nedevschi, et al. (2007) conducted a test on the performance of Wi-Fi-based long-distance links using IEEE 802.11b/g standards and their observation was rather disappointing. The studied links exhibited very high and variable packet loss, resulting in very poor usability of the network [14]. Flickenger et al. (2008) used high-gain directional antennas to achieve 6 Mbps over a 382 km link. Their findings were based on a TDMA-enhanced MAC protocol notification on IEEE 802.11g standard that is necessary for long-distance links. The requirement for a line of sight between the endpoints and the vulnerability to interference in the unlicensed band was the biggest limitation of this research [15].

Our proposed work involves implementing and improving the Wi-Fi network on campus by providing a better alternative to the existing campus Wi-Fi to increase internet speeds, bandwidth, throughput, upload, and download. The School of Engineering Sciences will be used as a case study. The quality of the network is independent of the number of students accessing the network at a given time. Additionally, the increased propagation rate of the signals will ensure that students, who are about 1 km farther away from the access points can still receive very strong Wi-Fi signals and hence, access the network.

III. SYSTEM DESIGN AND METHODOLOGY

A. Operational Flow Diagram of the system

The system design network makes use of an architecture with both wired and wireless means for transmitting and receiving data signals from one layer to another. Fiber optic cables and Category 6 cables (CAT 6 cables) were used in the wired sections of the architecture whereas Altai super Wi-Fi access points were used for the wireless transmission of data signals to end users. For efficient management of the network, a Mikrotik router is used as a network management system which allows for a wide range of flexibility in the management of the network. The operational flow diagram of the entire project is shown in Figure 1 below. The flow diagram shows the step-by-step approach taken to set up the network.

