IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 19, Issue 1, Ser. I (Jan. – Feb. 2024), PP 01-07
www.iosrjournals.org

Ranging Delays Computation For Passive Optical Network Backhaul Deployment

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Abstract:
Passive optical networks has cellular backhaul capabilities within the field of telecommunication engineering and it is imperative to consider various factors that may affect pon effectiveness as a backhaul network. Among these pivotal considerations, ranging delays will be discussed in this report. This investigation unveiled a refined model for the seamless analysis of transmission devoid of collision in passive optical network transmission for both the upstream and downstream directions. The investigation incorporated the coordinates of 60 enbs in the chosen mobile network to calculate the respective distances between the enbs. Dynamic delays for individual enbs were introduced, and the results were displayed. Notably, the longest fibre length node, had no delay, allowing for immediate transmission, while the shortest length enb experienced the highest delay. This model has been specifically designed for the creation of a passive optical network ranging delays tailored to meet the upstream transmission demands of cellular backhaul applications.

Index terms: *ranging delays, qos, pon, olt, onu, splitter*

Date of Submission: 04-02-2024 Date of Acceptance: 14-02-2024

I. INTRODUCTION

In recent times, mobile communication networks have undergone a series of developments, progressing from the initial 1G (first generation) services through to the 4G (fourth generation), and most recently, the introduction of 5G (fifth generation), as noted by Arun Agarwal and colleagues in 2019 [1]. Each succeeding generation of mobile cellular networks exhibits enhancements over its predecessor while also presenting its own set of challenges. Subscribers have transitioned from basic voice-only communications to engaging in data usage, online gaming, video streaming, machine-to-machine communication, and more [2].

In line with the commitments made by the International Telecommunication Union - Radio Communication Sector (ITU-R), 4G networks were designed to deliver up to 1 gigabit per second (Gbit/s) for low-mobility communications, such as pedestrians and stationary users, and 100 megabits per second (Mbit/s) for high-mobility communication, such as trains and vehicles [3]. However, as 4G is increasingly adopted, there is an expectation of a substantial surge in data traffic. This poses a significant concern for telecom operators to uphold their service level agreements.

The current microwave backhaul systems face various challenges, including adverse weather conditions, limited capacity, restricted range, and latency issues, to name a few [4]. To address these challenges and meet the demands of 4G (LTE) traffic in terms of unlimited capacity, minimal latency, scalability, and cost-effective backhaul, a Passive Optical Network (PON) has been identified as a viable technology [5].

A Passive Optical Network, often referred to as a PON, is fundamentally an optical network configured for point-to-multipoint or multipoint-to-point connections. It enables the optical transmission of various types of information, such as voice, data, and video, between a central point known as the Optical Line Terminal (OLT) and other endpoints called Optical Network Units (ONUs) [6]. A typical PON setup consists of a central node, the OLT, and multiple ONUs connected through fiber optics and splitters [7]. These ONUs serve as the nodes for transmitting data to buildings, homes, and the local neighborhood.

In this study, assessment of ranging delays for both upstream and downstream transmission for Passive Optical Network as mobile communication backhaul was carried out.. The chosen network service provider for this venture is SMILE 4G Mobile Networks, operating in the geographical region of Port Harcourt, Rivers State, Nigeria.

II. RESEARCH METHODOLOGY

In the design of Passive Optical Networks for cellular backhaul, with SMILE 4G Mobile Networks as focus, several factors were taken into account to ensure the realization of this project. The study incorporated various elements aimed at optimizing the placement of splitters for PON backhaul, with SMILE mobile communication network provider serving as the subject of analysis. The analysis was conducted using Port Harcourt as the selected geographical case study location.

In the context of data compilation, challenges frequently arise, particularly in contemporary Nigeria. The acquisition of data pinpointing the precise coordinates of all base stations (eNB) is consistently hindered by security issues. Nevertheless, in the pursuit of attaining accurate data for this analysis, a network monitoring facility was utilized. This facility offers cell identification numbers essential for correctly determining the coordinates of base transceiver stations for each network operator in Port Harcourt.

