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Investigation of 5G Network Signal Strength Variation in Abuja Metropolis with Atmospheric Parameters

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Abstract: The aim of this research work was to examine 5G network signal strength variation in the Abuja metropolis with atmospheric parameters. The research adopted an experimental research method by measuring the 5G network speed and quality using QualiPoc 5G software, temperature, pressure, and relative humidity with a portable digital thermometer, barometer, and hygrometer from 9:00 a.m. to 5:30 p.m. daily from September 2 to September 7, 2024. The result shows that the speed and quality of 5G network in the Abuja metropolis is influenced by atmospheric parameters such that upload is inversely proportional to the temperature, download, ping, and SNR except jitter, atmospheric pressure is directly proportional to the download and upload speed, and inversely proportional to upload speed, download speed, and SNR, while the relative humidity is directly proportional to the download speed, upload speed, ping, Jitter, and SNR, as shown in the correlation coefficients given as; -0.14, -0.10, -0.51, 0.05 and -0.24 for temperature; with 0.48, 0.05, -0.05, -0.17, -0.38 for pressure; and 0.28, 0.52, 0.26, 0.05 and 0.42 for relative humidity with the download and upload speeds, ping, jitter and signal quality (SNR) respectively. It was concluded from the results that there is a relationship between the 5G network signal in Abuja metropolis and the atmospheric condition, such that signal quality increases with a decrease in atmospheric temperature and speed while signal quality and speed decreases with increase in relative humidity. It is recommended that more data points be collected for the location to be able to show a more refined relationship since the data point used in this work was measured in over one week which is short.

Keywords: *Atmospheric condition, Download, signal strength, temperature, Upload, speed.*

I. INTRODUCTION

The first generation (1G) mobile communication, which was introduced in the 1980s, was based on the analog system, and the most popular was the advanced mobile phone system (AMPS), which was launched in the United States. In the late 1980s, an improvement to 1G communication came into existence in the form of 2G technology, and it was based on low-band digital data signaling. The analog technology was replaced by digital access techniques such as TDMA (Time division multiple access) and CDMA (code division multiple access). The most popular 2G wireless technology is known as Global Systems for Mobile Communications (GSM). In the year 2000, the third generation (3G) was introduced. The 3G brought great transformation in the mobile communication world. The 3G technology fulfills the specifications of International Mobile Telecommunications-2000 (IMT2000), the official International Telecommunication Union (ITU) which intended to provide wireless access to global telecommunication systems. The most important IMT-2000 proposal is the Universal Mobile Telecommunications System (UMTS) as the successor to GSM. The UMTS uses the W-CDMA, TD-CDMA, or TD-SCDMA air interfaces, in which WCDMA is the most popular air-interface technology for the UMTS, with the main components as Base Transmission Station (BTS), Radio Network Controller (RNC), as well as Wideband CDMA Mobile Switching Centre (WMSC) and SGSN/GGSN. In the late 2000s, the fourth generation (4G) technology was introduced. In the 2010s, the fifth generation (5G) was developed and launched in 2019. As the fifth generation (5G) is developed and implemented, the main differences as compared to 4G will be the use of much greater spectrum allocations at untapped millimeter-wave (MMW) frequency bands, highly directional beamforming antennas at both the mobile device and base station, longer battery life, lower outage probability, much higher bit rates in larger portions of the coverage area, lower infrastructure costs, and higher aggregate capacity for many simultaneous users in both licensed and unlicensed spectrums (e.g., the convergence of Wi-Fi and cellular). The backbone networks of 5G will move from copper and optical fibers to MMW wireless connections, allowing rapid deployment and mesh-like connectivity with cooperation between base stations (Dario, 2020). The increasing demand for multiple data and high speeds in our world today confirms the important role that modern technology plays in our daily lives. It provides the subscriber with a seamless experience for various applications such as streaming high-quality content and enabling effective remote work, which demonstrates the urgent need to build an advanced and effective communications infrastructure to meet these evolving requirements. Also, the significant surge in broadband data usage and smartphone adoption presents a pivotal factor in advancing mobile network (MN) development in recent years (Mahdi *et al*., 2024). People want to get in touch with their family and friends, this desire makes it more frustrating when the network quality is poor or doesn't go through at all. There have been serious complaints raised by GSM subscribers regarding the poor quality of services (QoS) rendered by the GSM operators in this study area. The most annoying aspect of this is the fact that all the GSM subscribers, irrespective of the operator, are affected (Ibrani*et al*., 2011). Many mobile phone users rely on signal bars as the measure of coverage, if a call is dropped or a web page begins to buffer, bars are typically the first indicator to always looks at. In reality, however, those bars have little to do with the actual strength of the cell signal. The number of bars can vary based on cell carrier, phone manufacturer, or even the way one holds the phone. The bottom line is that there is no standard for what these bars mean or what they actually measure, be it data or voice performance across 3G, 4G, or 5G networks. It may sound simple, but the only real evidence of signal strength that matters is call clarity and the number of dropped calls (Sa'adu*et al.*, 2019). Yekeen and Adefala (2020) did a work on the effect of the radiation as related to the specific absorption rate of mobile phones as well as the frequency of operation and how this affects human health. The method used in the research work was based on the comparison between the specific absorption rate and the average frequency of operation of a mobile carrier by adopting some formula, such as the Maxwell equation. In the work by Joseph *et al.*, (2020) on the topic "Performance Analysis of Mobile Network Services: A Case Study of Shiroro Power Station, Nigeria," the performance of four mobile network operators (MNOs) was measured, analyzed, and evaluated in Shiroro Power Station environs, and recommendations were made to improve the quality of their voice and data services. Drive test was performed using transmission environment monitoring software's (TEMs) and statistical analysis was done for performance evaluation. In the work by Dario (2018) for his master's degree program in Telecommunication Engineering on the topic "Investigation Of The Impact Of Atmospheric Effects On 5G Mobile Systems," a commercial software called WinProp was used to measure 5G signal levels in the city of Milan. This current research work focuses on the 5G network signal of the Abuja metropolis in the rainy season, which has not been done before based on the materials reviewed in this work.

