

(REVIEWED)

## ANALYSIS OF RESULTS

The project titled: Design and construction of a Power line communications (PLC) modem for domestic LAN.

(STAGE 4)

<b>Observation raised</b>	<b>Status</b>	<b>Action taken</b>
Section 1.1 (Introduction)	Amended as recommended by technical review	Paraphrased
Section 1.2 (Table 1)	Amended as recommended by technical review	Abbreviations and units corrected
Section 2.2 (Table 2)	Amended as recommended by technical review	Maximum data rate added
Section 3.1	Amended as recommended by technical review	Values of $F_c$ retaken again and updated correctly
Section 3.3.1	Amended as recommended by technical review	Test time was extended and reported that the module can function for as long as it is powered but experiences intermittent disconnection based on channel conditions) Figure 6:- Amended under flow chart page 18
Section 3.4	Amended as recommended by technical review with additional comments	<ul style="list-style-type: none"> <li>• Error control will affect the throughput positively</li> <li>• Megabits per second (Mbps) is used to describe the speed at which digital data travels from one point to</li> </ul>

		<p>another. The capacity of a connection is referred to as its bandwidth. Bandwidth is measured in bits per second and one Megabit per second is 1,000,000 bits per second.</p> <ul style="list-style-type: none"><li>• <b>Table 14</b> :- When the module was connected to the internet, the receiver was able to access the internet despite the lost datagram but at a lower speed. The module was able to achieve a speed of between 1-5Mbps despite the lost data. These modules can also be designed pair with more than one module and hence the lost packets are routed to other terminals for other devices applications.</li><li>• <b>Table 20</b> has been updated as recommended y</li></ul>
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		technical review
Section 4.1	Readings re-taken to address technical reviewer observation	The Analyzer reported the SNR value of 39dB (Fig 25) but another analyzer is being required to validate the reading
General comment	Adaptive modulation	The module encoder used The module support robust OFDM mode modulation 200Mbps (homeplug AV specification and IEEE1901 standard) PHY rate and it change its speed (modulation rate) as conditions in the radio network change. Interference from outside sources, such as changes in the environment (temperature, tree foliage, moving objects) all effect radio coverage.

## SECTION ONE

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### 1.1 Introduction

The project titled: Design and construction of a Power line communications (PLC) modem for domestic LAN.

PLC technology has provided an alternative means of data networking for in-home networking, in-building internet access, home networking, multimedia, and triple-play services by using the existing indoor powerline grid for networking and internet access has a number of advantages: no additional wiring is required, any electrical outlet can easily be converted to an access point by simply plugging in the PLC equipment, no complicated settings are usually required, and high speed and reliable communication can be provided at rates comparable to wireless LAN systems.

Power line communications (PLC) have been an active research area for many years, and it is still the case, mainly because they present economic and technical natural advantages for a wide range of applications using the existing electrical grid as transmission medium.

PLC is a promising broadband access technology. In this transmission mode, multimedia service signals, including high-speed data, voice, and video, are transmitted over low-voltage power lines.

PLC has such advantages as the power line is under the full jurisdiction of the power sector and easily managed; it can connect to any measurement and control point; signals can be transmitted through power lines, obviating the need to erect special lines and provides cost economy eliminating the use of additional wiring for LAN connectivity.

## 1.2 Recap of Stages Of Research

The recap of stages of the research is presented in Table 1

Table 1:-Summary of project stages

Stages	Synopsis	Observations/Conclusion
Noise characteristics	Modelling the noise characteristics in Nigeria domestic power supply	Detection of white noise, colored and impulse noise
Modulation scheme	Determine the best modulation scheme to mitigate the effect of noisy electrical channel	OFDM modulation scheme
Design of PLC modem	Design a modem that transmit between 1Mbps-5Mbps	Circuit diagram, Layout and fabrication achieved successfully

## SECTION TWO

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### 2.1 Further Design evaluation

In other to ensure effective data transmission and circuit protection and coupling. More details is given below.

### 2.2 OFDM Encoder Module (L200V)

Table 2: -Properties of the OFDM encoder module

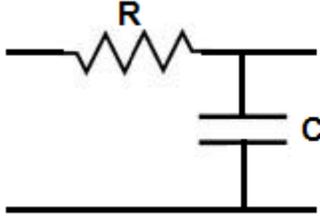
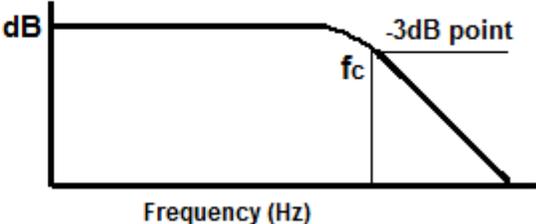
Parameter	Value
Range	300 Meters powerlines
Frequency	The working frequency ranged from 2-30MHz
Maximum data rate	200Mbps
Other parameters	Working Frequency:2-30MHz RF Sensitivity: -66 dBm Max output power:6 dBm
Power consumption	< 2W
Modulation scheme	OFDM

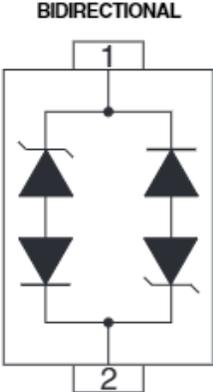
### 2.3 Power line coupling

The coupling to the power line requires some passive components in addition to the active filtering stage. It includes the DC decoupling capacitor C, the line transformer T, the power inductor L, and safety capacitor.

1. Filters.
2. Surge Protector.
3. ESD Suppressor (Ethernet - 10/100/1000 Base T).
4. Coupling transformer.

Table 3: Details of Filters and transient voltage suppressors

Item	Details
Filters	<p>The Filter operating in reception mode provides an efficient rejection of the 50 Hz signal (high-pass) and anti-aliasing (low-pass) for the digital filter. It is important to keep in mind that the filter is able to detect the <math>f_c</math> component of the carrier, but also the <math>f_c</math> components located around the sampling frequency (<math>f_{osc} / 2</math>) and its multiples.</p> <p>A low-pass filter is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design.</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <p style="text-align: center;">Figure 1: Low pass filter</p> $f_c = \frac{1}{2\pi RC} \tag{1}$ <p>Using equation (1)  <math>R=0.47\Omega</math>  <math>C=0.01\mu\text{f}</math> with high voltage tolerance of 500V. (C must be an X2 type capacitor, suited for 250 V AC line voltage)  <math>F=3.39\text{MHz}</math></p>
Surge	There is need for transient overvoltage protection with significantly reduced

<p>protector</p>	<p>capacitance in for High-Speed Line Protections. The capacitance is lowered by integrating a compensating diode in series. This integrated solution offers ESD protection for high-speed interfaces such as communication systems, computers, and computer peripherals.</p> <p>The SL05: ESD / Surge Protector as selected.</p> <ul style="list-style-type: none"> <li>• TVS Diode in Series with a Compensating Diode Offers &lt; 5 pF Capacitance</li> <li>• Peak Power Rating of 300 Watts, 8 x 20 μ s</li> <li>• Bi-Direction Protection can be achieved by using two devices</li> </ul>
<p>ESD Suppressor (Ethernet - 10/100/1000 Base T)</p>	<p>GBLCO8 is an ESD Suppressor. The ESD protection device using gap discharge. ESD suppressor protects Electric devices from ESD by utilizing the ability to decrease its resistance value rapidly when high voltage is applied to ESD Suppressor. A TVS diode (ESD protection diode) is a kind of Zener diode. It is a diode that is mainly used for static electricity (ESD) countermeasures. It protects integrated circuits and others from high-voltage ESD entering from a USB line etc.</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Figure 2: ESD Suppressor</p>
<p>Isolation transformer</p>	<p>For PLC systems where the operating frequency may be up to 500 kHz isolation transformers based on offer excellent transmission characteristics, high robustness against EMC interferences and safe galvanic insulation. The data from the encoder must be isolated from the mains . transmission transformer is used to achieve multi-mode feed network function of the main components.</p>

It plays a power synthesist role of power distribution. It has good high frequency characteristics and bandwidth characteristics and used in radio frequency electronics circuits.

Additional functions of the transformer is.

- i. To achieve broadband impedance matching.
- ii. To achieve balanced and unbalance conversion.
- iii. Power synthesis and power distribution.

The transmitter is coupled to the line via a capacitive coupler (to eliminate the DC or AC mains signal) and a transformer to provide galvanic isolation. Furthermore, impedance matching has to be implemented to maximize the signal transfer into the power line. Matching networks were considered in the PLC literature showing benefits in terms of an increase of the received signal power.

2.2.4.1 Transformer construction

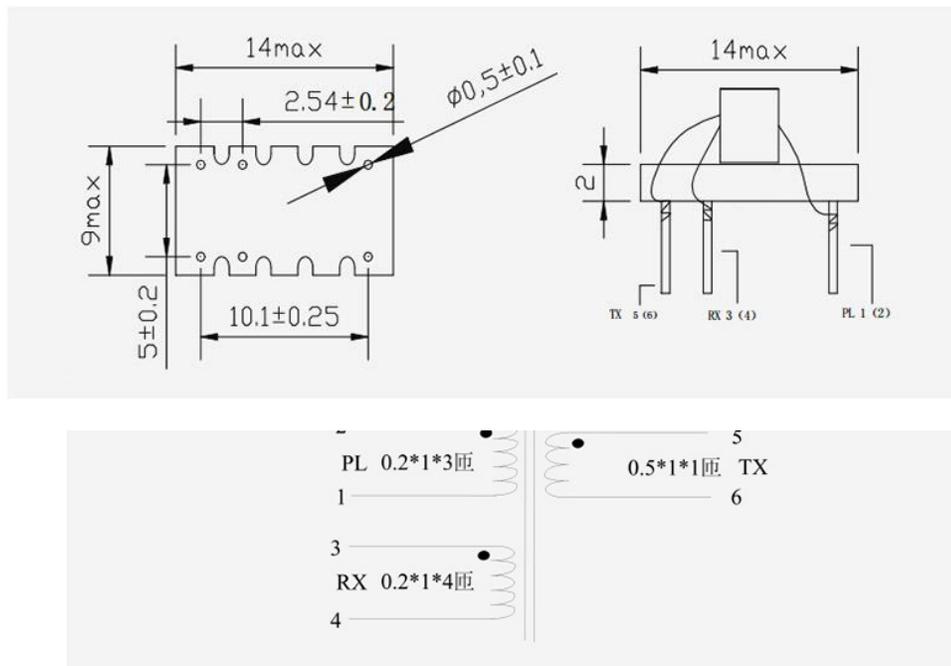


Figure 3: Transformer construction

NO	Name	Measuring end	Measurement
1	Inductance	TX	1.5μH@2MHz
	Inductance	RX	23 μH @2MHz
	Inductance	PL	11.7 μH @2MHz

	2	DC resistance	TX	6MΩ
	The transformer			
Transient Voltage Suppressors	Transients are temporary spikes or surges in voltage or current that can potentially impact circuits in ways ranging from minor glitches to catastrophic failure. A voltage transient can be anywhere from a few millivolts to thousands of volts, and they can last from nanoseconds to hundreds of milliseconds. Some transients are repetitive, such as those caused by inductive ringing in a motor, while other transients are more sporadic, such as ESD events. Current transients can be caused, for example, by inrush current. The FB120R/FB120 device used in the design is a transient voltage suppressor.			

#### 2.4 Impedance matching

The reason for impedance matching is whereas the input impedance of the module,  $Z_{IN}$ , must be conjugately matched to that of the signal source,  $Z_S$ , is to guarantee maximum power transmission between the signal source and the receiver through the transmission lines. In the absence of this, there will be signal reflection. This means that a portion of the electrical signal will be reflected at the interface between the portions with varying impedances as it travels through the circuit. Impedance matching between PLC modems and power line networks is generally accomplished with a series of passive lumped elements, such as transformers, capacitors, and inductors. The coupling transformers, which consist of a transformer and a capacitor, were used as PLC couplers for coupling, band-pass filtering, and impedance matching. The coupling capacitor (C) resonant with the leakage inductance (L) of the transformer functions as a band pass filter to allow the communication signal to pass through while filtering out band noise (including the main voltage). The terminal impedance is 50Ω while the powerline impedance varies with length and frequency according to the formula.

$$|Z_p| = \omega L l \Omega$$

Where:

$Z_p$  is powerline impedance.

$L$  is inductance.

$l$  is length of powerline (between 1 to 300m).

And because length will vary in a LAN scenario The impedance matching in this module is automatic and dynamic to a length of  $\leq 300$ .

## 2.5 Prototype

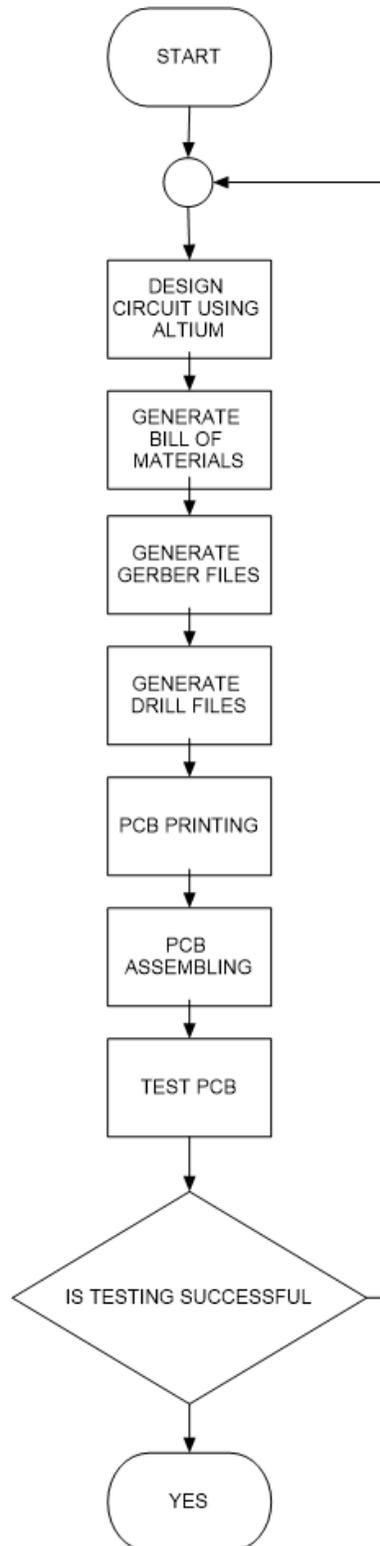


Figure 4: Prototyping the module flow chart



Figure 5: The prototype (PCB, without transformer, with transformer)

## SECTION THREE

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### Evaluation of the Power Line Communication modules in Home LAN

#### 3.1 Testing the Modules.

Differential mode coupling, which incorporates the live wire as one terminal and the neutral wire as another, is used for coupling the signal to the power line and decoupling from the power line. The coupling circuits are utilized to pair the modulated carrier signal onto and off the power line while maintaining the 50Hz insulation level. At the transmitting end the PLC modem and bidirectional coupling circuits turn the information into digital data packets that are digitally modulated with a higher oscillating frequency of 3.39MHz and carrier frequency centered around 13-70KHz. (Figure 23) The flow chart Figure 6 shows the steps in testing the modules.

