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A Comparative Study of Hybrid Network (Powerline Communication and Wi-Fi) and Wireless Network Using University of Benin's Computer Engineering Laboratory as a Case Study

Aideyan I. Winifred[a], K.B Erameh[b]

[a,b] Department of Computer Engineering, Faculty of Engineering, University of Benin, 1154, P.M.B, Ugbowo Lagos Road, Benin City, Nigeria.

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Abstract

In the last years, it can be observed that the fundamental and most implemented network used in Nigeria is the Wired LAN and Wireless LAN as a choice to enjoy high-speed broadband access. Because of the low cost and portability of Wi-Fi technologies, wireless network deployment has been widely accepted within residential environment. With the arrival of Power Line Communication (PLC) a whole new generation of last-mile broadband internet access solutions has surfaced which has low cost, high data-rates, better portability and forms a network over electrical wiring in an already existing infrastructure. In this article, we provide a comparative overview of the hybrid network (PLC and the Wi-Fi) and a pure wireless network. This study is based on cost survey and experimental setup analysis of the hybrid network and the wireless network. For the experimental measurement, it focuses on network parameters which consist of throughput, coverage, signal strength, transfer speed and packet loss using the University of Benin's Computer Laboratory as the test bud. As it was observed from the study, both networks performed above average so the users have to critically examine what he/she needs from a home network using the parameters listed above. In summary, it is advisable to apply hybrid network when building home network as it offers better advantages as regards to some of the network parameter and does not get affected by distance or wall barriers.

1. Introduction

The world is becoming more interconnected with the coming of the Internet and various new networking technologies. Candidate networking technologies for providing convenient and widespread residential and small/home office networking services could also be categorized as wired networks, wireless networks, and hybrid networks (no new wires networks) [1, 2]. Wireless networks like Bluetooth, HomeRF and 802.11x may be constructed by installing multiple interconnected Wireless Access Points (WAPs) and base stations within specific areas [3]. The best advantage of using wireless networks is the freedom to maneuver around while maintaining network connectivity. The most interesting and widely accepted wireless networking technologies is the family of IEEE 802.11x [4]. High-speed wireless LANs can provide the advantages of network connectivity without the restrictions of various numerous wires. Some kinds of buildings like ancient heritage buildings may disallow the laying of new wiring, making wireless networking a vital alternative. And noted that, the "no new wires" phenomenon involving wireless, together with PLC networking has become a significant catalyst for home networking and alternative broadband internet [5]. Powerline Communications (PLC) is a variety of communication that uses electrical

wiring to convey both data and electrical supply in form of alternating current (AC) through existing electrical infrastructure. It connects computers using existing power outlets within the home, essentially transforming every electrical outlet within the building into a network connection [3]. With the demand for combining diverse technologies increases, new specifications for hybrid networks are developed more frequently.

A hybrid network involves a type of network made of hybrid devices capable of both Wi-Fi and powerline communications [3]. This is a modern environment where different technologies can link up to provide better broadband access. It uses the present low-voltage (110/220V) power lines for communication based on the HomePlug Powerline Alliance's Standard and Wi-Fi, which enables one to establish an Ethernet class network over these lines and also wireless connections [1]. Power lines make a poor communication channel due to electrical noise, interference, and channel variability counting on the appliances in use. However, tests of Home plug powerline devices in some 500 homes show that 80% of outlet pairs are able to communicate at about 5 Mbps or higher [5]. Existing literatures has focused on [2] the results measurements demonstrate that throughput performance of the hybrid and non-hybrid network is incredibly similar when the communication is created within the same floor or between two floors. When the communication is carried out at least three floors, the measurements shown that hybrid technology can improve the signal quality in locations that cannot be covered with Wi-Fi device while [8] They have shown that PLC can yield significant performance gains when combined with Wi-Fi networks. They introduced an experimental framework and investigated the performance of PLC. [4] The main aim of this article was to conduct a practical and theoretical equivalence of the IEEE 802.11x and HomePlug 1.0 protocols and their capableness in providing networking functionalities. From the theoretical results, it can be observed that Home Plug 1.0 and 802.11x had similar level best efficiency. The significantly higher maximum PHY data rate of 802.11a would indicate that it should perform better than the other two standards, but in field tests its coverage was not as good.

This paper presents an investigation of two cost-effective, efficient and reliable options for providing good in-home networks. The first one is the wireless LAN based on the IEEE 802.11 standards only and the other is hybrid LAN based on IEEE 1905 standard (combination of PLC and Wi-Fi) using Signal Strength, Coverage, Packet loss, Transfer speed in using Computer Engineering laboratory which contained one hardware laboratory, the departmental library, one software laboratory and two administrative offices.