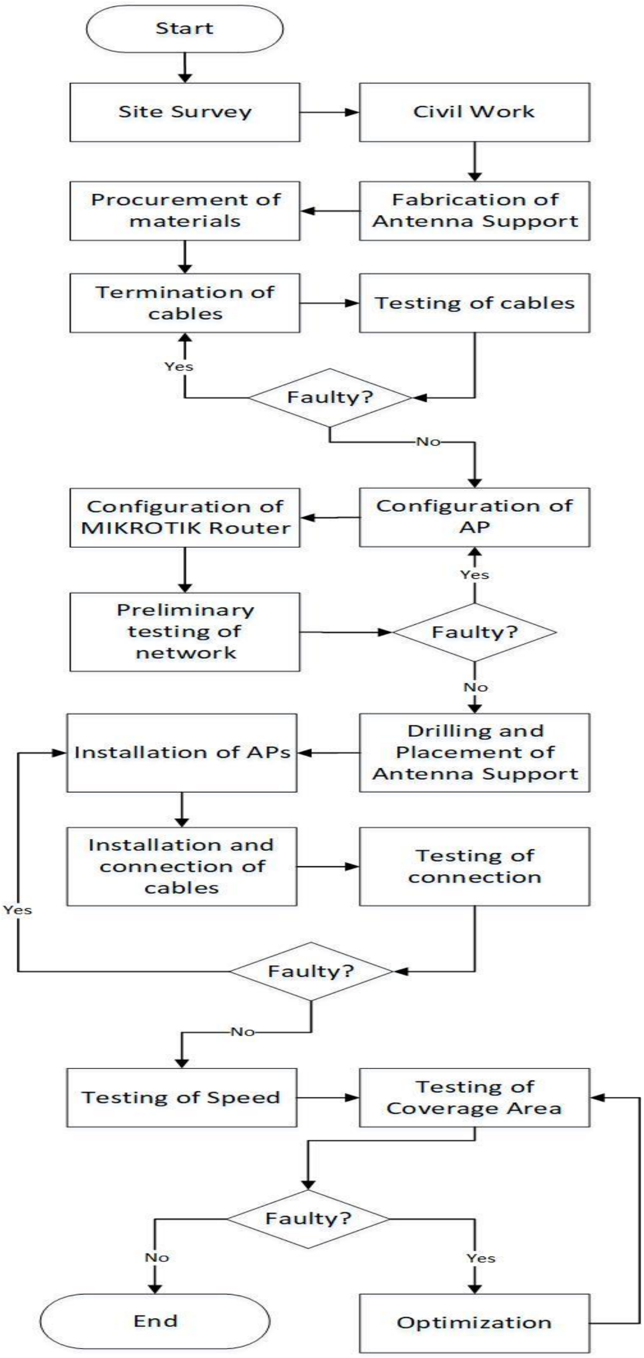

Figure 1: Operational Flow Diagram of the system

We modeled the design of the network using software before the actual implementation of our system. In simulating the model, we focused on the signal strength, download and upload speeds at various distances, coordinates of the various locations, antenna height, antenna angle, receiver sensitivity, and transmitter frequencies. We chose MATLAB WLAN Toolbox to model the network [16]. The results obtained from these simulations gave a fair idea of the expected results from the actual implementation.

B. System Architecture

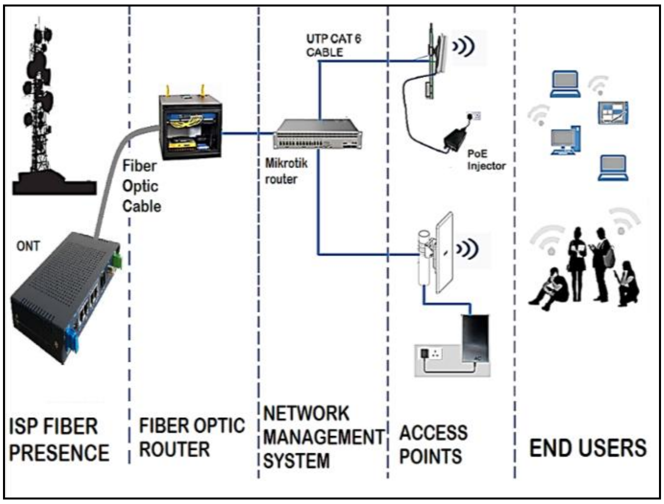

Figure 2: System Architectural Diagram

Figure 2 above shows the architectural layout of our public Wi-Fi network. Our architecture employs both wired and wireless means of transmitting signals across the network. It has five layers from the ISP fiber presence to the end users with a network management system inclusive to regulate the use of the network. This project was implemented at the premises of the U-TON Engineering Company in Accra, Ghana. MTN Ghana was the internet service provider (ISP) for this project. MTN provided us with two presence, fiber and wireless. The ever-growing transmission capacity demand in optical transmission systems has brought out the necessity of increasing spectral efficiency by employing different transmission techniques and also increasing transmission speed in optical networks [17]. We chose fiber for this project. After successfully running fiber presence to the premises, we connected the fiber optic cable to the fiber optic router. The fiber optic router is specifically equipped to support fiber internet. The fiber optic router connects to an optical network terminal (ONT) which converts the fiber optic signals into ethernet. For easier compatibility, the Huawei 300 Mbps wireless router was chosen for this purpose. This router operates at a 2.4 GHz frequency and offers a throughput of 300 Mbps. A special link function in the router allows the user to conveniently connect to a second router to extend signal strength and range, in our case, the Mikrotik router. A CAT 6 cable is connected from the ethernet port of the fiber optic router to the ethernet port of the Mikrotik 8-port router. The Mikrotik router is needed for the efficient management of the network. This involves user authentication, traffic management, bandwidth management, and network scalability. The Mikrotik router is connected to a laptop or any other personal computer, where the configuration of the router is done. This is the stage where the network is named, where user IDs are assigned, and the number of users is determined. Other restrictions to network usage are applied here. Two access points, the Altai A3-Ei dual-band 3x3 Wi-Fi access point (AP) and the Altai AX 500 2x2 802.11a wave 2 access point were used [18], [19]. The two APs can serve 1024 users. Both access points are connected to the LAN ports of the Mikrotik router from the ethernet ports on both access points using a CAT 6 cable. The access points have integrated 2.4 GHz and 5.0 GHz antennas, ethernet LEDs, power LEDs, ethernet ports, etc. After successfully connecting the cables from the Mikrotik router to the access points and testing them, the access points were installed on the walls at desired positions. After the successful installation of the access points, ethernet cables are run from the Mikrotik router to each access point. The access points were tested again and the necessary adjustments in the positioning of the antennas were done to get the best spot for end users.