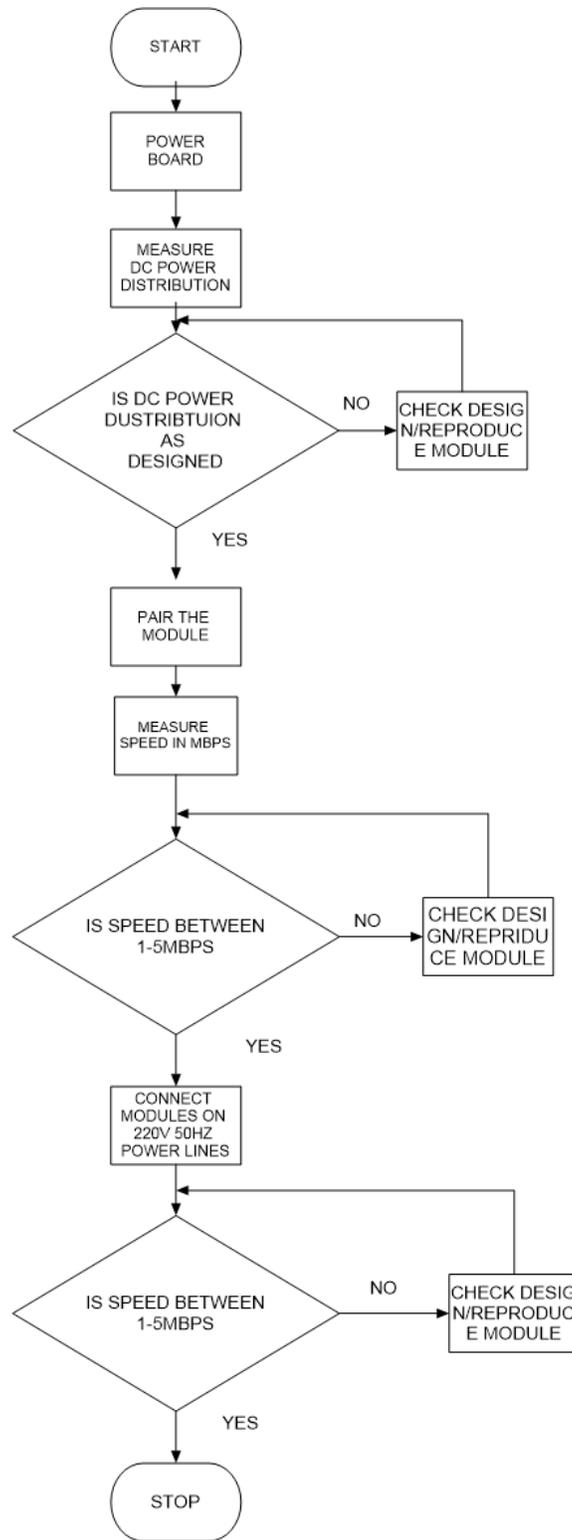


Figure 6: Flow chart of testing

All power component on the board must receive power as expected before testing can continue. There must be 100% power test success before the condition is satisfied.

### 3.2 Electrical supply to board

The electrical distribution to the modules are shown in Table 4.

Table 4: The electrical distribution to the modules

	Minimum value	Typical value	Maximum value	Unit
12V	11.5	12	12.85	V
3.3V	3.15	3.3	3.45	V
Operating current	125	130	145	mA

### 3.3 Measurement Setup

1. Iperf3 tool
2. Device Under Test (PLC Modules).
3. Spectrum analyzer.
4. 4G Airtel broadband modem.
5. Domestic appliances.
6. CAT 5e cable.

#### 3.3.1 Measurement area

Measurements were made in a 120m-square-foot apartment that is fed by a single-phase power installation in a seven-unit building that is part of the residential power distribution network and an Office Plaza. A laptop computer (client) was linked to an electrical wall outlet in room B, which is adjacent room A, and a laptop computer (server) was attached to an electrical wall outlet in room A. The two powerline modems were used to establish communication between the two computers. Actual throughput, jitter, and packet loss are assessed for various sending data rates (offered load). The highest transmission rate targeted was 50Mbps, but the module can

target up to 100Mbps data rate. The time ranges from 60 seconds to 1200 seconds per test (The module can function for as long as it is powered but experienced intermittent disconnection based on channel conditions)

Testing time extended to 1200 seconds

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[ 4] 870.00-880.00 sec 7.38 MBytes 6.19 Mbites/sec  
[ 4] 880.00-890.01 sec 7.75 MBytes 6.50 Mbites/sec  
[ 4] 890.01-900.01 sec 8.00 MBytes 6.71 Mbites/sec  
[ 4] 900.01-910.00 sec 7.00 MBytes 5.88 Mbites/sec  
[ 4] 910.00-920.00 sec 8.38 MBytes 7.02 Mbites/sec  
[ 4] 920.00-930.00 sec 7.62 MBytes 6.39 Mbites/sec  
[ 4] 930.00-940.01 sec 8.38 MBytes 7.02 Mbites/sec  
[ 4] 940.01-950.01 sec 7.25 MBytes 6.08 Mbites/sec  
[ 4] 950.01-960.01 sec 7.62 MBytes 6.39 Mbites/sec  
[ 4] 960.01-970.00 sec 7.25 MBytes 6.09 Mbites/sec  
[ 4] 970.00-980.00 sec 6.88 MBytes 5.77 Mbites/sec  
[ 4] 980.00-990.00 sec 8.12 MBytes 6.82 Mbites/sec  
[ 4] 990.00-1000.00 sec 8.12 MBytes 6.82 Mbites/sec  
[ 4] 1000.00-1010.00 sec 7.12 MBytes 5.98 Mbites/sec  
[ 4] 1010.00-1020.00 sec 8.00 MBytes 6.71 Mbites/sec  
[ 4] 1020.00-1030.00 sec 8.12 MBytes 6.82 Mbites/sec  
[ 4] 1030.00-1040.00 sec 7.12 MBytes 5.98 Mbites/sec  
[ 4] 1040.00-1050.01 sec 6.75 MBytes 5.66 Mbites/sec  
[ 4] 1050.01-1060.00 sec 8.00 MBytes 6.72 Mbites/sec  
[ 4] 1060.00-1070.01 sec 8.25 MBytes 6.92 Mbites/sec  
[ 4] 1070.01-1080.00 sec 8.88 MBytes 7.45 Mbites/sec  
[ 4] 1080.00-1090.00 sec 8.38 MBytes 7.03 Mbites/sec  
[ 4] 1090.00-1100.00 sec 7.25 MBytes 6.08 Mbites/sec  
[ 4] 1100.00-1110.00 sec 7.88 MBytes 6.61 Mbites/sec  
[ 4] 1110.00-1120.00 sec 7.38 MBytes 6.19 Mbites/sec

[ 4] 1120.00-1130.01 sec 7.75 MBytes 6.50 Mbites/sec  
 [ 4] 1130.01-1140.00 sec 7.62 MBytes 6.40 Mbites/sec  
 [ 4] 1140.00-1150.00 sec 6.88 MBytes 5.77 Mbites/sec  
 [ 4] 1150.00-1160.00 sec 7.88 MBytes 6.61 Mbites/sec  
 [ 4] 1160.00-1170.00 sec 7.38 MBytes 6.19 Mbites/sec  
 [ 4] 1170.00-1180.00 sec 8.38 MBytes 7.03 Mbites/sec  
 [ 4] 1180.00-1190.00 sec 7.25 MBytes 6.08 Mbites/sec  
 [ 4] 1190.00-1200.00 sec 8.38 MBytes 7.02 Mbites/sec  
 [ 4] 1200.00-1210.00 sec 4.50 MBytes 3.78 Mbites/sec

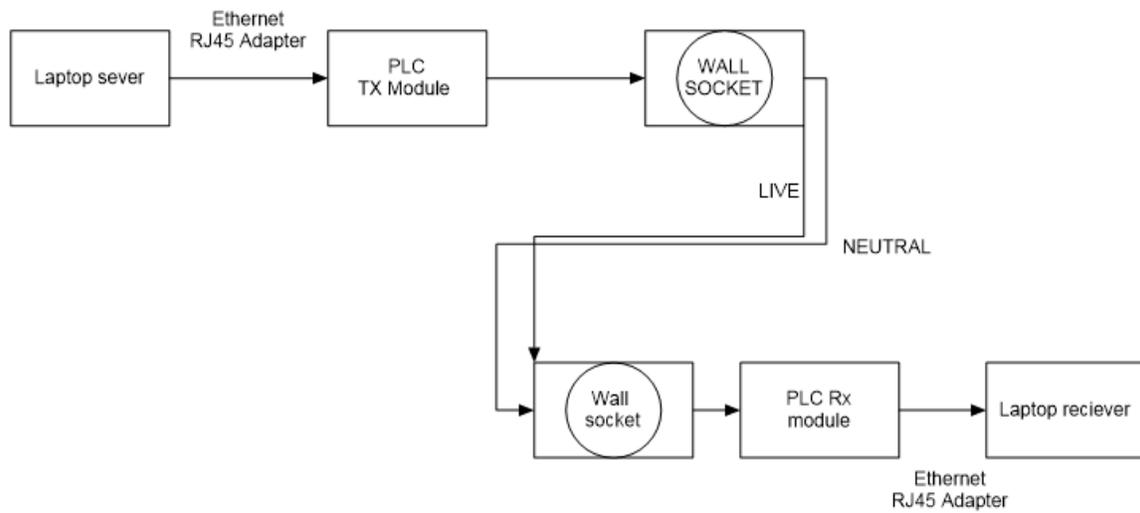


Figure 7: Measurement setup

Various home appliances active at the time of measurements are shown in Figure 8

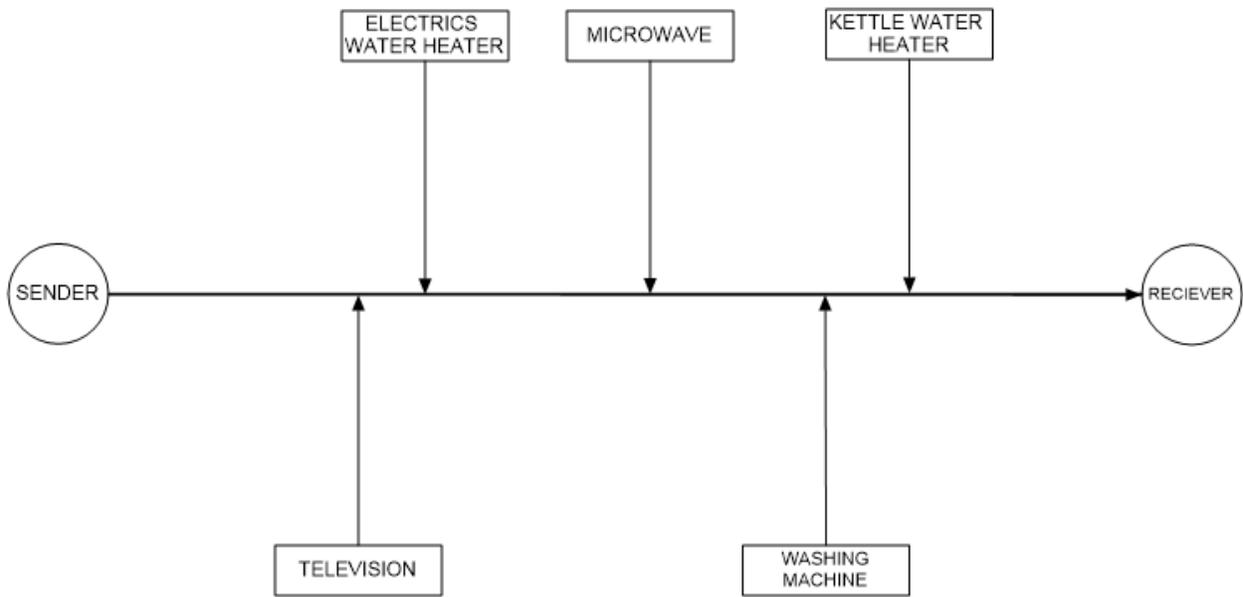


Figure 8: Setup with home appliances

The total TEST datagram sent is given below.

Table 5: The total TEST datagram sent is given below.

Specified bandwidth (Mbps)	Total average datagram sent
50	7600
10	1500
5	762
1	190

3.4 (3.2) Test Scenario 1

Module were paired and pinged to check the direct-to-direct connection as shown in Figure 9

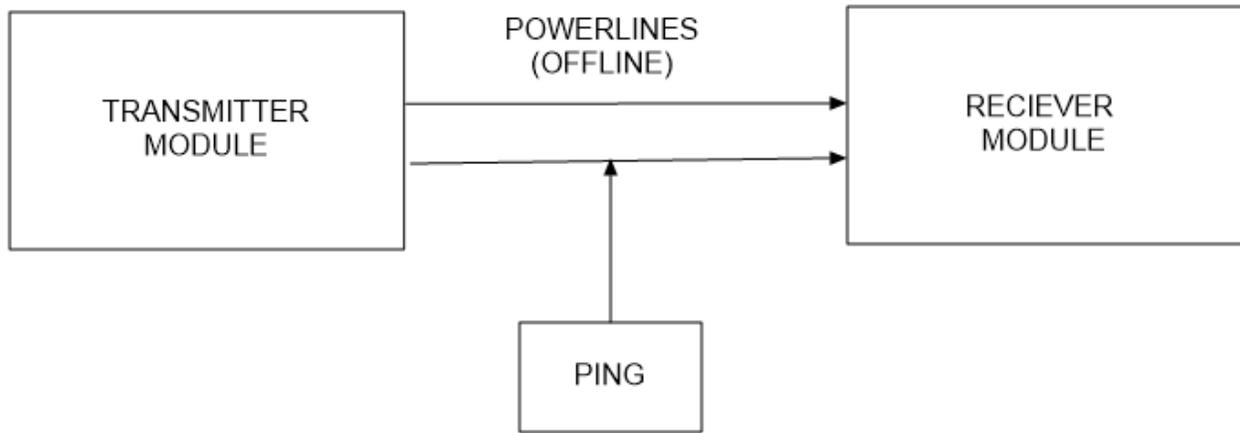


Figure 9: Ping network setup

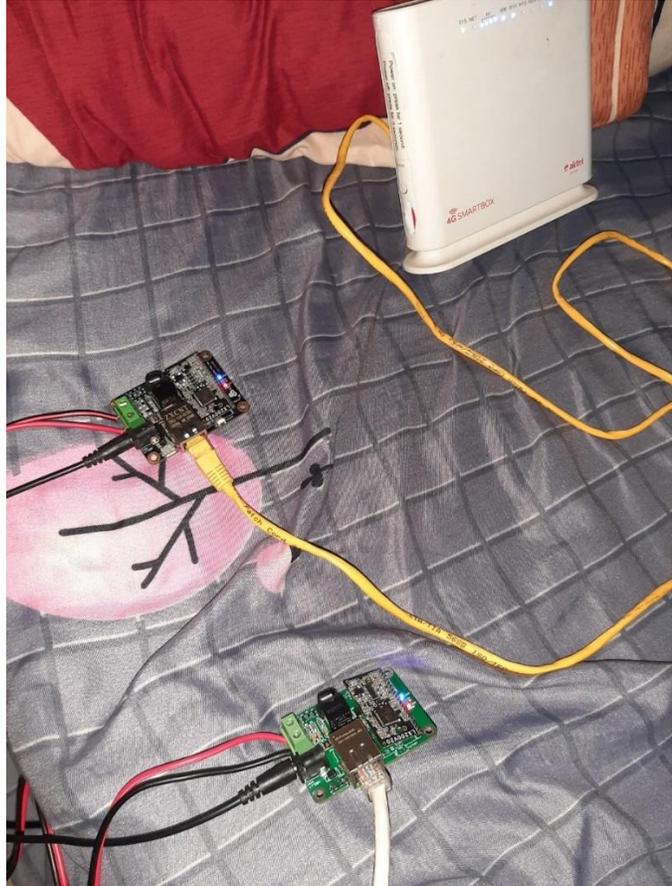
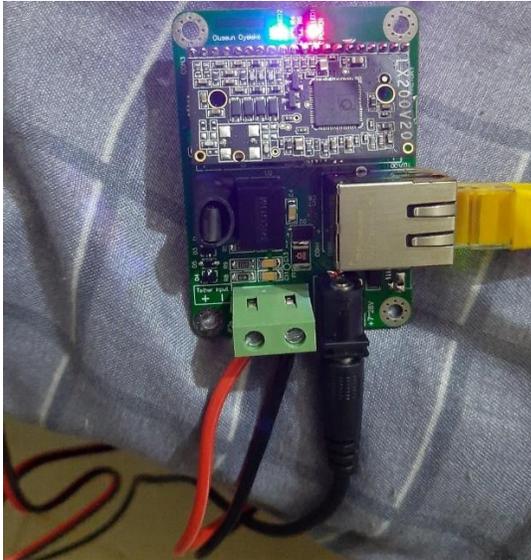