1.2. Governing Standards for the Network

a. IEEE 802.11 PHY Layer

At the physical layer, the family IEEE 802.11x (a\b\g\n) contains b frequency-hopping spread spectrum (FHSS) and direct sequence spread spectrum (DSSS) transmissions. Using the 2.45 gigahertz (GHz) Industrial, Scientific, and Medical (ISM) frequency band ,the original bit rates for IEEE 802.11 group was 2 and 1 megabits per second (Mbps. The maximum bit rate for IEEE 802.11a is 54 Mbps using orthogonal frequency-division multiplexing (OFDM) and the 5.8 gigahertz (GHz) frequency band while) while for IEEE 802.11b is 11 Mbps using DSSS.

b. IEEE 802.11 MAC Sublayer

At the Media Access Control sublayer, IEEE 802.11x family involves the carrier sense multiple access with collision avoidance (CSMA/CA) protocol. It provides multiples of functionality such as control medium access, support for roaming, authentication, power conservation and the mandatory asynchronous data service as well as an optional time-bounded service.

c. IEEE 1901

This standard uses transmission frequencies below 100 MHz with the high-speed rate of about 100 Mbps at the physical layer via power lines, known as broadband over cable (BPL) devices. This standard highlights the benefits and efficient use of the facility line communications channel of all types of BPL devices and the electrical wiring is a very versatile networking backbone that has an outlet in every room.

1.3 Data Measurement and Analysis Tool

a. Iperf

Iperf is network performance measurement tool for TCP and UDP protocol. It is a client and server mode which will measure throughput between two network nodes representing various parameters like time, packet size, for a testing network either one-way or two-way. The output of Iperf could be a time-stamped report consisting of the throughput and the amount of knowledge (traffic) transferred for a specific amount(duration), during this thesis, iperf was employed to get experimental traffic flow with different transfer rate in results.

b. NetSpot

NetSpot collates every detail about surrounding Wi-Fi networks and presents all metrics of the wireless data as an interactive table in real-time. It provides the ability to troubleshoot, support and improve your network's coverage, capacity, and signal level as well as transfer rate.

c.Command Prompt

The Command Prompt in Windows operating system (Os) provides the clients access to over 280 commands. These commands used Dir, Ipconfig and ping which shows the Ip address, packet loss and the transfer speed.

2. Methodology

2.1 Cost Survey

The various components used to set up the wireless and hybrid network was critically checked using the World Wide Web (limited to konga, Aliexpress and Jumia) as well as one on one interview in the Nigeria market; JOCHE Computer warehouse, Smile Benin office and Tadeo Empire.

2.2 Experimental Setup

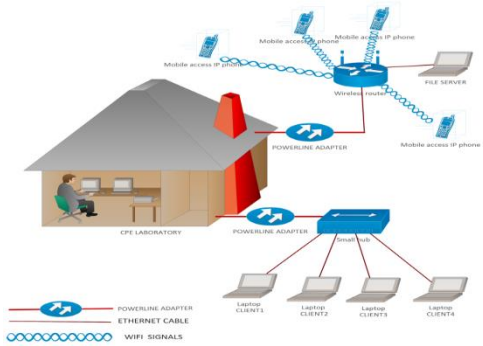

Figure 1: Hybrid Network

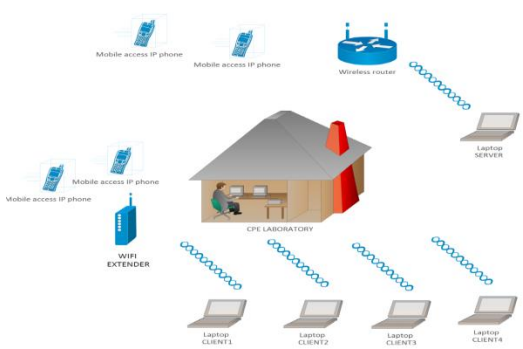

Figure 2: Wireless Network

In Figure 1, the router is connected to the powerline adapter transmitter at the base station and also connected to the laptop which is acting as the server via two ethernet cables The powerline adapter receiver is connected to the wall socket and also the hub at different distance intervals. In Figure 2, only the router was connected to power (for power supply) at the base station, then the clients connected wirelessly at different distance intervals for measurement.
The Computer Engineering laboratory consists of the hardware laboratory, software laboratory, departmental library and two administrative offices. Each network contains four PCs (one used as the file server while the rest were clients), the systems were moved from one point to another within the computer laboratory. The hybrid network usually requires direct wall sockets (no extensions) while the wireless network uses electromagnetic waves. The router (192.168.1.1) used assigned IP addresses to them dynamically. The distance intervals from point Zero to point F are displayed as follows:

Point Zero
The base station is where the file server system, router and the receiver are located (fixed location at the hardware laboratory for both networks).
Point A:
At the hardware lab, the powerline adapter's transmitter is placed at the wall socket 11ft away from the receiver.
Point B
At the hardware lab, the powerline adapter's transmitter is placed at the wall socket 54.4ft away from the receiver.
Point C:
At the hardware lab to the software lab, the powerline adapter's transmitter is placed at the wall socket 68.4ft away from the receiver.
Point D:
At the hardware lab to the software lab, the powerline adapter's transmitter is placed at the wall socket 69ft away from the receiver.
Point E:
At the hardware lab to the library, the powerline adapter's transmitter is placed at the wall socket 75.5ft away from the receiver.
Point F:
At the hardware lab to the library, the powerline adapter's transmitter is placed at the wall socket 86ft away from the receiver (in the other room).

Note:
Using the same distance of the hybrid network, the client computers were moved and measured at the same points for the wireless network.

2.3 Methodology Flow Chart

Table 1: Methodology Flow Chart

Hybrid Network	Wireless Network
• Setting up the network • Each PC receives IP address from the DHCP domain • Test the network for connectivity • Point A	• Setting up the network wirelessly • Each PC receives IP address from the DHCP domain • Test the network for connectivity • Point A

Ping the file server, transfer the 300mb file, use iperf3 tool. • Measure distance, transfer speed, throughput, packet loss and reliability of the network • Repeat the previous step at points B,C,D,E, F • Record values	Ping the file server, transfer the 300mb file, use iperf3 and NetSpot tool • Measure transfer speed, packet loss, throughput, signal strengthen, and the reliability of the network. • Repeat the previous step at points B,C,D,E,F • Record values

The computer laboratory has no network implemented before this project, so a mini-survey was carried out to check for the number of electrical appliances connected to electricity, the distance between them as well as the wall thickness which was 10.5 inches. Each room has two air conditioners of about 1.5hp, at least two fans and five wall sockets. The AC located at my base location (hardware lab) was powered off throughout the measurement period as it was affecting the Powerline transmitter, making the network unstable.

3. Results and Discussion

Table 2: Hybrid Network Parameter Measurements

Points	**Throughput (Mbytes)**			**Packet Loss (%)**			**Transfer Speed (Mbps)**			**Signal Strength (dBm)**		
	CLIENTS			**CLIENTS**			**CLIENTS**			**CLIENTS**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
A	76.4	77.2	84.4	0	0	0	9.34	8.94	8.60	-51	-55	-57
B	71.4	77.1	71.8	0	0	0	2.3	465kb	1.6	-63	-55	-68
C	21.1	19.9	21.0	0	0	0	819kb	1.39	1.04	-68	-75	-63
D	8.12	6.63	8.5	0	0	0	1.39	1.03	710kb	-74	-79	-76
E	528 Kb	400 Kb	6.15	25	75	25	655kb	452kb	554kb	-80	-79	-78
F	670kb	512 kb	667 Kb	100	100	100	--	--	--	-85	-75	-83

Table 3: Wireless Network Parameter Measurements

Points	Throughput (Mbytes)			Packet Loss (%)			Transfer Speed (Mbps)			Signal Strength (dBm)		
	CLIENTS			CLIENTS			CLIENTS			CLIENTS		
	1	2	3	1	2	3	1	2	3	1	2	3
A	19.9	9.95	19.8	0	0	0	2	2.8	1	-68	-60	-65
B	15.8	1.75	15.5	0	0	0	2.49	1.8	2	-70	-71	-74
C	9.0	7.63	2.62	0	0	0	863kb	1.04	710kb	-87	-78	-83
D	5.98	1.08	9.80	0	25	0	512kb	--	355kb	-79	-81	-69
E	3.64	4.24	6.44	0	25	25	766kb	512kb	355kb	-61	-66	-65
F	1.93	6.94	6.01	0	25	0	360kb	680kb	649kb	-69	-69	-75

From Tables 1 to 3, it was observed that at point A, B and C all the network parameter was stable and reliable for effective communication and transmission for both the networks. And losses began to occur, mostly in the hybrid network.