IV. IMPLEMENTATION AND TESTING

A. Configuration of APs and Routers

Two metal supports were mounted to hold the access points. To do this, we surveyed the entire building to identify suitable positions for the installation of the access points. In doing this, we considered several factors including wide coverage area, height, safety, and ease with which adjustments could be made to the positions of the access points after installation. All the parts of the access points and routers were configured and tested to ensure that they are working. They were then mounted on a metal support. The parts of the Mikrotik router were also assembled and configured. The configuration of the access points was done before they were mounted. We connect the access points to the Mikrotik router and then to a laptop. The configuration was done using a web software called Winbox. We set up a wireless interface and set the mode to ap-bridge, frequency to ap_operated_band, and SSID to network identification. We then name the access points and assign IP addresses to them. This is done for both access points.

For the Mikrotik router, open Winbox. Go to the bridge and change ‘bridge’ to LAN. Go to port and reserve Ports 1 and 2 for ‘internet in’ and ports 3 to 10. Now, go to IP then hotspot setup. Fill in the DNS details and name the network “XTAYCONNECT” and provide an admin name and password for the router. Add a gateway IP and add end users.

B. Creating a Login page

After successfully installing both access points, user accounts were created for various users to test the efficiency of the network. After turning on the Wi-Fi buttons, the name of the network, XTAYCONNECT appears and an attempt to use the network will redirect users to a sign-up page where users are required to enter their credentials before being able to access the network. A wrong input of credentials will display an invalid username or password message to the potential user. The login page was designed using HTML and hosted on the Mikrotik router. It requires specific HTML commands and syntax to be able to be compatible with the system and be responsive when being used. Internet access is not a requirement to access this page as it is not hosted online. When a user wants to access the Wi-Fi network, they can select the network “XTAYCONNECT”. They are redirected to a login page

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hosted on our network management system. The end user enters his/her credentials which are authenticated and verified to allow the person fast, reliable internet. If the details are wrong, they receive an error message and are directed to re-enter their credentials.

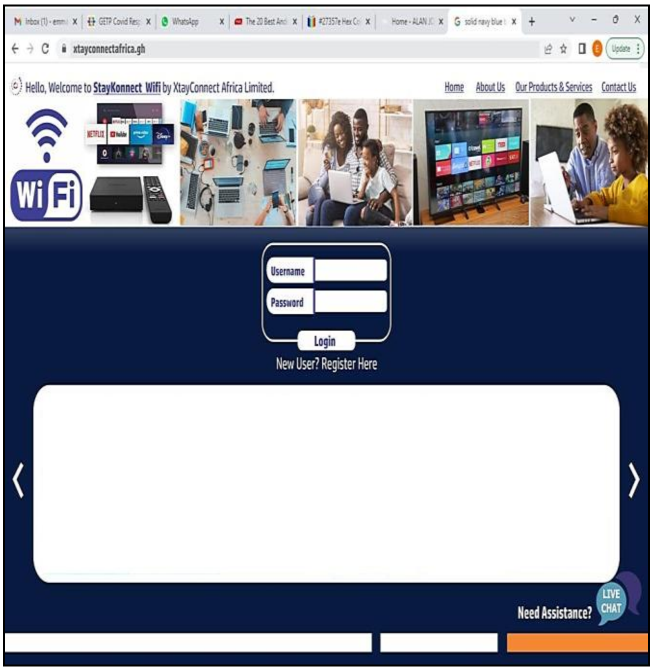

Figure 3: Image of Login Interface

C. Preliminary Testing of the System

Using a Wi-Fi analyzer, we navigated the streets to determine the full range of the network, the signal strengths at various locations, and the upload and download speed at various locations as well. We also determine the total number of users the network can support at a time and determine the average peak-hour speed.