Figure 10: Module powered and connected to LAN.

### 3.5(3.3) Test Scenario 2

In the test scenario 2 the modules were connected in the same house but about 150 meters apart using the electrical power lines with LIVE 220V, 50Hz supply. The transmitter was connected at the sitting room and the receiver was connected in the bedroom. The Airtel 4G smartbox broadband modem was connected to the transmitter and the receiver paired successfully but at a lower speed. A simplified block diagram is shown in Figure 12.

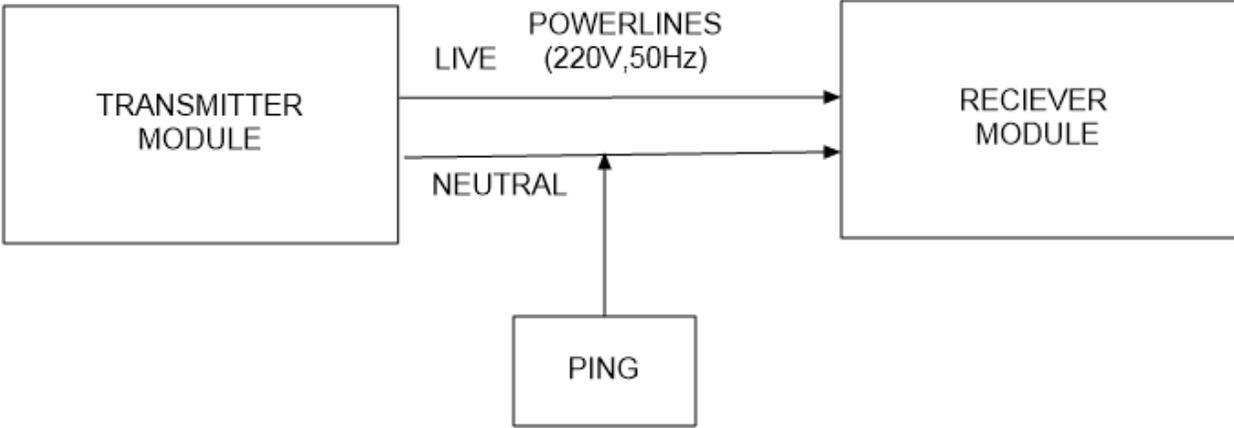


Figure 12: Pinging while connected to LIVE Powerline.



Figure 13: Test scenario 2 Home LAN (TX)

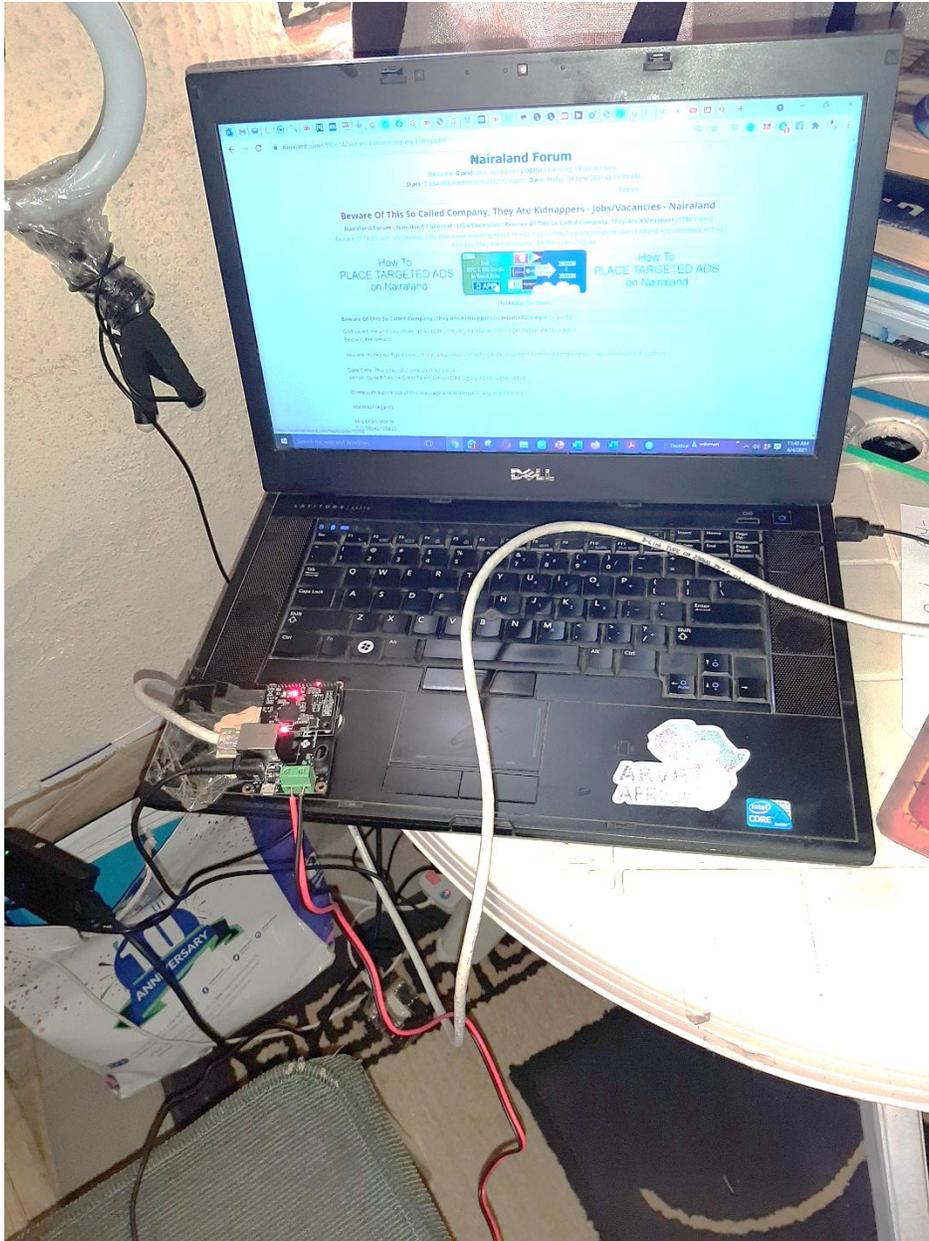


Figure 14: Test scenario 2 Home LAN (RX) with website opening

### 3.6(3.4) Tools analysis

Table 6: Iperf3 tools configuration

Tools	Description of function	Commands
Iperf3	The Iperf3 tool is used for the measurement of bandwidth, jitter and packet loss regarding UDP traffic. UDP traffic does not employ flow or error control mechanisms and it is used for realtime services such as video streams and VoIP	<pre>C:\iperf&gt;iperf3 -c 192.168.10.100 -w -64k -p -i 10 - t999  C:\WINDOWS\system32&gt;ping 192.168.10.100  C:\iperf&gt;iperf3 -c 192.168.10.100 -w -u -64k -p -i 10 -t2000  C:\iperf&gt;iperf3 -c 192.168.10.100 -w -u -64k -p -i 10 -t2000</pre>
	Set bandwidth to 1Mbits/sec	<pre>C:\iperf&gt;iperf3 -c 192.168.10.100 -b 1M -u -w - 64k -i 10 -t2000</pre>
	Set bandwidth to 5Mbits/sec	<pre>C:\iperf&gt;iperf3 -c 192.168.10.100 -b 5M -u -w - 64k -i 10 -t2000</pre>
	Set bandwidth to 10Mbits/sec	<pre>C:\iperf&gt;C:\iperf&gt;iperf3 -c 192.168.10.100 -b 10M -u -w - 64k -i 10 -t2000</pre>

	Set bandwidth to 50Mbits/sec	C:\iperf>iperf3 -c 192.168.10.100 -b 50M -u -w - 64k -i 10 -t2000
IP configuration		192.168.10.100 (Client) 192.168.10.101 (Server)

### 3.7(3.5) Testing and measurement of PLC modules

Table 7:- Measurement of time interval, Transfer and Bandwidth direct connection of module  
(10 seconds duration)

Interval (Time)	Transfer (Mbytes)	Bandwidth (Mbits/seconds)
0.00-1.00	9.12	76.4
1.00-2.00	9.5	79.7
2.00-3.00	9.62	80.8
3.00-4.00	9.38	78.6
4.00-5.00	9.25	77.7
5.00-6.00	9.25	77.5
6.00-7.00	9.38	78.7
7.00-8.00	9.25	77.7
8.00-9.00	9.62	80.8
9.00-10.00	9.38	78.6

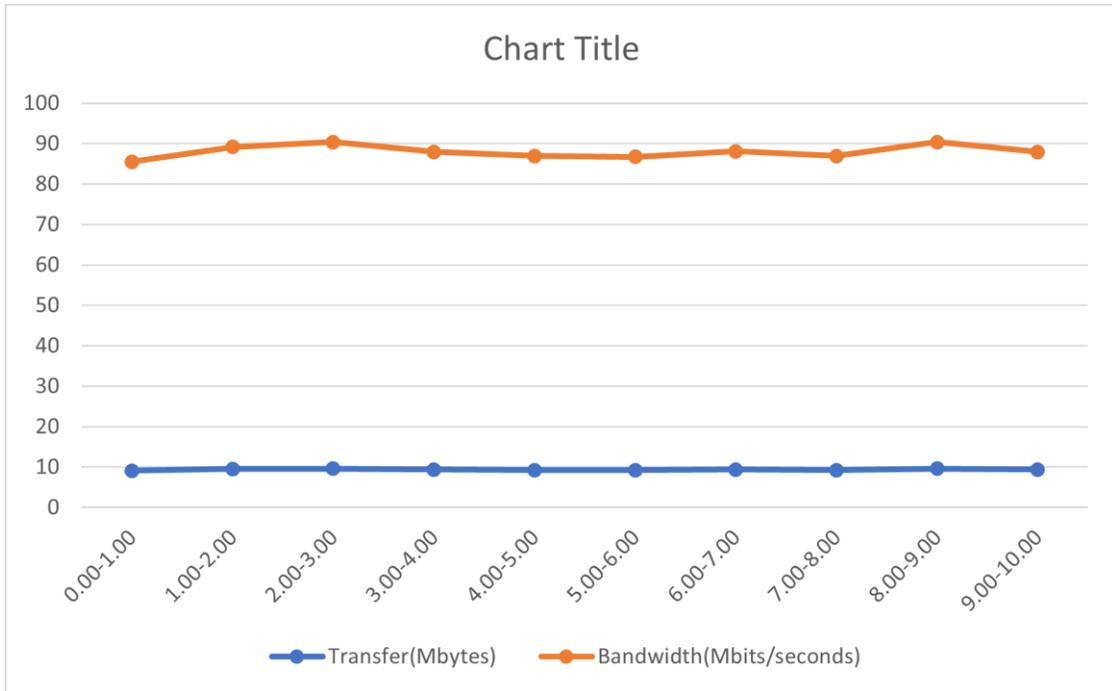


Figure 15: Graph of bandwidth and data transfer

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C:\Windows\System32\cmd.exe
--get-server-output      get results from server
--udp-counters-64bit    use 64-bit counters in UDP test packets

[KMG] indicates options that support a K/M/G suffix for kilo-, mega-, or giga-

iperf3 homepage at: http://software.es.net/iperf/
Report bugs to: https://github.com/esnet/iperf

C:\iperf>iperf3-c
'iperf3-c' is not recognized as an internal or external command,
operable program or batch file.

C:\iperf>iperf3 -c 192.168.10.100 -w -64k -p -i 10 -t999
iperf3: error - unable to connect to server: Cannot assign requested address

C:\iperf>iperf3 -c 192.168.10.100
Connecting to host 192.168.10.100, port 5201
[ 4] local 192.168.10.101 port 54060 connected to 192.168.10.100 port 5201
[ ID] Interval      Transfer    Bandwidth
[ 4] 0.00-1.00 sec  9.12 MBytes 76.4 Mbits/sec
[ 4] 1.00-2.00 sec  9.50 MBytes 79.7 Mbits/sec
[ 4] 2.00-3.00 sec  9.62 MBytes 80.8 Mbits/sec
[ 4] 3.00-4.00 sec  9.38 MBytes 78.6 Mbits/sec
[ 4] 4.00-5.00 sec  9.25 MBytes 77.7 Mbits/sec
[ 4] 5.00-6.00 sec  9.25 MBytes 77.5 Mbits/sec
[ 4] 6.00-7.00 sec  9.38 MBytes 78.7 Mbits/sec
[ 4] 7.00-8.00 sec  9.25 MBytes 77.7 Mbits/sec
[ 4] 8.00-9.00 sec  9.62 MBytes 80.8 Mbits/sec
[ 4] 9.00-10.00 sec 9.38 MBytes 78.6 Mbits/sec
-----
[ ID] Interval      Transfer    Bandwidth
[ 4] 0.00-10.00 sec 93.8 MBytes 78.6 Mbits/sec      sender
[ 4] 0.00-10.00 sec 93.7 MBytes 78.6 Mbits/sec      receiver

iperf Done.