To obtain precise coordinates for SMILE's base stations, various tools were instrumental in sourcing the required data. One such tool is the Net Monitor tool, a specialized online analytical application accessible on Apple, Windows, and Android operating systems. This tool provides supplementary access to the technical parameters of the mobile network, contingent upon the presence of the network card (SIM card) within the mobile device.

Figure 1: a Net Monitor app

The CELL FINDER ANALYTICAL TOOL, commonly referred to as "cell-finder," is a straightforward analytical instrument employed to ascertain the precise location of any given base station. It accomplishes this task by utilizing specific parameters, including the Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC), and Cell ID (CID). This online tool provides direct access to Google translation coordinates and even has the capability to supply satellite images of the immediate surroundings in which the base station is situated.

However, the effective use of the cell-finder application relies on having essential details at hand, which include:

I) Mobile Country Code (MCC): This code serves to identify the specific country in which the network provider's telecommunications company is situated.
II) Mobile Network Code (MNC): The MNC distinguishes the mobile operator, and the data tables furnished highlight MNC values for various mobile operators in West Africa and other regions.
III) Location Area Code (LAC): The LAC is a unique numeric identifier for the current location area. In this context, a location area is not defined geographically; rather, it encompasses a grouping of eNBs optimized for signaling, bounded together by a single code number.
IV) CELL-ID Number: Cell-ID numbers are primarily used to distinguish individual eNBs or sectors of eNBs within a given location area code. All of these parameters are comprehensively detailed within the data tables presented below.

Table 1: List of MCC and MNC codes for Nigeria

BRAND	**OPERATOR**	**MCC**	MNC
AIRTEL	Bharti Airtel Ltd.	621	20
SPECTRANET	SPECTRANET	621	24
VISAFONE	VISAFONE COMM T LTD	621	25
SMILE	SMILE COM. NIG.	621	27
MTN	MTN NG	621	30
GLO	GLOBACOM LTD	621	50

9ja Mobile	EMERGING MARKETS	621	60

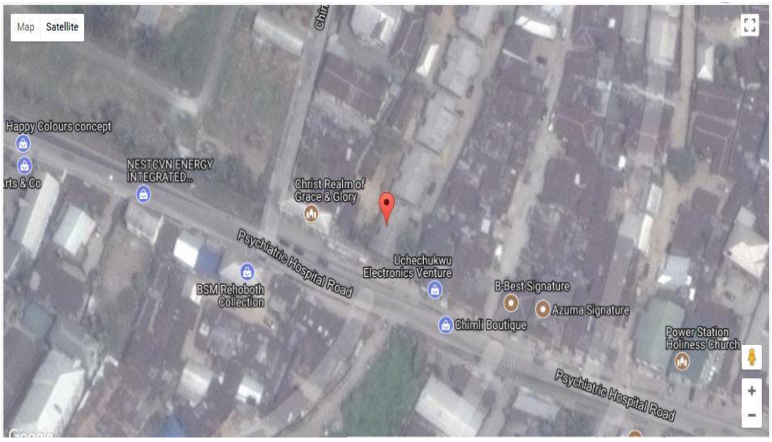

Figure 2: Satellite image indicating an eNb from the cell finder analytical tool.

Table 2: SMILE eNB coordinates in Portharcourt as obtained using Site finder tool