D. Simulation of Frequency Bands

We simulated various distances using MATLAB from the access points to the end users. This represents every coordinate point that we took measurements. The antenna used was a dual-band which used two frequencies (2.4 GHz and 5.0 GHz). We check the signal strength output for 2.4 GHz and 5.0 GHz frequency bands. This helped us to determine the signal strength. Their performances were within the acceptable range. The table below shows the signal strength obtained at different distances.

The signal strengths obtained were in the range of 13% to 76% for the 2.4 GHz band and 8% to 74% for the 5.0 GHz band respectively. The total change or loss between the distance of 0.04 km and 0.96 km from the access point to the end users for 2.4 GHz and 5.0 GHz were 63% and 66% respectively, which is within the acceptable range. The graph also showed a gradual decrease in signal strength as the distance increased. This is due to attenuation and other external environmental factors.

E. Results from System Implementation

The implementation results were recorded using a Wi-Fi analyzer software at the site. Parameters that were examined included signal strength, signal power, upload speed, and download speed. The measurements were taken at specific distances. The same process was repeated using the campus Wi-Fi at the School of Engineering Sciences, University of Ghana. The results obtained from both measurements were compared to determine the system's performance. Also, the signal strength from both readings was compared to the simulated results from the frequency bands.

Table 1: Signal strength for 2.4 GHz and 5 GHz frequency bands at different distances

Distance (km)	Signal strength (%) for 2.4 GHz	Signal Strength (%) for 5 GHz
0.04	76	74
0.06	75	73
0.08	72	71
0.24	68	73
0.36	66	57
0.40	44	61
0.56	46	55
0.64	53	43
0.72	31	16
0.80	15	12
0.96	13	8

i.2.4 GHz and 5 GHz frequency bands at different distances

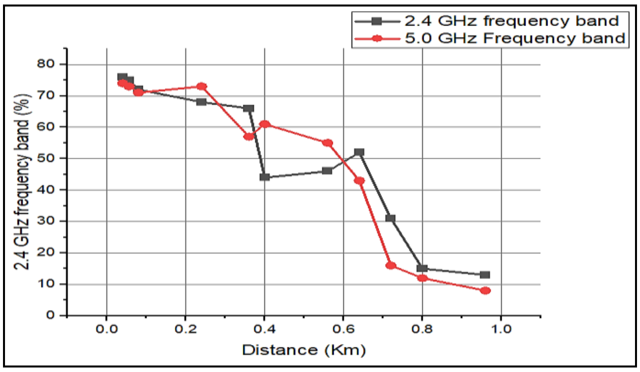

Figure 4: Graph of Signal Strength against Distance of Simulation

Table 2: Wi-Fi analyzer measurement at U-Ton Engineering Limited, Ghana

Distance (km)	Signal Strength (%)	Signal Power (dBm)	Upload (Mbps)	Download (Mbps)
0.04	83	-57	41.30	40.30
0.06	58	-51	19.92	25.34
0.08	73	-43	24.14	29.04
0.24	56	-56	4.05	25.20
0.36	69	-59	4.11	9.85
0.40	50	-60	17.4	18.20
0.56	42	-69	0.10	0.47
0.64	50	-68	1.79	5.85
0.72	41	-88	0.01	0.08
0.80	39	-76	0.69	0.84
0.96	40	-79	0.65	2.65

Table 3: Wi-Fi analyzer measurement at the School of Engineering Sciences, University of Ghana

Distance (km)	Signal Strength (%)	Signal Power (dBm)	Upload (Mbps)	Download (Mbps)
0.04	75	-69	8.07	0.52
0.06	44	-71	6.06	0.94
0.08	46	-58	7.56	0.62
0.24	40	-64	5.28	0.59
0.36	37	-60	5.35	0.56
0.40	40	-68	1.47	0.50
0.56	35	-66	2.60	0.13
0.64	38	-72	0.35	0.32
0.72	32	-65	3.00	0.72
0.80	65	-44	12.44	0.90
0.96	41	-66	11.25	0.77