C:\iperf>

C:\iperf>

C:\iperf>

C:\iperf>iperf3 -c 192.168.10.100 -w -64k -p -i 10 -t999
```

Figure 16: CMD line interface

Table 8:- Measurement of time interval, Transfer and Bandwidth direct connection of module (620 seconds duration)

Interval (Time)	Transfer (Mbytes)	Bandwidth (Mbits/sec)
0.00-10.00	107	89.5
10.00-20.00	106	89.3
20.00-30.00	98	82.2
30.00-40.00	89.1	74.8
40.00-50.00	107	89.6
50.00-60.00	107	90
60.00-70.00	107	89.9
70.00-80.00	107	89.5
80.00-90.00	94.6	79.4
90.00-100.00	91.1	76.4
100.00-110.00	107	89.9
110.00-120.00	107	89.4
120.00-130.00	107	89.5
130.00-140.00	107	89.5
140.00-150.00	94.6	79.4
150.00-160.00	90.8	76.1
160.00-170.00	107	89.5
170.00-180.00	107	89.8
180.00-190.00	107	89.7
190.00-200.00	107	89.4
200.00-210.01	94.4	79.1
210.01-220.01	89.9	75.4
220.01-230.00	106	89.3
230.00-240.00	107	89.5
240.00-250.00	107	89.7
250.00-260.00	45.6	38.3

260.00-270.00	49.6	41.6
270.00-280.00	89.5	75.1
280.00-290.00	107	90
290.00-300.00	106	89.2
300.00-310.00	107	89.5
310.00-320.00	107	89.8
320.00-330.00	96.1	80.6
330.00-340.00	91.8	77
340.00-350.00	107	89.7
350.00-360.00	107	89.5
360.00-370.00	106	88.9
370.00-380.00	105	88
380.00-390.00	94.6	79.4
390.00-400.00	25.4	21.3
400.00-410.00	11.6	9.75
410.00-420.00	53.5	44.9
420.00-430.00	0	0
430.00-440.00	0	0
440.00-450.00	66.4	55.7
450.00-460.00	92.4	77.5
460.00-470.00	107	89.7
470.00-480.00	53.5	44.9
480.00-490.00	0	0
490.00-500.00	0	0
500.00-510.01	0	0
510.01-520.00	60.2	50.6
520.00-530.01	107	89.7
530.01-540.00	107	89.5
540.00-550.00	107	89.4
550.00-560.00	107	89.6

560.00-570.01	94.2	79
570.01-580.00	89.9	75.4
580.00-590.00	107	90
590.00-600.00	107	89.5
600.00-610.01	107	89.5
610.01-620.00	107	90.1
620.00-630.00	95.6	80.2
630.00-640.00	88.4	74.1

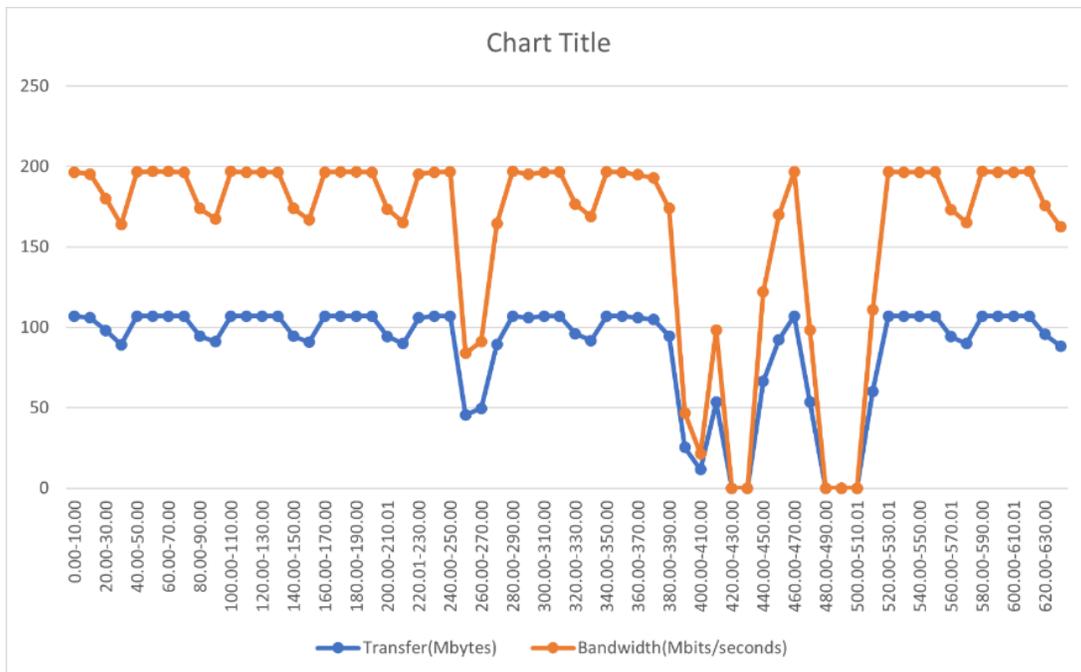


Figure 17: Graph of bandwidth and data transfer

Table 9: - Measurement Of Time Interval, Transfer And Bandwidth Unspecified Bandwidth On Powerline With PHCN (30meters)

[ ID]	Interval	Transfer	Bandwidth
[ 4]	0.00-10.00 sec	10.4 MBytes	8.70 Mbits/sec
[ 4]	10.00-20.00 sec	9.75 MBytes	8.18 Mbits/sec
[ 4]	20.00-30.00 sec	9.75 MBytes	8.18 Mbits/sec
[ 4]	30.00-40.00 sec	9.62 MBytes	8.08 Mbits/sec
[ 4]	40.00-50.00 sec	9.38 MBytes	7.86 Mbits/sec
[ 4]	50.00-60.00 sec	9.50 MBytes	7.97 Mbits/sec
[ 4]	60.00-70.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	70.00-80.00 sec	9.38 MBytes	7.87 Mbits/sec
[ 4]	80.00-90.00 sec	9.38 MBytes	7.86 Mbits/sec
[ 4]	90.00-100.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	100.00-110.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	110.00-120.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	120.00-130.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	130.00-140.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	140.00-150.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	150.00-160.00 sec	9.25 MBytes	7.76 Mbits/sec
[ 4]	160.00-170.00 sec	8.62 MBytes	7.24 Mbits/sec
[ 4]	170.00-180.00 sec	8.62 MBytes	7.23 Mbits/sec
[ 4]	180.00-190.00 sec	8.50 MBytes	7.13 Mbits/sec
[ 4]	190.00-200.00 sec	8.38 MBytes	7.03 Mbits/sec
[ 4]	200.00-210.00 sec	8.12 MBytes	6.82 Mbits/sec
[ 4]	210.00-220.00 sec	7.62 MBytes	6.40 Mbits/sec
[ 4]	220.00-230.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	230.00-240.01 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	240.01-250.00 sec	7.50 MBytes	6.30 Mbits/sec
[ 4]	250.00-260.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	260.00-270.00 sec	7.75 MBytes	6.50 Mbits/sec

[ 4]	270.00-280.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	280.00-290.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	290.00-300.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	300.00-310.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	310.00-320.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	320.00-330.01 sec	8.12 MBytes	6.81 Mbits/sec
[ 4]	330.01-340.01 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	340.01-350.01 sec	7.88 MBytes	6.60 Mbits/sec
[ 4]	350.01-360.00 sec	7.88 MBytes	6.61 Mbits/sec
[ 4]	360.00-370.00 sec	7.88 MBytes	6.61 Mbits/sec
[ 4]	370.00-380.00 sec	7.75 MBytes	6.50 Mbits/sec
[ 4]	380.00-390.00 sec	7.75 MBytes	6.50 Mbits/sec
[ 4]	390.00-400.00 sec	7.62 MBytes	6.40 Mbits/sec
[ 4]	400.00-410.00 sec	7.38 MBytes	6.19 Mbits/sec
[ 4]	410.00-420.00 sec	7.25 MBytes	6.08 Mbits/sec
[ 4]	420.00-430.00 sec	7.00 MBytes	5.87 Mbits/sec
[ 4]	430.00-440.00 sec	7.12 MBytes	5.98 Mbits/sec
[ 4]	440.00-450.00 sec	7.75 MBytes	6.50 Mbits/sec
[ 4]	450.00-460.00 sec	7.62 MBytes	6.40 Mbits/sec
[ 4]	460.00-470.00 sec	7.88 MBytes	6.61 Mbits/sec
[ 4]	470.00-480.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	480.00-490.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	490.00-500.00 sec	7.88 MBytes	6.61 Mbits/sec
[ 4]	500.00-510.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	510.00-520.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	520.00-530.00 sec	8.12 MBytes	6.82 Mbits/sec
[ 4]	530.00-540.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	540.00-550.00 sec	8.12 MBytes	6.82 Mbits/sec
[ 4]	550.00-560.00 sec	8.00 MBytes	6.71 Mbits/sec
[ 4]	560.00-570.00 sec	8.12 MBytes	6.82 Mbits/sec

[ 4]	570.00-580.00 sec	7.62 MBytes	6.40 Mbits/sec
[ 4]	580.00-590.00 sec	7.25 MBytes	6.08 Mbits/sec
[ 4]	590.00-600.00 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	600.00-610.00 sec	7.38 MBytes	6.19 Mbits/sec
[ 4]	610.00-620.00 sec	7.25 MBytes	6.08 Mbits/sec
[ 4]	620.00-630.01 sec	7.50 MBytes	6.29 Mbits/sec
[ 4]	630.01-640.00 sec	7.38 MBytes	6.19 Mbits/sec
[ 4]	640.00-650.01 sec	7.25 MBytes	6.08 Mbits/sec
[ 4]	650.01-660.01 sec	7.12 MBytes	5.98 Mbits/sec
[ 4]	660.01-670.00 sec	7.25 MBytes	6.09 Mbits/sec
[ 4]	670.00-680.00 sec	7.25 MBytes	6.08 Mbits/sec
[ 4]	680.00-690.00 sec	7.38 MBytes	6.19 Mbits/sec
[ 4]	690.00-700.00 sec	7.38 MBytes	6.19 Mbits/sec
[ 4]	700.00-710.00 sec	7.88 MBytes	6.61 Mbits/sec
[ 4]	710.00-720.00 sec	7.75 MBytes	6.50 Mbits/sec

Table 10:- Measurement Of Time Interval, Transfer And Bandwidth at Unspecified Bandwidth  
On Powerline With PHCN (60meters)

[ ID]	Interval	Transfer	Bandwidth
[ 5]	0.00-10.01 sec	4.01 MBytes	3.36 Mbits/sec
[ 5]	10.01-20.00 sec	3.89 MBytes	3.27 Mbits/sec
[ 5]	20.00-30.00 sec	4.52 MBytes	3.80 Mbits/sec
[ 5]	30.00-40.00 sec	4.18 MBytes	3.51 Mbits/sec
[ 5]	40.00-50.00 sec	4.14 MBytes	3.47 Mbits/sec
[ 5]	50.00-60.00 sec	4.32 MBytes	3.62 Mbits/sec
[ 5]	60.00-70.01 sec	3.94 MBytes	3.30 Mbits/sec
[ 5]	70.01-80.00 sec	3.87 MBytes	3.24 Mbits/sec
[ 5]	80.00-90.00 sec	3.89 MBytes	3.26 Mbits/sec
[ 5]	90.00-100.00 sec	3.87 MBytes	3.25 Mbits/sec

[ 5]	100.00-110.00 sec	3.86 MBytes	3.24 Mbits/sec
[ 5]	110.00-120.00 sec	3.81 MBytes	3.20 Mbits/sec
[ 5]	120.00-130.00 sec	3.66 MBytes	3.07 Mbits/sec
[ 5]	130.00-140.00 sec	3.67 MBytes	3.08 Mbits/sec
[ 5]	140.00-150.00 sec	3.70 MBytes	3.10 Mbits/sec
[ 5]	150.00-160.01 sec	3.68 MBytes	3.08 Mbits/sec
[ 5]	160.01-170.01 sec	3.65 MBytes	3.06 Mbits/sec
[ 5]	170.01-180.00 sec	3.26 MBytes	2.74 Mbits/sec
[ 5]	180.00-190.00 sec	3.17 MBytes	2.66 Mbits/sec
[ 5]	190.00-200.00 sec	4.37 MBytes	3.67 Mbits/sec
[ 5]	200.00-210.00 sec	4.82 MBytes	4.04 Mbits/sec
[ 5]	210.00-220.00 sec	4.55 MBytes	3.82 Mbits/sec
[ 5]	220.00-230.00 sec	4.53 MBytes	3.80 Mbits/sec
[ 5]	230.00-240.00 sec	4.41 MBytes	3.70 Mbits/sec
[ 5]	240.00-250.00 sec	4.19 MBytes	3.52 Mbits/sec
[ 5]	250.00-260.00 sec	3.77 MBytes	3.16 Mbits/sec
[ 5]	260.00-270.00 sec	3.46 MBytes	2.90 Mbits/sec
[ 5]	270.00-280.00 sec	3.66 MBytes	3.07 Mbits/sec
[ 5]	280.00-290.00 sec	3.53 MBytes	2.96 Mbits/sec
[ 5]	290.00-300.00 sec	3.78 MBytes	3.17 Mbits/sec
[ 5]	300.00-310.00 sec	3.47 MBytes	2.91 Mbits/sec
[ 5]	310.00-320.00 sec	2.67 MBytes	2.24 Mbits/sec
[ 5]	320.00-330.00 sec	4.03 MBytes	3.38 Mbits/sec
[ 5]	330.00-340.00 sec	3.39 MBytes	2.84 Mbits/sec

Table 11:- Measurement Of Time Interval, Total Datagrams On 5Mbps Bandwidth On Powerline  
With Generator (Server/Transmitting Module)

[ ID]	Interval	Transfer	Bandwidth	Total Datagrams
[ 4]	0.00-10.00 sec	5.95 MBytes	4.99 Mbits/sec	762

[ 4]	10.00-20.01 sec	5.93 MBytes	4.97 Mbits/sec	759
[ 4]	20.01-30.01 sec	5.95 MBytes	5.00 Mbits/sec	762
[ 4]	30.01-40.00 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	40.00-50.00 sec	5.98 MBytes	5.02 Mbits/sec	765
[ 4]	50.00-60.00 sec	5.95 MBytes	4.99 Mbits/sec	761
[ 4]	60.00-70.00 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	70.00-80.01 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	80.01-90.00 sec	5.95 MBytes	5.00 Mbits/sec	762
[ 4]	90.00-100.00 sec	6.00 MBytes	5.03 Mbits/sec	768
[ 4]	100.00-110.00 sec	5.95 MBytes	4.99 Mbits/sec	762
[ 4]	110.00-120.00 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	120.00-130.01 sec	5.94 MBytes	4.98 Mbits/sec	760
[ 4]	130.01-140.00 sec	5.95 MBytes	5.00 Mbits/sec	762
[ 4]	140.00-150.01 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	150.01-160.01 sec	5.96 MBytes	5.00 Mbits/sec	763
[ 4]	160.01-170.00 sec	5.97 MBytes	5.01 Mbits/sec	764
[ 4]	170.00-224.45 sec	8.00 KBytes	1.20 Kbits/sec	1
[ 4]	224.45-224.45 sec	0.00 Bytes	0.00 bits/sec	0
[ 4]	224.45-224.45 sec	0.00 Bytes	0.00 bits/sec	0
[ 4]	224.45-224.45 sec	0.00 Bytes	0.00 bits/sec	0
[ 4]	224.45-224.46 sec	0.00 Bytes	0.00 bits/sec	0

Table 12:- Measurement Of Time Interval, Jitter, Lost/Total Datagrams On 5Mbps Bandwidth  
On Powerline With Generator (Client/Receiving Module)

[ 5]	Interval	Transfer	Bandwidth	Jitter	Lost/Total	Datagrams
[ 5]	0.00-10.00 sec	1.40 MBytes	1.17 Mbits/sec	35.511 ms	477/656	-73%
[ 5]	10.00-20.00 sec	656 KBytes	537 Kbits/sec	49.857 ms	543/625	-87%
[ 5]	20.00-30.01 sec	1.06 MBytes	891 Kbits/sec	50.040 ms	660/796	-83%
[ 5]	30.01-40.00 sec	3.35 MBytes	2.81 Mbits/sec	20.384 ms	534/963	-55%
[ 5]	40.00-50.01 sec	5.97 MBytes	5.01 Mbits/sec	19.988 ms	0/764	0%
[ 5]	50.01-60.01 sec	5.95 MBytes	4.99 Mbits/sec	23.832 ms	0/761	0%
[ 5]	60.01-70.00 sec	5.38 MBytes	4.52 Mbits/sec	22.241 ms	61/750	-8.10%
[ 5]	70.00-80.01 sec	2.95 MBytes	2.47 Mbits/sec	32.815 ms	379/757	-50%
[ 5]	80.01-90.00 sec	2.54 MBytes	2.13 Mbits/sec	34.289 ms	441/766	-58%
[ 5]	90.00-100.00 sec	4.27 MBytes	3.58 Mbits/sec	22.652 ms	225/772	-29%
[ 5]	100.00-110.00 sec	5.18 MBytes	4.35 Mbits/sec	22.830 ms	94/757	-12%
[ 5]	110.00-120.00 sec	4.55 MBytes	3.81 Mbits/sec	23.301 ms	181/763	-24%
[ 5]	120.00-130.01 sec	3.91 MBytes	3.28 Mbits/sec	25.735 ms	262/762	-34%
[ 5]	130.01-140.00 sec	4.66 MBytes	3.91 Mbits/sec	22.691 ms	182/779	-23%

		MBytes	Mbits/sec	ms		
[ 5]	140.00-150.01 sec	4.28 MBytes	3.59 Mbits/sec	34.675 ms	123/671	-18%
[ 5]	150.01-160.01 sec	376 KBytes	308 Kbits/sec	80.979 ms	671/718	-93%
[ 5]	160.01-170.01 sec	608 KBytes	498 Kbits/sec	41.797 ms	560/636	-88%
[ 5]	170.01-180.00 sec	576 KBytes	472 Kbits/sec	34.359 ms	184/256	-72%
[ 5]	180.00-190.01 sec	0.00 Bytes	0.00 bits/sec	34.359 ms	0/0	0%
[ 5]	190.01-200.01 sec	0.00 Bytes	0.00 bits/sec	34.359 ms	0/0	0%
[ 5]	200.01-210.01 sec	0.00 Bytes	0.00 bits/sec	34.359 ms	0/0	0%
[ 5]	210.01-220.01 sec	0.00 Bytes	0.00 bits/sec	34.359 ms	0/0	0%
[ 5]	220.01-230.00 sec	1008 KBytes	827 Kbits/sec	85.751 ms	297/423	-70%



Table 13:- Measurement Of Time Interval, Total Datagrams On 10Mbps Bandwidth On Powerline With Generator (Server/Transmitting Module)

[ ID]	Interval	Transfer	Bandwidth	Total Datagrams
[ 4]	0.00-10.00 sec	11.9 MBytes	9.94 Mbites/sec	1517
[ 4]	10.00-20.00 sec	11.9 MBytes	9.99 Mbites/sec	1524
[ 4]	20.00-30.00 sec	11.9 MBytes	10.0 Mbites/sec	1527
[ 4]	30.00-40.00 sec	12.0 MBytes	10.0 Mbites/sec	1532
[ 4]	40.00-50.00 sec	11.9 MBytes	9.95 Mbites/sec	1519
[ 4]	50.00-60.00 sec	11.9 MBytes	9.98 Mbites/sec	1523
[ 4]	60.00-70.00 sec	12.0 MBytes	10.0 Mbites/sec	1530
[ 4]	70.00-80.00 sec	11.9 MBytes	10.0 Mbites/sec	1528
[ 4]	80.00-90.01 sec	12.0 MBytes	10.0 Mbites/sec	1534
[ 4]	90.01-100.00 sec	11.8 MBytes	9.93 Mbites/sec	1514
[ 4]	100.00-110.00 sec	11.9 MBytes	9.98 Mbites/sec	1524
[ 4]	110.00-120.00 sec	11.9 MBytes	10.0 Mbites/sec	1528
[ 4]	120.00-130.01 sec	11.9 MBytes	9.98 Mbites/sec	1524
[ 4]	130.01-140.00 sec	12.0 MBytes	10.1 Mbites/sec	1534
[ 4]	140.00-150.00 sec	11.9 MBytes	9.97 Mbites/sec	1521
[ 4]	150.00-160.00 sec	11.9 MBytes	10.0 Mbites/sec	1527
[ 4]	160.00-170.00 sec	12.0 MBytes	10.0 Mbites/sec	1531
[ 4]	170.00-180.00 sec	11.9 MBytes	9.95 Mbites/sec	1518
[ 4]	180.00-190.00 sec	11.9 MBytes	10.0 Mbites/sec	1526
[ 4]	190.00-200.00 sec	11.9 MBytes	10.0 Mbites/sec	1526
[ 4]	200.00-210.00 sec	11.9 MBytes	10.0 Mbites/sec	1527
[ 4]	210.00-220.00 sec	11.9 MBytes	10.0 Mbites/sec	1526

Table 14:- Measurement Of Time Interval, Jitter, Lost/Total Datagrams On 10Mbps Bandwidth  
On Powerline With Generator (Client/Receiving Module)

[ ID]	Interval	Transfer	Bandwidth	Jitter	Lost/Total	Datagrams
[ 5]	0.00-10.01 sec	3.79 MBytes	3.18 Mbits/sec	21.499 ms	482/967	-50%
[ 5]	10.01-20.00 sec	2.27 MBytes	1.90 Mbits/sec	30.334 ms	1593/1883	-85%
[ 5]	20.00-30.00 sec	1.80 MBytes	1.51 Mbits/sec	33.761 ms	556/786	-71%
[ 5]	30.00-40.00 sec	904 KBytes	741 Kbits/sec	33.110 ms	981/1094	-90%
[ 5]	40.00-50.00 sec	2.34 MBytes	1.97 Mbits/sec	18.404 ms	2315/2615	-89%
[ 5]	50.00-60.00 sec	1.66 MBytes	1.39 Mbits/sec	27.077 ms	1385/1597	-87%
[ 5]	60.00-70.01 sec	2.17 MBytes	1.82 Mbits/sec	54.089 ms	517/795	-65%
[ 5]	70.01-80.01 sec	1.47 MBytes	1.23 Mbits/sec	23.485 ms	608/796	-76%
[ 5]	80.01-90.01 sec	1.95 MBytes	1.64 Mbits/sec	53.961 ms	566/816	-69%
[ 5]	90.01-100.01 sec	960 KBytes	786 Kbits/sec	45.402 ms	524/644	-81%
[ 5]	100.01-110.00 sec	1000 KBytes	820 Kbits/sec	59.309 ms	526/651	-81%
[ 5]	110.00-120.00 sec	1.16 MBytes	970 Kbits/sec	64.886 ms	517/665	-78%

[ 5]	120.00-130.01 sec	1.40 MBytes	1.17 Mbits/sec	52.047 ms	496/675	-73%
[ 5]	130.01-140.00 sec	1.17 MBytes	983 Kbits/sec	41.729 ms	592/742	-80%
[ 5]	140.00-150.01 sec	752 KBytes	616 Kbits/sec	178.736 ms	820/914	-90%
[ 5]	150.01-160.01 sec	1.48 MBytes	1.25 Mbits/sec	90.323 ms	478/668	-72%
[ 5]	160.01-170.01 sec	2.45 MBytes	2.06 Mbits/sec	35.497 ms	1244/1558	-80%
[ 5]	170.01-180.01 sec	1.22 MBytes	1.02 Mbits/sec	57.105 ms	981/1137	-86%
[ 5]	180.01-190.00 sec	816 KBytes	669 Kbits/sec	67.494 ms	511/613	-83%
[ 5]	190.00-200.00 sec	1.27 MBytes	1.07 Mbits/sec	87.733 ms	1155/1318	-88%
[ 5]	200.00-210.01 sec	712 KBytes	583 Kbits/sec	48.406 ms	532/621	-86%
[ 5]	210.01-220.01 sec	1.89 MBytes	1.59 Mbits/sec	33.971 ms	530/772	-69%
[ 5]	220.01-230.01 sec	2.90 MBytes	2.43 Mbits/sec	48.991 ms	482/853	-57%