S/N	LAT 1(degree)	LONG 1(degree)	LAT (radian)	LONG1(radian)
eNB 1	4.83656	7.02861	0.084414	0.12267
eNB 2	4.77368	7.01428	0.083316	0.12242
eNB 3	4.799948	6.993902	0.083775	0.12207
eNB 4	4.829351	7.091902	0.084288	0.12378
eNB 5	4.770555	7.022393	0.083262	0.12256
eNB 6	4.874584	6.983038	0.085078	0.12188
eNB 7	4.869227	7.11365	0.084984	0.12416
eNB 8	4.71955	7.15183	0.082372	0.12482
eNB 9	4.855379	7.064134	0.084742	0.12329
eNB 10	4.790941	7.120734	0.083618	0.12428
eNB 11	4.785376	7.008187	0.083521	0.12232
eNB 12	4.832672	7.06854	0.084346	0.12337
eNB 13	4.803861	6.988323	0.083843	0.12197
eNB 14	4.81974	7.06564	0.08412	0.12332
eNB 15	4.743986	7.041728	0.082798	0.1229
eNB 16	4.79387	7.030763	0.083669	0.12271
eNB 17	4.748951	7.098856	0.082885	0.1239
eNB 18	4.777272	7.062001	0.083379	0.12326
eNB 19	4.834117	6.984506	0.084371	0.1219
eNB 20	4.856524	7.040508	0.084762	0.12288
eNB 21	4.806404	7.042423	0.083888	0.12291
eNB 22	4.814565	6.978764	0.08403	0.1218
eNB 23	4.829766	6.958811	0.084295	0.12145
eNB 24	4.892311	6.914281	0.085387	0.12068
eNB 25	4.847984	7.049188	0.084613	0.12303
eNB 26	4.851431	6.983489	0.084673	0.12188
eNB 27	4.808117	6.996657	0.083917	0.12211
eNB 28	4.90283	6.99907	0.085571	0.12216
eNB 29	4.978889	6.961111	0.086898	0.12149
eNB 30	4.62843	7.2701	0.080781	0.12689
eNB 31	4.996944	6.95	0.087213	0.1213
eNB 32	4.953889	7.011111	0.086462	0.12237
eNB 33	4.966944	6.986944	0.08669	0.12195
eNB 34	4.828889	7.021944	0.08428	0.12256
eNB 35	4.81687	7.01119	0.08407	0.12237
eNB 36	4.931694	7.002138	0.086074	0.12221
eNB 37	4.8407	6.96812	0.084486	0.12162
eNB 38	4.8597833	6.9791583	0.084819	0.12181
eNB 39	4.8469444	7.0369444	0.084595	0.12282
eNB 40	4.85847	6.96575	0.084796	0.12158
eNB 41	4.88	7.01	0.085172	0.12235
eNB 42	4.866944	7.03	0.084944	0.1227
eNB 43	4.837774	7.037036	0.084435	0.12282
eNB 44	4.884205	7.137983	0.085245	0.12458
eNB 45	4.781493	7.039845	0.083453	0.12287
eNB 46	4.811602	6.956136	0.083978	0.12141
eNB 47	4.90111	6.92694	0.085541	0.1209

eNB 48	4.90582	6.90656	0.085623	0.12054
eNB 49	4.802444	6.944	0.083818	0.1212
eNB 50	4.8354	7.05281	0.084394	0.12309
eNB 51	4.794722	7.049722	0.083684	0.12304
eNB 52	4.758056	7.011944	0.083044	0.12238
eNB 53	4.8269444	6.9961111	0.084246	0.12211
eNB 54	4.815	7.0419444	0.084038	0.12291
eNB 55	4.71	7.165	0.082205	0.12505
eNB 56	4.8233007	7.0571862	0.084182	0.12317
eNB 57	4.81532	7.06522	0.084043	0.12331
eNB 58	4.89497	7.0153	0.085433	0.12244
eNB 59	4.862628	7.015303	0.084869	0.12244
eNB 60	4.827644	7.01449	0.084258	0.12243

The information provided in Table 2, including the coordinates and distribution of eNBs, plays a vital role in determining the optimal location for the splitter. Given that the switch location is assumed to house the Optical Line Terminal (OLT), with each eNB serving as an Optical Network Unit (ONU), the placement of the splitter is of utmost importance to minimize both fiber cable length and attenuation, thereby ensuring a robust network design.