i. Signal Strength

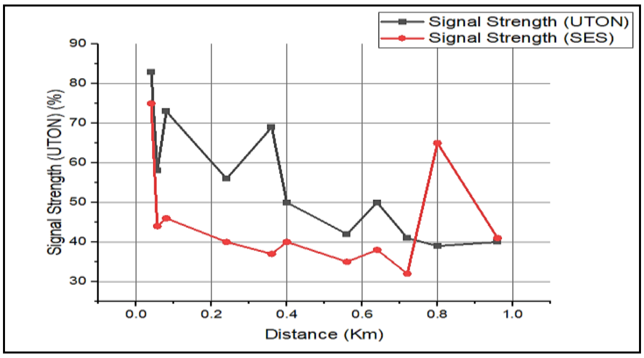

Figure 5: Graph of Signal Strength against Distance

From the site implementation, it was observed that the signal strength was in the range of 39% to 83%. The difference was 44%. The significant difference between the simulation results and practical results was that the simulation results did not account for obstruction from buildings, tall structures, and other factors as compared to the practical results. Between 0.36 km and 0.56 km, there is a drop in signal strength as a result of a church building located directly opposite the project site. This building was a significant obstruction to the signal from our access point causing a drop in signal strength. Results from the School of Engineering Sciences showed that signal strength was in the range of 41%-75%. The difference was 34%. At 0.8 km, there is a spike in signal strength as a result of interference from another access point. This access point was not part of the reference point. This occurred because of the arrangement of access points used on campus. Our distance was 0.8 km away from the reference access point but it was closer to another access point in the vicinity which interfered with and caused this rise in signal strength at that point. From the above graph, it is evident that the signal strength of our system is relatively higher than the existing Wi-Fi setup at the School of Engineering Sciences. Despite all the obstructions we faced, our system performed better.

ii. Signal Power

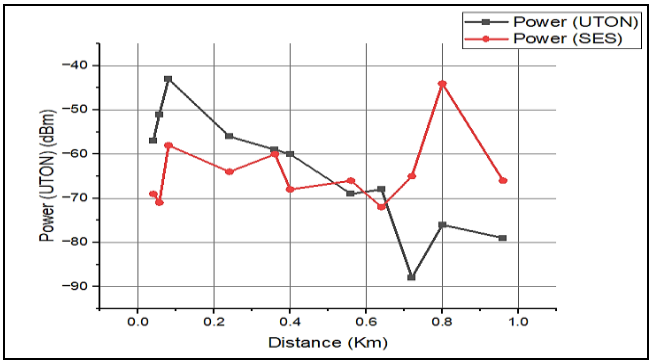

Figure 6: Graph of Power against Distance

From the graph, the results obtained from the site measurement were in the range of -43 dBm to -88 dBm. The difference was -45 dBm. But we also realized the power kept reducing with an increase in distance. This is due to the large-scale fading which is the gradual decrease in the power of a signal with an increase in distance. The School of Engineering Wi-Fi had a power measurement of -44 dBm to -72 dBm. Similar to the signal strength, we noticed that at 0.8 km, there is a spike in power as a result of interference from another access point other than our reference access point which is closer to the point at which we recorded our results. From the above graph, the overall output and performance of our system concerning power are relatively higher than the existing Wi-Fi setup at the School of Engineering Sciences although there are instances where the School's Wi-Fi setup is higher due to the interference from another access point other than our reference access point causing a spike in the power.