```
C:\Windows\System32\cmd.exe - iperf3 -c 192.168.10.100 -b 50M -u -w -64k -i 10 -t2000

C:\iperf>iperf3
C:\Users\wikiman>cd..
Connecting to 192.168.10.100
[ 4] local 1C:\Users\wikiman>cd..
[ ID] Interval
[ 4] 0.00-0.00 sec: C:\>cd iperf
[ 4] 10.00-10.00 sec: C:\iperf>iperf3 -c 192.168.10.100 -b 50M -u -w -64k -i 10 -t2000
[ 4] 20.00-20.00 sec: C:\iperf>iperf3 -c 192.168.10.100 -b 50M -u -w -64k -i 10 -t2000
[ 4] 30.00-30.00 sec: iperf3: error - unable to connect to server: Connection timed out
[ 4] 40.00-40.00 sec: C:\iperf>
[ 4] 50.00-50.00 sec: C:\iperf>
[ 4] 60.00-60.00 sec: C:\iperf>
[ 4] 70.00-70.00 sec: C:\iperf>
[ 4] 80.00-80.00 sec: C:\iperf>iperf3 -c 192.168.10.100 -b 50M -u -w -64k -i 10 -t2000
[ 4] 90.01-90.01 sec: Connecting to host 192.168.10.100, port 5201
[ 4] 100.00-100.00 sec: [ 4] local 192.168.10.101 port 60059 connected to 192.168.10.100 port 5201
[ ID] Interval      Transfer     Bandwidth   Total Datagrams
[ 4] 110.00-110.00 [ 4] 0.00-10.00 sec 59.5 MBytes 49.9 Mbits/sec 7618
[ 4] 120.00-120.00 [ 4] 10.00-20.01 sec 59.2 MBytes 49.6 Mbits/sec 7577
[ 4] 130.01-130.01 [ 4] 20.01-30.00 sec 59.6 MBytes 50.0 Mbits/sec 7630
[ 4] 140.00-140.00 [ 4] 30.00-40.00 sec 59.7 MBytes 50.0 Mbits/sec 7636
[ 4] 150.00-150.00 [ 4] 40.00-50.00 sec 59.5 MBytes 49.9 Mbits/sec 7621
[ 4] 160.00-160.00 [ 4] 50.00-60.00 sec 59.9 MBytes 50.2 Mbits/sec 7665
[ 4] 170.00-170.00 [ 4] 60.00-70.00 sec 59.3 MBytes 49.8 Mbits/sec 7595
[ 4] 180.00-180.00 [ 4] 70.00-80.00 sec 59.6 MBytes 50.0 Mbits/sec 7630
[ 4] 190.00-190.00 [ 4] 80.00-90.00 sec 59.6 MBytes 50.0 Mbits/sec 7629
[ 4] 200.00-200.00 [ 4] 90.00-100.00 sec 59.6 MBytes 50.0 Mbits/sec 7634
[ 4] 210.00-210.00 [ 4] 100.00-110.00 sec 59.6 MBytes 50.0 Mbits/sec 7623
[ 4] 110.00-110.00 [ 4] 110.00-120.00 sec 59.6 MBytes 50.0 Mbits/sec 7630
[ 4] 120.00-120.00 [ 4] 120.00-130.00 sec 59.6 MBytes 50.0 Mbits/sec 7623
[ 4] 130.00-130.00 [ 4] 130.00-140.00 sec 59.7 MBytes 50.0 Mbits/sec 7636
[ 4] 140.00-140.00 [ 4] 140.00-150.00 sec 59.7 MBytes 50.1 Mbits/sec 7637
```

Figure 19: CMD Line for 50MBps bandwidth

Table 15:- Measurement Of Time Interval, Total Datagrams On 50Mbps Bandwidth On Powerline With PHCN (Server/Transmitting Module)

[ ID]	Interval	Transfer	Bandwidth	Total Datagrams
[ 4]	0.00-10.00 sec	59.5 MBytes	49.9 Mbites/sec	7618
[ 4]	10.00-20.01 sec	59.2 MBytes	49.6 Mbites/sec	7577
[ 4]	20.01-30.00 sec	59.6 MBytes	50.0 Mbites/sec	7630
[ 4]	30.00-40.00 sec	59.7 MBytes	50.0 Mbites/sec	7636
[ 4]	40.00-50.00 sec	59.5 MBytes	49.9 Mbites/sec	7621
[ 4]	50.00-60.00 sec	59.9 MBytes	50.2 Mbites/sec	7665
[ 4]	60.00-70.00 sec	59.3 MBytes	49.8 Mbites/sec	7595
[ 4]	70.00-80.00 sec	59.6 MBytes	50.0 Mbites/sec	7630
[ 4]	80.00-90.00 sec	59.6 MBytes	50.0 Mbites/sec	7629
[ 4]	90.00-100.00 sec	59.6 MBytes	50.0 Mbites/sec	7634
[ 4]	100.00-110.00 sec	59.6 MBytes	50.0 Mbites/sec	7623
[ 4]	110.00-120.00 sec	59.6 MBytes	50.0 Mbites/sec	7630
[ 4]	120.00-130.00 sec	59.6 MBytes	50.0 Mbites/sec	7623
[ 4]	130.00-140.00 sec	59.7 MBytes	50.0 Mbites/sec	7636
[ 4]	140.00-150.00 sec	59.7 MBytes	50.1 Mbites/sec	7637
[ 4]	150.00-160.00 sec	59.5 MBytes	49.9 Mbites/sec	7621

Table 16:- Measurement Of Time Interval, Jitter, Lost/Total Datagrams On 50Mbps Bandwidth  
On Powerline With PHCN (Client/Receiving Module)

[ ID]	Interval	Transfer	Bandwidth	Jitter	Lost/Total	Datagram s
[ 5]	0.00-10.00 sec	4.34 MBytes	3.64 Mbites/sec	57.246 ms	419/974	-43%
[ 5]	10.00-20.00 sec	896 KBytes	734 Kbits/sec	181.336 ms	499/611	-82%
[ 5]	20.00-30.00 sec	1.66 MBytes	1.40 Mbites/sec	18.238 ms	511/724	-71%
[ 5]	30.00-40.01 sec	3.20 MBytes	2.69 Mbites/sec	18.696 ms	554/964	-57%
[ 5]	40.01-50.01 sec	1.36 MBytes	1.14 Mbites/sec	75.181 ms	573/747	-77%
[ 5]	50.01-60.01 sec	1.02 MBytes	858 Kbits/sec	104.637 ms	510/641	-80%
[ 5]	60.01-70.01 sec	1.90 MBytes	1.59 Mbites/sec	59.946 ms	522/765	-68%
[ 5]	70.01-80.00 sec	2.88 MBytes	2.42 Mbites/sec	36.624 ms	540/909	-59%
[ 5]	80.00-90.02 sec	2.85 MBytes	2.39 Mbites/sec	36.457 ms	596/961	-62%
[ 5]	90.02-100.00 sec	2.83 MBytes	2.38 Mbites/sec	45.422 ms	552/914	-60%
[ 5]	100.00-110.01 sec	1.27 MBytes	1.07 Mbites/sec	60.835 ms	611/774	-79%
[ 5]	110.01-120.00 sec	2.37 MBytes	1.99 Mbites/sec	20.356 ms	560/863	-65%
[ 5]	120.00-130.01 sec	3.13 MBytes	2.63 Mbites/sec	13.927 ms	582/983	-59%
[ 5]	130.01-140.01 sec	4.23 MBytes	3.55 Mbites/sec	24.342 ms	948/1490	-64%
[ 5]	140.01-150.01 sec	984 KBytes	806 Kbits/sec	107.571 ms	579/702	-82%
[ 5]	150.01-160.00 sec	920 KBytes	755 Kbits/sec	52.544 ms	604/719	-84%
[ 5]	160.00-170.00 sec	1.07 MBytes	898 Kbits/sec	74.601 ms	559/696	-80%

Table 17:- Measurement Of Time Interval, Total Datagrams On 1Mbps Bandwidth On Powerline  
With PHCN (Server/Transmitting Module)

[ ID]	Interval	Transfer	Bandwidth	Total Datagrams
[ 4]	0.00-10.00 sec	1.52 MBytes	1.27 Mbites/sec	194
[ 4]	10.00-20.00 sec	1.50 MBytes	1.26 Mbites/sec	192
[ 4]	20.00-30.00 sec	1.49 MBytes	1.25 Mbites/sec	191
[ 4]	30.00-40.00 sec	1.48 MBytes	1.25 Mbites/sec	190
[ 4]	40.00-50.00 sec	1.49 MBytes	1.25 Mbites/sec	191
[ 4]	50.00-60.00 sec	1.48 MBytes	1.25 Mbites/sec	190
[ 4]	60.00-70.00 sec	1.51 MBytes	1.26 Mbites/sec	193
[ 4]	70.00-80.00 sec	1.49 MBytes	1.25 Mbites/sec	191
[ 4]	80.00-90.00 sec	1.29 MBytes	1.08 Mbites/sec	165
[ 4]	90.00-100.00 sec	1.51 MBytes	1.26 Mbites/sec	193
[ 4]	100.00-110.01 sec	968 KBytes	793 Kbits/sec	121
[ 4]	110.01-120.01 sec	840 KBytes	688 Kbits/sec	105
[ 4]	120.01-130.01 sec	912 KBytes	747 Kbits/sec	114
[ 4]	130.01-140.00 sec	856 KBytes	701 Kbits/sec	107
[ 4]	140.00-150.00 sec	816 KBytes	669 Kbits/sec	102
[ 4]	150.00-160.00 sec	1.51 MBytes	1.26 Mbites/sec	193
[ 4]	160.00-170.00 sec	1.05 MBytes	885 Kbits/sec	135

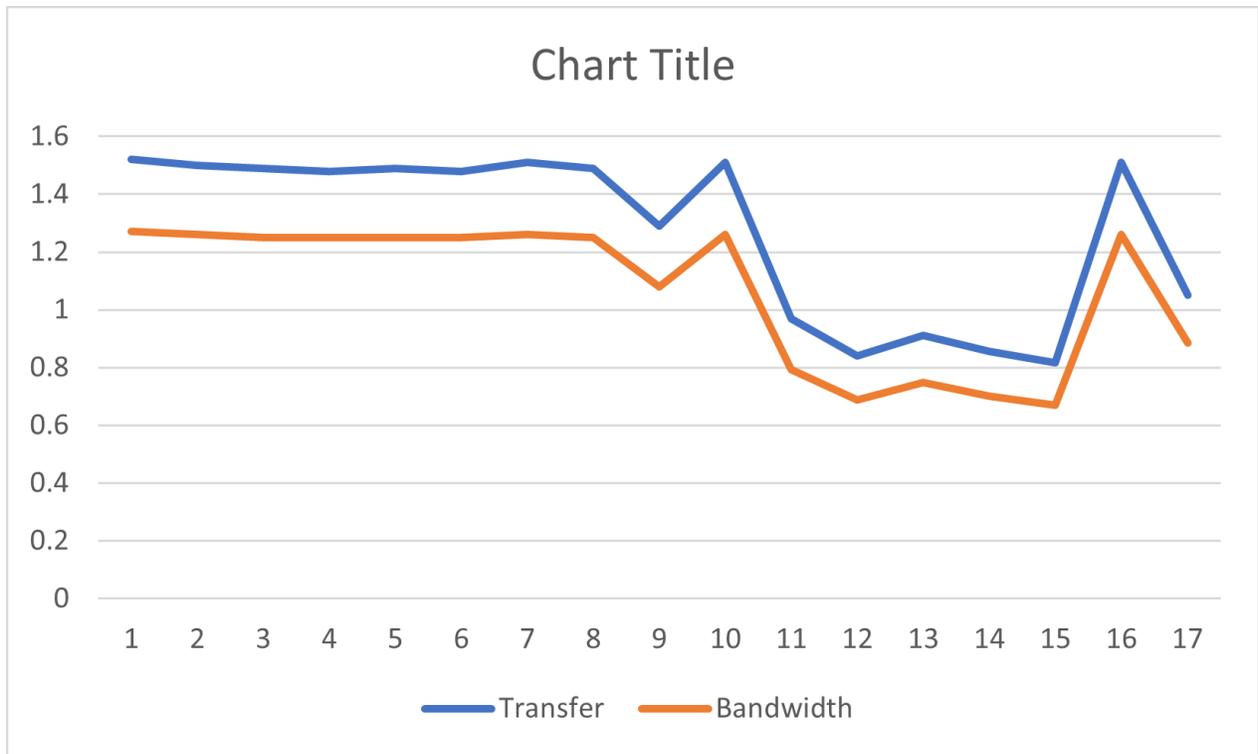


Table 18:- Measurement Of Time Interval, Jitter, Lost/Total Datagrams On 1Mbps Bandwidth On Powerline With PHCN (Client/Receiving Module)

[ ID]	Interval	Transfer	Bandwidth	Jitter	Lost/Total Datagrams
[ 10]	0.00-10.00 sec	1.49 MBytes	1.25 Mbits/sec	14.662 ms	0/191 (0%)
[ 10]	10.00-20.01 sec	1.52 MBytes	1.27 Mbits/sec	15.507 ms	0/194 (0%)
[ 10]	20.01-30.01 sec	1.48 MBytes	1.25 Mbits/sec	11.366 ms	0/190 (0%)
[ 10]	30.01-40.01 sec	1.49 MBytes	1.25 Mbits/sec	13.730 ms	0/191 (0%)
[ 10]	40.01-50.01 sec	1.49 MBytes	1.25 Mbits/sec	12.257 ms	0/191 (0%)
[ 10]	50.01-60.00 sec	1.48 MBytes	1.25 Mbits/sec	13.993 ms	0/190 (0%)
[ 10]	60.00-70.00 sec	1.50 MBytes	1.26 Mbits/sec	9.651 ms	0/192 (0%)
[ 10]	70.00-80.01 sec	1.49 MBytes	1.25 Mbits/sec	11.541 ms	0/191 (0%)
[ 10]	80.01-90.01 sec	1.29 MBytes	1.08 Mbits/sec	3.857 ms	0/165 (0%)
[ 10]	90.01-100.01 sec	1.51 MBytes	1.26 Mbits/sec	11.602 ms	0/193 (0%)

[ 10]	100.01-110.01 sec	976 KBytes	799 Kbits/sec	2.212 ms	0/122 (0%)
[ 10]	110.01-120.01 sec	840 KBytes	688 Kbits/sec	2.500 ms	0/105 (0%)
[ 10]	120.01-130.00 sec	912 KBytes	748 Kbits/sec	2.272 ms	0/114 (0%)
[ 10]	130.00-140.00 sec	856 KBytes	701 Kbits/sec	2.224 ms	0/107 (0%)
[ 10]	140.00-150.01 sec	808 KBytes	662 Kbits/sec	2.848 ms	0/101 (0%)
[ 10]	150.01-160.01 sec	1.51 MBytes	1.26 Mbits/sec	12.454 ms	0/193 (0%)
[ 10]	160.01-170.01 sec	1.06 MBytes	891 Kbits/sec	2.581 ms	0/136 (0%)

Another test was taken this time in a 4 storey plaza with about 80 offices and over a distance of 300m. Table 19 shows the bandwidth and transfer rate. As can be seen the bandwidth drastically reduced based on the distance and size of the building. The routes data travels is almost infinite.

Table 19:- Measurement Of Time Interval, Jitter, Lost/Total Datagrams On 1Mbps Bandwidth  
On Powerline With PHCN (Client/Receiving Module)

[ ID]	Interval	Transfer	Bandwidth