Table 3 presents a detailed breakdown of the distances between the specified coordinates at 4.82760N and 7.02540E, which represent the exchange/switch, and all fifty-nine eNBs within the SMILE Port Harcourt network. In the context of great circle distance calculations, the cumulative length is determined to be 440.240 kilometers, while a total distance of 564.45 kilometers is computed for walking distance. As emphasized in the manual and automatic methods analysis in the research carried out by R.O Okeke and V.E Idigo in [8], the preference for walking distances is based on their practicality and ability to account for obstacles and obstructions in real-world scenarios. Utilizing the same coordinates acquired from the automated approach, the Google map tool yields a total walking distance of 564.45 kilometers.

This design incorporates both Wavelength Division Multiplexing (WDM) and Time Division Multiplexing (TDM) Passive Optical Network (PON) arrangements, hence earning the designation of a Hybrid PON Network. Within the TDM-PON configuration, each ONU transmits its signal to the OLT at distinct time slots, as these ONUs are positioned at varying distances from the OLT. The signals or data originating from these ONUs, located at different distances, inevitably experience different propagation delays on their way to the OLT. To address this challenge, it becomes necessary to establish a timing reference, thereby enabling the OLT to receive signals from each ONU at the anticipated time. This approach minimizes the risk of potential collisions with other ONUs that are scheduled to transmit during subsequent time slots, irrespective of their respective distances from the OLT. As depicted in Figure 3, ONUn, situated farthest from the OLT, and ONU1, which is closest to the OLT, illustrate the potential for collision if ONUn begins its transmission during its designated time slot. To avert such collisions, a ranging delay is calculated based on the individual distance of each ONU to the splitter.

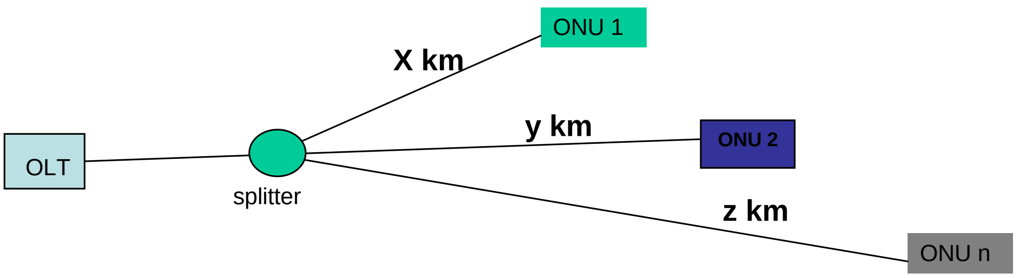

Figure 3: ONUs with different Distances to the Splitter

This design assumes a fibre with a refractive index (n) of 1.5 and speed of light 3E8km/s

Ranging delay D $= \frac{X-Y}{2E8}$ (1)

Where X = Farthest eNB

Y = eNB under consideration,

2E8 = V= Velocity of light

But $V = \frac{C}{n} = \frac{3E8}{1.5} = 2E8$ (2)

Considering farthest eNB and eNB0 (exchange) and Substituting their distances to equation 1, D is obtained as follows:

$$D = \frac{25.4 - 4.8}{2E8} = 20.6\,/2E8 = 1.03E-7\ s$$

Table 3: Breakdown of distances between coordinate 4.8276^0, 7.0254^0, Exchange/ switch and eNBs.