Over 75ft from the base station, the packet loss rose from 0% to 25% when the client pinged the server system to test for connectivity in the hardware laboratory, the two ACs were turned on but they were in adjacent position from point C AND D's wall sockets. In the wireless network due to the presence of thick walls, it was observed that the packet loss started from point D for only one of the client systems. Then from point E and F, it was discovered that the packet loss was 25% and transmission still occurred smoothly

It was observed that the transfer speed for the hybrid network was much higher when compared to the wireless network. The maximum speed was 9.34mbps and 2.9 Mbps respectively during the process of transferring a 300mb file from the server to the client systems simultaneously. From point E (Library) the transfer speed drastically went down, it was greatly affected by both the distance and the presence of various electrical appliances (mobile phones, laptops, and the air conditioner) plugged to the wall sockets. Then for point F, the receiver was connected directly under the AC's switch so we have negligible transfer speed which ended up at 0 Mbps after 13% of transmission.

The signal strength for the mobile phones of both networks remained the same. The mobile phones signal strength for point A, B AND C status was very good, it was observed to have a signal for different applications that required very stable, reliable, well-timed delivery of data packets. They

mostly varied as we moved from one point to another then points D, E and F, the signal strength was just good for reliable packet delivery.
Signal strength for the clients' systems at points A and B only was very good then from point C and D was average but fluctuating. Due to the presence of the Wi-Fi extender, the signal picked up again and was stable with very good signal strength for more efficient communications and transmission. Based on findings, it is advisable to apply hybrid network in the developing of a home network as it offers better advantages as regards to all the network parameter and that we avoid the use of extra or new cables that needs permanent maintenance and might also cost up to few thousands naira when installed in an environment. This technology already exists in domestic application which allows data transfer at high throughput via the electrical network. However, the main disadvantages that the network starts fluctuating when the electrical appliances are of high rating are connected the physical environment becomes very uncongenial for the data transportation, thus there are still other properties of the power systems which influence the high-speed communications negatively (such as losses in the cable, propagation in multiple paths and the noise) than for which it is advisable to use wireless networks when these conditions applied.

Table 4: Comparison for One-On-One and Online Interview

Name of company	**Router ₦**	**Powerline adapter ₦**	**Wi-Fi Extender ₦**	**Hub ₦**	**website**	**Router ₦**	**Powerline adapter ₦**	**Wi-Fi Extender ₦**	**Hub ₦**
JOCHE	25,700	-	17,300	5000	JUMIA	20,500	36,000	15,999	10,000
SMILE	23,400	-	-	-	ALIEXPRESS	24,909	13,288	14,400	9,515
TADEO	23,000	-	16,000	4500	KONGA	25,000	35,000	14,500	5,400

During the one-on-one interview, the first two companies had zero or little idea about the powerline adapter; it was only Tadeo that had the possibility of ordering the device from his Chinese supplier. It was also found that our every own jumia.com had to use Jumia global to make it available for users but the only issue is that it became expensive while the other Aliexpress and Konga had the component available.

4. Conclusion

This study compared the two networks for implementing small/home office network without extra cable installation in the environ. Throughput for the hybrid network shows higher values of transmissions than the wireless network which was just average. For data rates of 5 Mbps and higher, the hybrid network took the lead due to its little higher maximum data rate. The overall results from Table 1 and Table 2 show that the hybrid network outmatches the wireless network. But the wireless network performs better under congested conditions such as overloading from electrical appliances; this really affected the loss rate of the hybrid network. In terms of coverage, the recorded data showed that the hybrid network had the best coverage until the Wi-Fi extender was added to the wireless network and at that point, the wireless network had the best coverage. As the measurement

was carried out and recorded, it showed that the hybrid network exhibited greater link stability while wireless network showed greater variability in both close and far distance from the base station. The awareness of the powerline adapter is very low leading to the unavailability of the device, from Table 4 the components to make up the wireless network is readily available and much cheaper so it takes the lead in the cost analysis. Both the PLC and wireless technology have significant scope for improvement over the existing standards as evaluated in this project. The users have to critically examine what he/ she needs from a home network: average speed, higher throughput, 0% rate loss or a cheaper and easy to setup network.

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Appendix

Table A1: Signal Strength and Status

Signal Strength	Status	
-30 dBm	Awesome (90-100)	Maximum achievable signal strength. The client can only be a few feet from the AP to achieve this.
-67 dBm	Very Good (75-89)	Minimum signal strength for targeted applications that needs very reliable or fast delivery of data packets.
-70 dBm	Okay (50-74)	Required signal strength for reliable packet delivery.
-80 dBm	Below Average (45-50)	Minimum signal strength for basic connectivity. Packet delivery may be unreliable.
-90 dBm	Bad (0-44)	Encountering the noise floor. Very low connectivity.