[ 4]	0.00-10.00 sec	512 KBytes	419 Kbits/sec
[ 4]	10.00-20.01 sec	256 KBytes	210 Kbits/sec
[ 4]	20.01-30.01 sec	256 KBytes	210 Kbits/sec
[ 4]	30.01-40.01 sec	384 KBytes	315 Kbits/sec
[ 4]	40.01-50.00 sec	384 KBytes	315 Kbits/sec
[ 4]	50.00-60.00 sec	384 KBytes	315 Kbits/sec
[ 4]	60.00-70.00 sec	512 KBytes	419 Kbits/sec
[ 4]	70.00-80.00 sec	384 KBytes	315 Kbits/sec
[ 4]	80.00-90.00 sec	384 KBytes	315 Kbits/sec
[ 4]	90.00-100.00 sec	384 KBytes	315 Kbits/sec
[ 4]	100.00-110.00 sec	384 KBytes	315 Kbits/sec
[ 4]	110.00-120.00 sec	256 KBytes	210 Kbits/sec
[ 4]	120.00-130.00 sec	384 KBytes	315 Kbits/sec
[ 4]	130.00-140.00 sec	512 KBytes	419 Kbits/sec
[ 4]	140.00-150.00 sec	256 KBytes	210 Kbits/sec
[ 4]	150.00-160.00 sec	384 KBytes	315 Kbits/sec
[ 4]	160.00-170.00 sec	256 KBytes	210 Kbits/sec
[ 4]	170.00-180.00 sec	384 KBytes	315 Kbits/sec
[ 4]	180.00-190.00 sec	384 KBytes	315 Kbits/sec
[ 4]	190.00-200.00 sec	512 KBytes	419 Kbits/sec
[ 4]	200.00-210.00 sec	384 KBytes	315 Kbits/sec
[ 4]	210.00-220.00 sec	512 KBytes	419 Kbits/sec
[ 4]	220.00-230.00 sec	640 KBytes	524 Kbits/sec
[ 4]	230.00-240.00 sec	512 KBytes	419 Kbits/sec
[ 4]	240.00-250.00 sec	512 KBytes	419 Kbits/sec

[ 4]	250.00-260.00 sec	640 KBytes	524 Kbits/sec
[ 4]	260.00-270.00 sec	640 KBytes	524 Kbits/sec
[ 4]	270.00-280.00 sec	512 KBytes	419 Kbits/sec
[ 4]	280.00-290.00 sec	512 KBytes	419 Kbits/sec
[ 4]	290.00-300.01 sec	384 KBytes	314 Kbits/sec
[ 4]	300.01-310.00 sec	384 KBytes	315 Kbits/sec
[ 4]	310.00-320.01 sec	512 KBytes	419 Kbits/sec
[ 4]	320.01-330.00 sec	512 KBytes	420 Kbits/sec

From Table 7 - 19 we can see that as bandwidth increases, the data packets received also increased but as there are packet loss too confirming Shannon Hartley theory for data transmissison. At 1MBPS bandwidth the packet loss was totally lost but at 5MBps to 50MBPS there was considerable improvement.

In PLC there are three main factor responsible for packet losses

1. Noise
2. Multi routes packet travel
3. Distance

Electric appliances and loads that are arbitrarily linked to and detached from the powerline grid, affecting the network topology, also cause interference and noise to in-home PLC. Multipath exists in the powerline channel, and the channel response changes with time and frequency.

However, the advantage is that the packets lost can be recovered and used for other points in case the server modem is sending to multiple client modem. And this is the basics of Internet of things. Also note the datagram received are payloads from the iper3 tool. In real use like multimedia or internet streaming more data will be sent through the bandwidth than those reported in Table 5.

The usage of powerline communication for domestic LAN is for data transmission and internet sharing in an aggressive channel is made possible by OFDM. When connected to the internet the

modules were able to provide internet usability between speeds of 88Mbps to 1.3Mbps. The speed will greatly be affected by the internet service providers and the factors above.

Figure 22-25 shows the spectrum diagrams displaying the center frequencies, harmonics and waveform as recorded by the analyzer. The center frequency is gotten from the formular.

$$f_c = \frac{f_{osc}}{64}$$

Where:

$f_c$  is carrier frequency.

$f_{osc}$  is total oscillation frequencies.

64 is OFDM carriers.

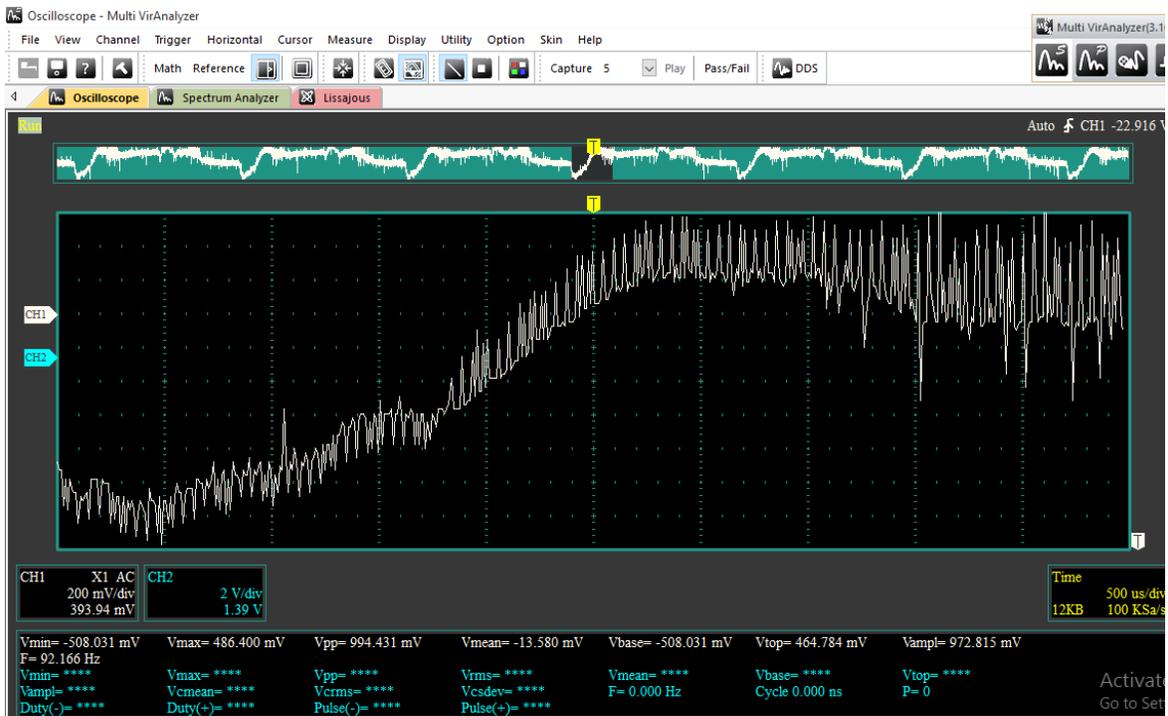


Figure 22: Carrier waveform



Figure 23: Center Carrier frequency of upper range 64KHz (On LV Line)

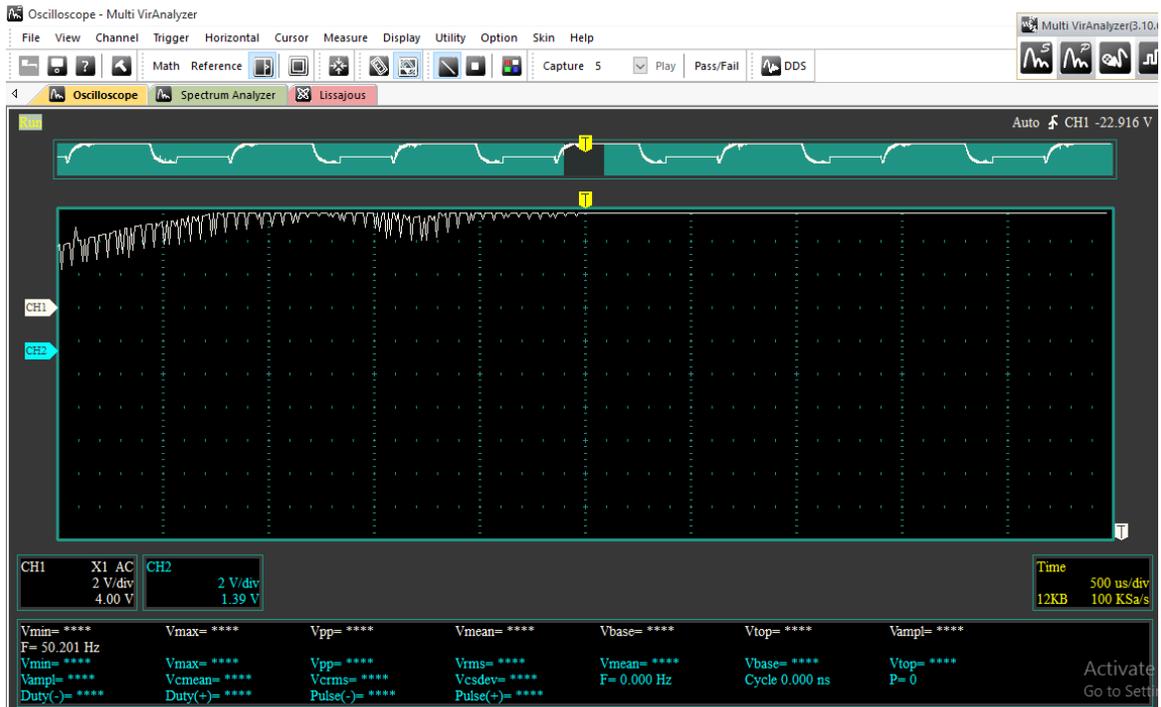


Figure 24: Speed test (Airtel 4G HBB)



Figure 25: Center Carrier frequency of lower range 13KHz (On LV Line) with harmonic

## SECTION 4

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### 4.1 Summary of Findings

The best modulation OFDM (bits per carrier) is chosen with the goal of maximizing transmission speed while preserving the appropriate bit error rate (BER). DHS MAC offers further flexibility, such as alternative scheduling transmission formats based on impulsive noise and channel impedance. As can be seen, the two layers PHY and MAC cooperate, interact, and share information, resulting in a cross-layer design of the adapters that aims to improve performance. To keep BER at acceptable levels for multimedia services, it is better to reduce throughput (transmission speed).

Theses readings were taken between 12am -3pm

Table 20

**Home (Airtel HBB)**

Internet Speed (Mbps)	Distance(m)	Off live (Mbps)	On live (Mbps)
17	30	14	3.2
	60	13	3.0
	90	6.4	2.0
	120	5.3	1.8

Internet Speed (Mbps)	Distance(m)	Off live (Mbps)	On live (Mbps)
3.7	30	3.3	2.2
	60	3.1	2.1
	90	2.9	1.5
	120	2.5	0.9
	150	Module pair but not data transfer	Module pair but not data transfer

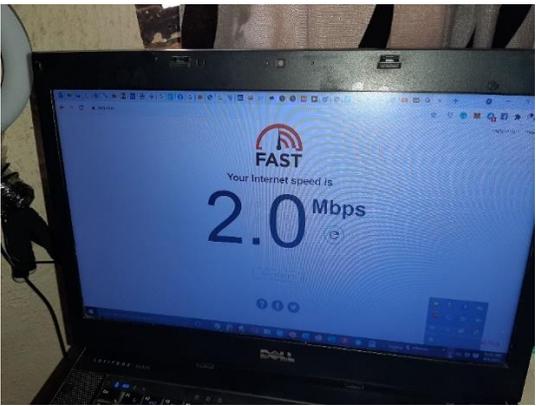
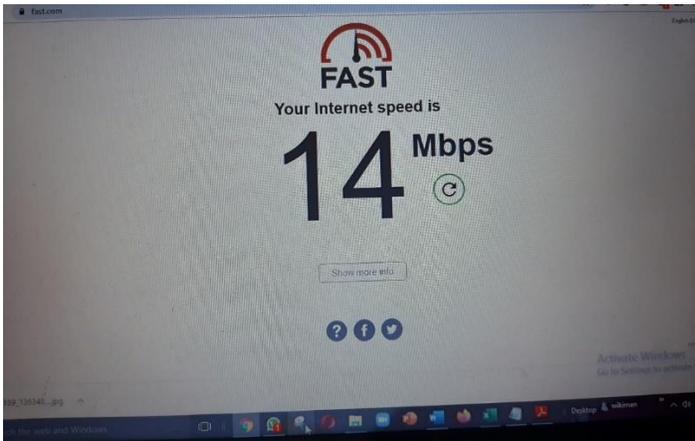
**Office (Galaxy back bone)**

Internet Speed (Mbps)	Distance(m)	Off live (Mbps)	On live (Mbps)
16	30	Reading could not be taken in this mode due to office restrictions	2.9
	60		2.2
	90		2.1
	120		Module pair but not data transfer
	150		Module pair but not data transfer

SCREENSHOTS OF VARIOUS SPEED TEST

 <p>FAST Your Internet speed is <b>3.7</b> Mbps</p>	 <p>FAST Your Internet speed is <b>2.1</b> Mbps</p> <p>Show more info</p>
	 <p>FAST Your Internet speed is <b>2.5</b> Mbps</p> <p>Show more info</p>
	 <p>FAST Your Internet speed is <b>1.5</b> Mbps</p> <p>Show more info</p>

 <p>FAST</p> <p>Your Internet speed is</p> <h1>16 Mbps</h1> <p>Show more info</p> <p>? f t</p>	 <p>FAST</p> <p>Your Internet speed is</p> <h1>2.9 Mbps</h1> <p>Show more info</p>
	 <p>FAST</p> <p>Your Internet speed is</p> <h1>2.2 Mbps</h1> <p>Show more info</p>
	 <p>FAST</p> <p>Your Internet speed is</p> <h1>2.1 Mbps</h1> <p>Show more info</p>



fast.com

**FAST**  
Your Internet speed

# 2.0 Mbps

Show more info

NetPerSec

Graph | Options | Display | About

Received: 203.1 KBytes

Current: 44.3 KBytes/s

Average: 22.2 KBytes/s

Max: 22.2 KBytes/s

Send: 7.8 MBytes

Current: 1.2 MBytes/s

Average: 637.9 KBytes/s

Max: 1000.0 KBytes/s

Display:  Current  Bar graph  Mps per second (Bps)   
 Average  Line graph  Bytes per second (Bps)

OK Cancel Help

**FAST**

# 3.0 Mbps

⏸

**FAST**

# 3.1 Mbps

⏸

Internet speed test ×

<b>1.30</b> Mbps download	<b>0.70</b> Mbps upload
------------------------------	----------------------------

Server: Tunis

Your Internet connection is very slow.

Your Internet download speed is very low. Web browsing should work, but videos could load slowly.

[LEARN MORE](#) [TEST AGAIN](#)

Table 21: Summary of Speed and SNR

Parameters	Results
Speed off LV powerlines	88 Mbps
Speed on LV powerlines	3.2 Mbps
Carrier frequency	13-64KHz
Maximum distance of data transmission	100m
SNR	39.017dB
SINAD (Signal-to-Noise and Distortion.)	29.3dB

In conclusion the prototype was designed and fabricated, and testing carried out shows a minimum speed of 3MBPS and maximum of 88MBPS. The module can be successfully implemented into a IOT systems, smart grids, machine automation and energy monitoring systems with recommended data rates between 3-5MBps.

#### FURTHER RESEARCH

The following are further research areas from this work.

1. Phase noise (VCO with high spectral purity and harmonic suppression).
2. Termination at Domestic distribution board.
3. Harmonic suppression techniques.
4. Multi carrier modulation for 5G standards.
5. Implementation of IoT application for home automation, energy consumption and security.
6. Adaptive filtering

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## APPENDIX

### ADDITIONAL READING TAKEN

100Mbps