	EXCHANGE/NODB PARAMETERS				SPLITTER PARAMETERS (using the authomatic approach)					
	LAT1 (Degrees)	LAT1 (Radians)	LONG1 (Degrees)	LONG1 (Radians)	LAT2 (Degrees)	LAT2 (Radians)	LONG2 (Degrees)	LONG2 (Radians)	GREAT CIRCLE DISTANCE (KM)	WALKING DISTANCE (KM)
exchange	4.808117	0.08392	6.996657	0.12211	4.8276	0.08426	7.0254	0.12262	3.851776	4.8
eNB 1	4.8366	0.08441	7.0286	0.12267	4.8276	0.08426	7.0254	0.12262	1.061707	1.4
eNB 2	4.7737	0.08332	7.0142	0.12242	4.8276	0.08426	7.0254	0.12262	6.120542	7.8
eNB 3	4.7999	0.08377	6.9939	0.12207	4.8276	0.08426	7.0254	0.12262	4.655009	5.6
eNB 4	4.8294	0.08429	7.0919	0.12378	4.8276	0.08426	7.0254	0.12262	7.370938	10.1
eNB 5	4.7706	0.08326	7.0224	0.12256	4.8276	0.08426	7.0254	0.12262	6.346822	7.7
eNB 6	4.8746	0.08508	6.983	0.12188	4.8276	0.08426	7.0254	0.12262	7.027223	9.7
eNB 7	4.8692	0.08498	7.1137	0.12416	4.8276	0.08426	7.0254	0.12262	10.82182	13.8
eNB 8	4.7196	0.08237	7.1518	0.12482	4.8276	0.08426	7.0254	0.12262	18.44975	23.7
eNB 9	4.8554	0.08474	7.0641	0.12329	4.8276	0.08426	7.0254	0.12262	5.285984	6
eNB 10	4.7909	0.08362	7.1207	0.12428	4.8276	0.08426	7.0254	0.12262	11.32068	14.3
eNB 11	4.7854	0.08352	7.0082	0.12232	4.8276	0.08426	7.0254	0.12262	5.064685	5.9
eNB 12	4.8327	0.08435	7.0685	0.12337	4.8276	0.08426	7.0254	0.12262	4.809035	7.3
eNB 13	4.8039	0.08384	6.9883	0.12197	4.8276	0.08426	7.0254	0.12262	4.882963	6.5
eNB 14	4.8197	0.08412	7.0656	0.12332	4.8276	0.08426	7.0254	0.12262	4.539999	7.1
eNB 15	4.743	0.08278	7.0417	0.1229	4.8276	0.08426	7.0254	0.12262	9.578913	12.1
eNB 16	4.7939	0.08367	7.0308	0.12271	4.8276	0.08426	7.0254	0.12262	3.794737	5
eNB 17	4.748	0.08287	7.0989	0.1239	4.8276	0.08426	7.0254	0.12262	12.02797	19
eNB 18	4.7773	0.08338	7.062	0.12326	4.8276	0.08426	7.0254	0.12262	6.908652	8.1
eNB 19	4.8341	0.08437	6.9845	0.1219	4.8276	0.08426	7.0254	0.12262	4.588992	6
eNB 20	4.8565	0.08476	7.0405	0.12288	4.8276	0.08426	7.0254	0.12262	3.622968	4.8
eNB 21	4.8064	0.08389	7.0424	0.12291	4.8276	0.08426	7.0254	0.12262	3.017467	3.8
eNB 22	4.8146	0.08403	6.9788	0.1218	4.8276	0.08426	7.0254	0.12262	5.36188	7.1
eNB 23	4.8298	0.0843	6.9588	0.12145	4.8276	0.08426	7.0254	0.12262	7.383352	8.9
eNB 24	4.8923	0.08539	6.9143	0.12068	4.8276	0.08426	7.0254	0.12262	14.25756	16.5
eNB 25	4.848	0.08461	7.0492	0.12303	4.8276	0.08426	7.0254	0.12262	3.478413	4
eNB 26	4.8514	0.08467	6.9835	0.12189	4.8276	0.08426	7.0254	0.12262	5.343786	7.8
eNB 27	4.8081	0.08392	6.9967	0.12212	4.8276	0.08426	7.0254	0.12262	3.848902	4.8