iii. Upload Speed

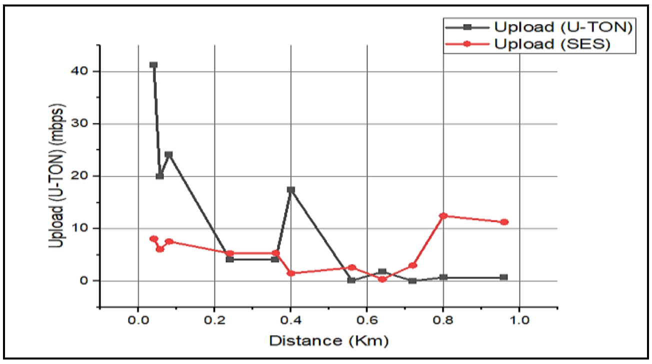

Figure 7: Graph of Upload against Distance

The upload speed of our implemented system was sloping down whiles the distance increased. Its range was from 0.01 to 41.3 Mbps and the difference was 41.29. The effect of the interference at a distance of 0.72 km is also seen here. At the School of Engineering Sciences, there was a spike in upload speed at 0.8 km as a result of interference from another access point other than our reference access point which is closer to the point at which we recorded our results. The peak upload speeds of our system at the distances recorded are faster than the existing Wi-Fi setup at the School of Engineering Sciences. Our observations showed earlier that the upload speed of the school's system is quite high compared to the download speed and compares with our system well in this regard.

iv. Download Speed

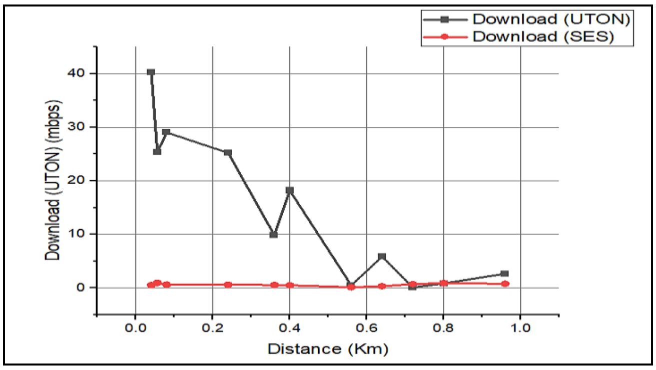

Figure 8: Graph of Download against Distance

The download speed of our implemented system was sloping down while the distance increased. Its range was from 0.08 to 40.3 Mbps and the difference was 40.22. Generally, download speed makes up the internet experience for most users. In any activity, downloading consumes more data hence the comparatively higher values for the download speeds. In the Engineering School, the effect of the interference at a distance of 0.72 km is seen. There is a spike in download speed as a result of interference from another access point other than our reference access point which is closer to the point at which we recorded our results. We also noticed that the upload speeds of the Wi-Fi setup of the School of Engineering Sciences were higher than the download speeds and a major factor to the low internet speeds experienced by students and lecturers as a higher majority of productivity is dependent on download speed. From the above graph, in terms of download speed, our system at different distances recorded a faster download speed than the existing Wi-Fi setup at the School of Engineering Sciences. This means that it will provide faster internet speeds and improve throughput at peak hours.

IV. CONCLUSION

The public Wi-Fi network in the University of Ghana, particularly the School of Engineering Sciences has not adequately met the needs of the students and lecturers, making it necessary for a new and improved Wi-Fi network to support the existing campus network. Challenges such as low internet speeds, limited bandwidth, and outdated equipment are unable to support the increasing needs of users. The objective of the research was to set up a network with relatively better performance than the existing campus network. One major advantage of our architecture is the ability to scale up the network to serve more users without compromising on performance. The Mikrotik router served as a network management system and allows for feasible scalability of the network without any major change in the network architecture and without compromising on performance. This innovation together with other improved technologies saw the newly set up network outperform the existing campus network in all aspects. Implementation of our proposed system to complement the existing campus Wi-Fi will significantly improve internet connectivity in the school. This will enable students and lecturers to undertake their research, participate in virtual classes, take online quizzes, and take online courses. Additionally, the increased propagation rate of the signals will ensure that students, who are about 1 km farther away from the access points can still receive very strong Wi-Fi signals and hence, access the network. It is recommended that a taller pole support for the access point should be used to increase the coverage area. Also, the employment of repeaters or amplifiers at points where signal strength begins to reduce will facilitate constant strong signals at every distance in the APs range and even beyond.

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REFERENCES

[1] S. C. Gao, L. W. Li, M. S. Leong, and T. S. Yeo, “Dual polarized slot coupled planner antenna with wide bandwidth, IEEE Trans. Antennas Propagation, vol. 51, Mar. 2003, pp. 441-448.