```
C:\iperf>iperf3 -c 192.168.10.100 -w -u -64k -p -i 10 -t2000 -b 100M
```

Connecting to host 192.168.10.100, port 5201

[ 4] local 192.168.10.101 port 63637 connected to 192.168.10.100 port 5201

[ ID]	Interval	Transfer	Bandwidth
[ 4]	0.00-10.00 sec	9.75 MBytes	8.18 Mbites/sec
[ 4]	10.00-20.00 sec	8.12 MBytes	6.82 Mbites/sec
[ 4]	20.00-30.00 sec	8.00 MBytes	6.71 Mbites/sec
[ 4]	30.00-40.00 sec	7.88 MBytes	6.61 Mbites/sec
[ 4]	40.00-50.00 sec	8.25 MBytes	6.92 Mbites/sec
[ 4]	50.00-60.00 sec	8.75 MBytes	7.34 Mbites/sec
[ 4]	60.00-70.00 sec	8.00 MBytes	6.71 Mbites/sec
[ 4]	70.00-80.00 sec	4.88 MBytes	4.09 Mbites/sec
[ 4]	80.00-90.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	90.00-100.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	100.00-110.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	110.00-120.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	120.00-130.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	130.00-140.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	140.00-150.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	150.00-160.01 sec	0.00 Bytes	0.00 bits/sec
[ 4]	160.01-170.01 sec	0.00 Bytes	0.00 bits/sec
[ 4]	170.01-180.01 sec	256 KBytes	210 Kbits/sec
[ 4]	180.01-190.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	190.00-200.00 sec	0.00 Bytes	0.00 bits/sec
[ 4]	200.00-210.00 sec	1.00 MBytes	839 Kbits/sec
[ 4]	210.00-220.00 sec	8.75 MBytes	7.34 Mbites/sec
[ 4]	220.00-230.00 sec	7.75 MBytes	6.50 Mbites/sec

[ 4] 230.00-240.00 sec 7.38 MBytes 6.19 Mbbits/sec  
[ 4] 240.00-250.00 sec 7.62 MBytes 6.40 Mbbits/sec  
[ 4] 250.00-260.00 sec 7.38 MBytes 6.19 Mbbits/sec  
[ 4] 260.00-270.00 sec 7.75 MBytes 6.50 Mbbits/sec  
[ 4] 270.00-280.00 sec 7.50 MBytes 6.29 Mbbits/sec  
[ 4] 280.00-290.01 sec 8.38 MBytes 7.02 Mbbits/sec  
[ 4] 290.01-300.01 sec 7.38 MBytes 6.19 Mbbits/sec  
[ 4] 300.01-310.00 sec 7.00 MBytes 5.88 Mbbits/sec  
[ 4] 310.00-320.00 sec 7.75 MBytes 6.50 Mbbits/sec  
[ 4] 320.00-330.00 sec 9.88 MBytes 8.28 Mbbits/sec  
[ 4] 330.00-340.00 sec 7.25 MBytes 6.08 Mbbits/sec  
[ 4] 340.00-350.00 sec 7.50 MBytes 6.29 Mbbits/sec  
[ 4] 350.00-360.00 sec 8.75 MBytes 7.34 Mbbits/sec  
[ 4] 360.00-370.00 sec 7.88 MBytes 6.61 Mbbits/sec  
[ 4] 370.00-380.00 sec 7.25 MBytes 6.08 Mbbits/sec  
[ 4] 380.00-390.00 sec 7.12 MBytes 5.98 Mbbits/sec  
[ 4] 390.00-400.00 sec 7.25 MBytes 6.08 Mbbits/sec  
[ 4] 400.00-410.00 sec 6.25 MBytes 5.24 Mbbits/sec  
[ 4] 410.00-420.01 sec 2.12 MBytes 1.78 Mbbits/sec  
[ 4] 420.01-430.00 sec 4.88 MBytes 4.09 Mbbits/sec  
[ 4] 430.00-440.00 sec 3.00 MBytes 2.52 Mbbits/sec  
[ 4] 440.00-450.00 sec 4.38 MBytes 3.67 Mbbits/sec  
[ 4] 450.00-460.01 sec 6.50 MBytes 5.45 Mbbits/sec  
[ 4] 460.01-470.01 sec 5.75 MBytes 4.82 Mbbits/sec  
[ 4] 470.01-480.01 sec 6.00 MBytes 5.03 Mbbits/sec  
[ 4] 480.01-490.00 sec 7.00 MBytes 5.88 Mbbits/sec  
[ 4] 490.00-500.00 sec 7.88 MBytes 6.61 Mbbits/sec  
[ 4] 500.00-510.00 sec 8.50 MBytes 7.13 Mbbits/sec  
[ 4] 510.00-520.00 sec 8.50 MBytes 7.13 Mbbits/sec  
[ 4] 520.00-530.00 sec 9.12 MBytes 7.66 Mbbits/sec  
[ 4] 530.00-540.00 sec 7.38 MBytes 6.19 Mbbits/sec

[ 4] 540.00-550.00 sec 6.75 MBytes 5.66 Mbbits/sec  
[ 4] 550.00-560.00 sec 7.00 MBytes 5.87 Mbbits/sec  
[ 4] 560.00-570.00 sec 8.12 MBytes 6.82 Mbbits/sec  
[ 4] 570.00-580.00 sec 8.00 MBytes 6.71 Mbbits/sec  
[ 4] 580.00-590.00 sec 7.25 MBytes 6.08 Mbbits/sec  
[ 4] 590.00-600.00 sec 8.25 MBytes 6.92 Mbbits/sec  
[ 4] 600.00-610.00 sec 6.38 MBytes 5.35 Mbbits/sec  
[ 4] 610.00-620.00 sec 6.50 MBytes 5.45 Mbbits/sec  
[ 4] 620.00-630.00 sec 8.12 MBytes 6.82 Mbbits/sec  
[ 4] 630.00-640.00 sec 8.12 MBytes 6.82 Mbbits/sec  
[ 4] 640.00-650.00 sec 7.62 MBytes 6.40 Mbbits/sec  
[ 4] 650.00-660.00 sec 8.25 MBytes 6.92 Mbbits/sec  
[ 4] 660.00-670.00 sec 6.25 MBytes 5.24 Mbbits/sec  
[ 4] 670.00-680.00 sec 8.38 MBytes 7.02 Mbbits/sec  
[ 4] 680.00-690.00 sec 8.12 MBytes 6.82 Mbbits/sec  
[ 4] 690.00-700.00 sec 6.62 MBytes 5.56 Mbbits/sec  
[ 4] 700.00-710.00 sec 7.62 MBytes 6.39 Mbbits/sec  
[ 4] 710.00-720.01 sec 9.00 MBytes 7.55 Mbbits/sec  
[ 4] 720.01-730.00 sec 7.38 MBytes 6.19 Mbbits/sec  
[ 4] 730.00-740.00 sec 7.38 MBytes 6.19 Mbbits/sec  
[ 4] 740.00-750.00 sec 7.88 MBytes 6.61 Mbbits/sec  
[ 4] 750.00-760.00 sec 7.75 MBytes 6.50 Mbbits/sec  
[ 4] 760.00-770.01 sec 7.75 MBytes 6.50 Mbbits/sec  
[ 4] 770.01-780.00 sec 7.62 MBytes 6.40 Mbbits/sec  
[ 4] 780.00-790.00 sec 7.75 MBytes 6.50 Mbbits/sec  
[ 4] 790.00-800.00 sec 7.88 MBytes 6.61 Mbbits/sec  
[ 4] 800.00-810.00 sec 7.25 MBytes 6.08 Mbbits/sec  
[ 4] 810.00-820.00 sec 6.62 MBytes 5.56 Mbbits/sec  
[ 4] 820.00-830.00 sec 5.88 MBytes 4.93 Mbbits/sec  
[ 4] 830.00-840.00 sec 6.12 MBytes 5.14 Mbbits/sec  
[ 4] 840.00-850.00 sec 7.25 MBytes 6.08 Mbbits/sec

[ 4] 850.00-860.00 sec 7.62 MBytes 6.40 Mb/s  
[ 4] 860.00-870.00 sec 7.38 MBytes 6.19 Mb/s  
[ 4] 870.00-880.00 sec 7.38 MBytes 6.19 Mb/s  
[ 4] 880.00-890.01 sec 7.75 MBytes 6.50 Mb/s  
[ 4] 890.01-900.01 sec 8.00 MBytes 6.71 Mb/s  
[ 4] 900.01-910.00 sec 7.00 MBytes 5.88 Mb/s  
[ 4] 910.00-920.00 sec 8.38 MBytes 7.02 Mb/s  
[ 4] 920.00-930.00 sec 7.62 MBytes 6.39 Mb/s  
[ 4] 930.00-940.01 sec 8.38 MBytes 7.02 Mb/s  
[ 4] 940.01-950.01 sec 7.25 MBytes 6.08 Mb/s  
[ 4] 950.01-960.01 sec 7.62 MBytes 6.39 Mb/s  
[ 4] 960.01-970.00 sec 7.25 MBytes 6.09 Mb/s  
[ 4] 970.00-980.00 sec 6.88 MBytes 5.77 Mb/s  
[ 4] 980.00-990.00 sec 8.12 MBytes 6.82 Mb/s  
[ 4] 990.00-1000.00 sec 8.12 MBytes 6.82 Mb/s  
[ 4] 1000.00-1010.00 sec 7.12 MBytes 5.98 Mb/s  
[ 4] 1010.00-1020.00 sec 8.00 MBytes 6.71 Mb/s  
[ 4] 1020.00-1030.00 sec 8.12 MBytes 6.82 Mb/s  
[ 4] 1030.00-1040.00 sec 7.12 MBytes 5.98 Mb/s  
[ 4] 1040.00-1050.01 sec 6.75 MBytes 5.66 Mb/s  
[ 4] 1050.01-1060.00 sec 8.00 MBytes 6.72 Mb/s  
[ 4] 1060.00-1070.01 sec 8.25 MBytes 6.92 Mb/s  
[ 4] 1070.01-1080.00 sec 8.88 MBytes 7.45 Mb/s  
[ 4] 1080.00-1090.00 sec 8.38 MBytes 7.03 Mb/s  
[ 4] 1090.00-1100.00 sec 7.25 MBytes 6.08 Mb/s  
[ 4] 1100.00-1110.00 sec 7.88 MBytes 6.61 Mb/s  
[ 4] 1110.00-1120.00 sec 7.38 MBytes 6.19 Mb/s  
[ 4] 1120.00-1130.01 sec 7.75 MBytes 6.50 Mb/s  
[ 4] 1130.01-1140.00 sec 7.62 MBytes 6.40 Mb/s  
[ 4] 1140.00-1150.00 sec 6.88 MBytes 5.77 Mb/s  
[ 4] 1150.00-1160.00 sec 7.88 MBytes 6.61 Mb/s