eNB 28	4.9028	0.08557	6.999	0.12216	4.8276	0.08426	7.0254	0.12262	8.858675	11.2
eNB 29	4.9789	0.0869	6.9611	0.12149	4.8276	0.08426	7.0254	0.12262	18.26983	23.5
eNB 30	4.9969	0.08721	6.95	0.1213	4.8276	0.08426	7.0254	0.12262	20.59538	24.1
eNB 31	4.9539	0.08646	7.0111	0.12237	4.8276	0.08426	7.0254	0.12262	14.133	17
eNB 32	4.9669	0.08669	6.9869	0.12194	4.8276	0.08426	7.0254	0.12262	16.06601	20.4
eNB 33	4.8289	0.08428	7.0219	0.12256	4.8276	0.08426	7.0254	0.12262	0.413866	0.55
eNB 34	4.8169	0.08407	7.0112	0.12237	4.8276	0.08426	7.0254	0.12262	1.97259	2.6
eNB 35	4.9317	0.08607	7.0021	0.12221	4.8276	0.08426	7.0254	0.12262	11.85975	14.3
eNB 36	4.8407	0.08449	6.9681	0.12162	4.8276	0.08426	7.0254	0.12262	6.513767	8.3
eNB 37	4.8598	0.08482	6.9792	0.12181	4.8276	0.08426	7.0254	0.12262	6.246802	8.7
eNB 38	4.8469	0.08459	7.0369	0.12282	4.8276	0.08426	7.0254	0.12262	2.495824	3.1
eNB 41	4.8669	0.08494	7.03	0.1227	4.8276	0.08426	7.0254	0.12262	4.399581	6.9
eNB 42	4.8378	0.08444	7.037	0.12282	4.8276	0.08426	7.0254	0.12262	1.714152	2.2
eNB 43	4.8842	0.08525	7.138	0.12458	4.8276	0.08426	7.0254	0.12262	13.97321	17.8
eNB 44	4.7815	0.08345	7.0398	0.12287	4.8276	0.08426	7.0254	0.12262	5.368672	5.8
eNB 45	4.8116	0.08398	6.9561	0.12141	4.8276	0.08426	7.0254	0.12262	7.881978	10.2
eNB 46	4.9011	0.08554	6.9269	0.1209	4.8276	0.08426	7.0254	0.12262	13.6343	17
eNB 47	4.9058	0.08562	6.9066	0.12054	4.8276	0.08426	7.0254	0.12262	15.77522	18.5
eNB 48	4.8024	0.08382	6.944	0.1212	4.8276	0.08426	7.0254	0.12262	9.444577	12
eNB 49	4.8354	0.08439	7.0528	0.12309	4.8276	0.08426	7.0254	0.12262	3.157376	4.4
eNB 50	4.7947	0.08368	7.0497	0.12304	4.8276	0.08426	7.0254	0.12262	4.542345	5.5
eNB 51	4.7581	0.08304	7.0119	0.12238	4.8276	0.08426	7.0254	0.12262	7.871492	9.5
eNB 52	4.8269	0.08425	6.9961	0.1221	4.8276	0.08426	7.0254	0.12262	3.247388	4.2
eNB 53	4.815	0.08404	7.0419	0.1229	4.8276	0.08426	7.0254	0.12262	2.303337	3.8
eNB 54	4.71	0.08221	7.165	0.12505	4.8276	0.08426	7.0254	0.12262	20.25556	25.4
eNB 55	4.8233	0.08418	7.0572	0.12317	4.8276	0.08426	7.0254	0.12262	3.55576	6.2
eNB 56	4.815	0.08404	7.0652	0.12331	4.8276	0.08426	7.0254	0.12262	4.627112	7.1
eNB 57	4.894	0.08542	7.0153	0.12244	4.8276	0.08426	7.0254	0.12262	7.467662	9.8
eNB 58	4.8626	0.08487	7.0153	0.12244	4.8276	0.08426	7.0254	0.12262	4.049514	6.1
eNB 59	4.8276	0.08426	7.0145	0.12243	4.8276	0.08426	7.0254	0.12262	1.207725	1.8
									440.2402	564.45