[2] Y. Liu, J. Xue, H. Wang, and S. Gong, “Low-profile omnidirectional dual-polarized antenna for 2.4 GHz WLAN applications,” *Electron. Lett.*, vol. 50, no. 14, Jul. 2014, pp. 975-976.

[3] E. A. Okon, “Analysis of internet access and use by academic staff in the University of Calabar, Calabar, Nigeria”, vol. 31, no.7, Mar. 2010, pp. 535-545.

[4] E. A. Okon “Internet access and use: A study of undergraduate students in three Nigerian universities” vol 28, no. 4, 2009, pp. 555-567

[5] A. Y. Lotfy, A. M. Zaki, Tarek Abd-El-Hafeez, and T. M. Mahmoud, “Privacy issues of public WiFi networks”, Proceedings of the International Conference on Artificial Intelligence and Computer Vision, Jun. 2021, Settat, Morocco.

[6] I. Ullah “A study and analysis of Public WiFi”, Final Thesis, Department of Computer and Information Science, Oct. 2012.

[7] A. Sheth, S. Nedevschi, R. Patra, S. Surana, et al, “Packet Loss Characterization in Wi-Fi based Long distance Network,” IEEE Communications Magazine, vol 22, 2007, pp. 311-320.

[8] D. Aguayo, J. Bicket, S. Biswas, D. S. J. D. Couto, and R Morris, “Architecture and Evaluation of an Unplanned 802.11b Mesh Network”, Proceedings from the annual international conference on mobile computing and networking, Oct 8, 2005.

[9] R. Patra, N. S., S. Surana, et al, “WiLDNet: Design and implementation of High-Performance Wi-Fi Based Long Distance Networks., 4th USENIX Symposium on Networked Systems Design & Implementation, Apr. 2007, pp. 87-100.

[10] K. Nwanua Ohei and R. Brink, “The effectiveness of Wi-Fi Network Technology on Campuses and residences for an improved learning experience and Engagement”, vol. 39, no. 1, Mar. 2021.

[11] Luca Belli, Bruno Ramos, “The Community Networks Manual: How to Build Internet Yourself”, Nations Internet Governance Forum, Nov. 2018.

[12] Barend Kobben “Wireless Campus LBS: A Test Bed for WiFi Positioning and Location Based Services”, vol. 34, no. 4, Mar. 2013, pp. 285-292

[13] M. N. Mardiana and W. Haslina, “Current threats of wireless networks”, 3rd International Conference on digital Information Processing and Communications, DICTAP, 2013, Czech Republic.

[14] A. Sheth, S. Nedevschi, R. Patra, S. Surana, et al, “Packet Loss Characterization in Wi-Fi based Long distance Network,” IEEE Communications Magazine, vol 22, 2007, pp. 311- 320.

[15] R. Flickenger, S. Okay, I. Pietrosemoli, M. Zennaro, and C. Fonda, “Very Long-Distance Wi-Fi Networks”, Proceedings of the second ACM SIGCOMM workshop on Network systems for developing region, Aug. 2008.

[16] L. S. Xiao, L. Li, S. W. Cheung, and T. I. Yuk, “Dual-band antenna with compact radiator for 2.4/5.2/5.8 GHz WLAN applications,”

IEEE Trans. Antennas Propagation., vol. 60, no. 12, Dec. 2012, pp. 5924–5931

[17] Aboagye Isaac Adjaye, Chen Fushen, and Cao Yongshen "Performance Analysis of 112 Gb/s PDM-DQPSK Optical System with Frequency Swept Coherent Detected Spectral Amplitude Labels' WCE, Jul. 2016, London, UK.

[18] R. Murty, J. Padhye, A. Wolman, and M. Welsh, "Dyson: An Architecture for Extensible Wireless LANs," Proc. 2010 USENIX Annu. Tech. Conf., 2010, pp. 14-27.

[19] S. Pandey and V. Tyagi, "Performance Analysis of Wired and Wireless Network Using NS-2 Simulator", International Journal of Computer Application, vol. 72, no. 21, Jun. 2013, pp. 38-44.

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