```
[ 4] 1160.00-1170.00 sec 7.38 MBytes 6.19 Mbites/sec
[ 4] 1170.00-1180.00 sec 8.38 MBytes 7.03 Mbites/sec
[ 4] 1180.00-1190.00 sec 7.25 MBytes 6.08 Mbites/sec
[ 4] 1190.00-1200.00 sec 8.38 MBytes 7.02 Mbites/sec
[ 4] 1200.00-1210.00 sec 4.50 MBytes 3.78 Mbites/sec
```

---

```
C:\Users\LENOVO\Documents\iperf>iperf3 -s -l 10
```

```
-----
Server listening on 5201
-----
```

```
Accepted connection from 192.168.10.101, port 63636
```

```
[ 5] local 192.168.10.100 port 5201 connected to 192.168.10.101 port 63637
```

```
[ ID] Interval      Transfer  Bandwidth
[ 5] 0.00-1.01 sec  964 KBytes 7.84 Mbites/sec
[ 5] 1.01-2.00 sec  1.23 MBytes 10.4 Mbites/sec
[ 5] 2.00-3.00 sec  1.13 MBytes 9.47 Mbites/sec
[ 5] 3.00-4.00 sec  1008 KBytes 8.27 Mbites/sec
[ 5] 4.00-5.00 sec   997 KBytes 8.16 Mbites/sec
[ 5] 5.00-6.00 sec  1.03 MBytes 8.64 Mbites/sec
[ 5] 6.00-7.00 sec  1015 KBytes 8.32 Mbites/sec
[ 5] 7.00-8.00 sec   883 KBytes 7.23 Mbites/sec
[ 5] 8.00-9.00 sec   738 KBytes 6.04 Mbites/sec
[ 5] 9.00-10.00 sec  702 KBytes 5.77 Mbites/sec
[ 5] 10.00-11.00 sec  902 KBytes 7.38 Mbites/sec
[ 5] 11.00-12.00 sec  906 KBytes 7.42 Mbites/sec
[ 5] 12.00-13.00 sec  895 KBytes 7.33 Mbites/sec
[ 5] 13.00-14.00 sec  781 KBytes 6.39 Mbites/sec
[ 5] 14.00-15.00 sec  849 KBytes 6.96 Mbites/sec
[ 5] 15.00-16.00 sec  872 KBytes 7.14 Mbites/sec
[ 5] 16.00-17.00 sec  868 KBytes 7.11 Mbites/sec
```

[ 5] 17.00-18.00 sec 758 KBytes 6.21 Mbits/sec  
[ 5] 18.00-19.00 sec 700 KBytes 5.72 Mbits/sec  
[ 5] 19.00-20.00 sec 801 KBytes 6.56 Mbits/sec  
[ 5] 20.00-21.00 sec 906 KBytes 7.42 Mbits/sec  
[ 5] 21.00-22.01 sec 1.02 MBytes 8.56 Mbits/sec  
[ 5] 22.01-23.01 sec 984 KBytes 8.06 Mbits/sec  
[ 5] 23.01-24.01 sec 816 KBytes 6.69 Mbits/sec  
[ 5] 24.01-25.01 sec 802 KBytes 6.57 Mbits/sec  
[ 5] 25.01-26.01 sec 744 KBytes 6.10 Mbits/sec  
[ 5] 26.01-27.00 sec 752 KBytes 6.19 Mbits/sec  
[ 5] 27.00-28.00 sec 712 KBytes 5.84 Mbits/sec  
[ 5] 28.00-29.00 sec 688 KBytes 5.64 Mbits/sec  
[ 5] 29.00-30.00 sec 704 KBytes 5.76 Mbits/sec  
[ 5] 30.00-31.01 sec 708 KBytes 5.76 Mbits/sec  
[ 5] 31.01-32.00 sec 765 KBytes 6.32 Mbits/sec  
[ 5] 32.00-33.00 sec 634 KBytes 5.20 Mbits/sec  
[ 5] 33.00-34.00 sec 744 KBytes 6.09 Mbits/sec  
[ 5] 34.00-35.00 sec 761 KBytes 6.23 Mbits/sec  
[ 5] 35.00-36.00 sec 787 KBytes 6.45 Mbits/sec  
[ 5] 36.00-37.00 sec 795 KBytes 6.50 Mbits/sec  
[ 5] 37.00-38.00 sec 815 KBytes 6.69 Mbits/sec  
[ 5] 38.00-39.00 sec 1.00 MBytes 8.41 Mbits/sec  
[ 5] 39.00-40.00 sec 992 KBytes 8.14 Mbits/sec  
[ 5] 40.00-41.00 sec 1.02 MBytes 8.54 Mbits/sec  
[ 5] 41.00-42.01 sec 774 KBytes 6.30 Mbits/sec  
[ 5] 42.01-43.00 sec 691 KBytes 5.70 Mbits/sec  
[ 5] 43.00-44.00 sec 792 KBytes 6.49 Mbits/sec  
[ 5] 44.00-45.01 sec 784 KBytes 6.39 Mbits/sec  
[ 5] 45.01-46.00 sec 749 KBytes 6.17 Mbits/sec  
[ 5] 46.00-47.00 sec 830 KBytes 6.79 Mbits/sec  
[ 5] 47.00-48.00 sec 866 KBytes 7.08 Mbits/sec

[ 5] 48.00-49.00 sec 892 KBytes 7.31 Mbits/sec  
[ 5] 49.00-50.00 sec 1.03 MBytes 8.63 Mbits/sec  
[ 5] 50.00-51.00 sec 1.10 MBytes 9.19 Mbits/sec  
[ 5] 51.00-52.01 sec 903 KBytes 7.39 Mbits/sec  
[ 5] 52.01-53.00 sec 835 KBytes 6.87 Mbits/sec  
[ 5] 53.00-54.00 sec 838 KBytes 6.86 Mbits/sec  
[ 5] 54.00-55.00 sec 936 KBytes 7.65 Mbits/sec  
[ 5] 55.00-56.00 sec 1017 KBytes 8.33 Mbits/sec  
[ 5] 56.00-57.01 sec 964 KBytes 7.87 Mbits/sec  
[ 5] 57.01-58.00 sec 739 KBytes 6.07 Mbits/sec  
[ 5] 58.00-59.00 sec 749 KBytes 6.15 Mbits/sec  
[ 5] 59.00-60.00 sec 896 KBytes 7.33 Mbits/sec  
[ 5] 60.00-61.00 sec 886 KBytes 7.27 Mbits/sec  
[ 5] 61.00-62.00 sec 842 KBytes 6.90 Mbits/sec  
[ 5] 62.00-63.00 sec 771 KBytes 6.31 Mbits/sec  
[ 5] 63.00-64.00 sec 808 KBytes 6.62 Mbits/sec  
[ 5] 64.00-65.00 sec 771 KBytes 6.31 Mbits/sec  
[ 5] 65.00-66.00 sec 788 KBytes 6.46 Mbits/sec  
[ 5] 66.00-67.00 sec 818 KBytes 6.69 Mbits/sec  
[ 5] 67.00-68.01 sec 816 KBytes 6.66 Mbits/sec  
[ 5] 68.01-69.00 sec 802 KBytes 6.61 Mbits/sec  
[ 5] 69.00-70.00 sec 852 KBytes 6.98 Mbits/sec  
[ 5] 70.00-71.00 sec 868 KBytes 7.09 Mbits/sec  
[ 5] 71.00-72.00 sec 973 KBytes 7.99 Mbits/sec  
[ 5] 72.00-73.00 sec 906 KBytes 7.42 Mbits/sec  
[ 5] 73.00-74.01 sec 850 KBytes 6.91 Mbits/sec  
[ 5] 74.01-75.01 sec 1.00 MBytes 8.42 Mbits/sec  
[ 5] 75.01-176.73 sec 128 KBytes 10.3 Kbits/sec  
[ 5] 176.73-179.46 sec 0.00 Bytes 0.00 bits/sec  
[ 5] 179.46-180.02 sec 0.00 Bytes 0.00 bits/sec  
[ 5] 180.02-180.46 sec 0.00 Bytes 0.00 bits/sec

[ 5] 180.46-181.09 sec 0.00 Bytes 0.00 bits/sec