III. RESULTS AND DISCUSSION

As shown in Table 3, eNB54 is situated at the greatest distance from the Splitter, while eNB33 is positioned closest to the Splitter. In each row of the fourth column in Table 4, the distance separating the farthest eNB from each of the other eNB is recorded. For the exchange point (eNB0), the distance between the farthest eNB (eNB54) and eNB0 measures 20.6 kilometres (25.4 - 4.8 kilometres). The same procedure was employed to derive the values in columns 4 and 5 of Table 4.

In the context of upstream transmission, during which each eNB (ONU) is transmitting signals to the OLT, a timing delay is introduced for each eNB to prevent collisions at the combiner and subsequently at the OLT, as elucidated in Figure 3. The determination of these delays for individual eNBs is carried out using Equations (1) and (2), with the results presented in Table 4. Figure 4 illustrates these assigned delays for all eNBs, including the exchange point (OLT). Notably, eNB 54, which boasts the longest fibre length of 30.2 kilometers, is allocated no delay (0.0 seconds). This signifies that eNB 54 can transmit without any delay, given its position as the farthest point within the network. Conversely, eNB 33, with the shortest length of 5.35 kilometers, carries the highest delay of 1.24E-7 seconds. All other assigned delays are represented accordingly in the plot depicted in Figure 4.

Table 4: Delay distribution for all the eNB

S/N	IDENTITIES	eNBs FIBRE LENGTH (km)	DISTANCE BTW FARTHEST eNB and EACH eNB	RANGING DELAY (s)
0	Exchange	4.80	20.60	1.03E-07
1	eNB1	1.40	24.00	1.20E-07
2	eNB2	7.80	17.60	8.80E-08
3	eNB3	5.60	19.80	9.90E-08
4	eNB4	10.10	15.30	7.65E-08
5	eNB5	7.70	17.70	8.85E-08
6	eNB6	9.70	15.70	7.85E-08
7	eNB7	13.80	11.60	5.80E-08
8	eNB8	23.70	1.70	8.50E-09
9	eNB9	6.00	19.40	9.70E-08
10	eNB10	14.30	11.10	5.55E-08
11	eNB11	5.90	19.50	9.75E-08
12	eNB12	7.30	18.10	9.05E-08
13	eNB13	6.50	18.90	9.45E-08
14	eNB14	7.10	18.30	9.15E-08
15	eNB15	12.10	13.30	6.65E-08
16	eNB16	5.00	20.40	1.02E-07
17	eNB17	19.00	6.40	3.20E-08
18	eNB18	8.10	17.30	8.65E-08
19	eNB19	6.00	19.40	9.70E-08
20	eNB20	4.80	20.60	1.03E-07
21	eNB21	3.80	21.60	1.08E-07
22	eNB22	7.10	18.30	9.15E-08
23	eNB23	8.90	16.50	8.25E-08
24	eNB24	16.50	8.90	4.45E-08
25	eNB25	4.00	21.40	1.07E-07
26	eNB26	7.80	17.60	8.80E-08
27	eNB27	4.80	20.60	1.03E-07
28	eNB28	11.20	14.20	7.10E-08
29	eNB29	23.50	1.90	9.50E-09
30	eNB30	24.10	1.30	6.50E-09
31	eNB31	17.00	8.40	4.20E-08
32	eNB32	20.40	5.00	2.50E-08
33	eNB33	0.55	24.85	1.24E-07
34	eNB34	2.60	22.80	1.14E-07
35	eNB35	14.30	11.10	5.55E-08
36	eNB36	8.30	17.10	8.55E-08
37	eNB37	8.70	16.70	8.35E-08
38	eNB38	3.10	22.30	1.12E-07
39	eNB39	9.10	16.30	8.15E-08
40	eNB40	7.80	17.60	8.80E-08
41	eNB41	6.90	18.50	9.25E-08
42	eNB42	2.20	23.20	1.16E-07
43	eNB43	17.80	7.60	3.80E-08
44	eNB44	5.80	19.60	9.80E-08
45	eNB45	10.20	15.20	7.60E-08
46	eNB46	17.00	8.40	4.20E-08
47	eNB47	18.50	6.90	3.45E-08

48	eNB48	12.00	13.40	6.70E-08
49	eNB49	4.40	21.00	1.05E-07
50	eNB50	5.50	19.90	9.95E-08
51	eNB51	9.50	15.90	7.95E-08
52	eNB52	4.20	21.20	1.06E-07
53	eNB53	3.80	21.60	1.08E-07
54	eNB54	25.40	0.00	0.00E+00
55	eNB55	6.20	19.20	9.60E-08
56	eNB56	7.10	18.30	9.15E-08
57	eNB57	9.80	15.60	7.80E-08
58	eNB58	6.10	19.30	9.65E-08
59	eNB59	1.80	23.60	1.18E-07

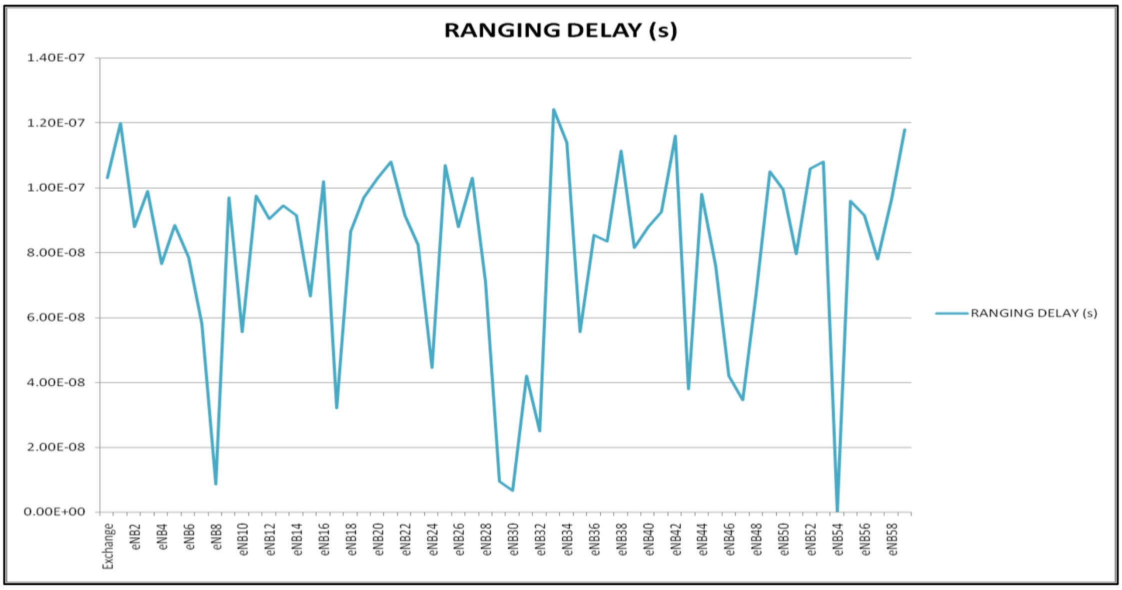

Figure 4.5: Ranging delay for eNBs in the PON network

IV. Conclusions

This study focused on achieving optimal delay computation for the backhaul of Passive Optical Networks (PON) and cost-effective PON deployment. The primary objective of this research was to establish a basis for analysing ranging delays for PONs, while considering the locations of eNodeBs. The analysis centred on the assets of the mobile network operator SMILE Networks. The research was conducted within the geographical area of Port-Harcourt city, situated in Rivers State, Nigeria. The investigation incorporated the coordinates of 60 Smile eNBs to calculate the respective distances between the eNBs. An algorithmic model in [8] was utilised to determine the optimal location for the splitter, with the aim of minimising the distance between the splitter and the 60 eNBs. Dynamic Delays for individual eNBs were introduced, and the results were displayed. Notably, the longest fibre length node, had no delay, allowing for immediate transmission, while the shortest length node experienced the highest delay.

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