II. STUDY AREA

Abuja, the capital city of Nigeria, is located between latitude 8.25^0 and 9.20^0 north of the equator and longitude 6.45^0 and 7.39^0 east of the Greenwich meridian. It was created in 1976 from parts of Kogi State, Nasarawa State, and Niger State. It has a land area of about 7315km^2, and is bounded by Niger State to the west and north, Kaduna to the northeast, Kogi to the south west, and Nasarawa to the east and south. The rainy season occurs between April and September, and the dry season between October and March each year. The vegetation is guinea forest savanna, with the rainy season occurring from April to September and the dry season from October to March. It has some high mountains and a few trees and short grasses with an average temperature of 25.7^oC and an annual rainfall of about 1200 mm (Ale *et al.*, 2024)

III. RESEARCH METHODOLOGY

A. Materials

The instruments used for the research work are; digital thermometer, barometer, hygrometer, and computer, the software used was QualiPoc 5G software. Other software used for the work are Python software and Microsoft Excel software.

B. Method

The 5G signal speed which is the upload and download, as well as the ping and jitter, along with the signal or network quality (SINR), were measured using the QualiPoc 5G software installed on a laptop and connected to a 5G network. The reading was taken at an interval of 30 minutes beginning from 9:00 a.m. to 5:30 p.m. daily from September 2 to September 7, 2024. The atmospheric parameters consisting of temperature, pressure, and relative humidity were measured with a digital thermometer, barometer, and hygrometer concurrently with the 5G parameters. The average of the half values of the parameters of the 5G network and atmospheric parameters in the one week from September 2–7, was taken, and a single value was gotten for each half hour in each of the parameters. The averaged data was used to determine the relationship between the 5G network signal strength and the atmospheric parameters, as well as determining the nature of the variation of each of the parameters with this study period. Correlation analysis was used to determine the relationship between the 5G network signal strength and atmospheric parameters.

IV. RESULTS AND DISCUSSION

Table 1 shows the average values of the 5G network, and some atmospheric components (temperature, pressure, and relative humidity) measured in the first week in the month of September from 9:00 am to 5:30 pm. The parameters of the 5G network considered in this work are upload and download speeds, ping, jitter, and the SINR. The SNR is defined as the ratio of the signal power to the sum of interference and noise power. The higher the values, the better the signal. From the table, it can be observed that the 5G signal parameters vary with time, as half hourly variation was experienced by each of the parameters. But the variation; that is; the increment or the decrement is not uniform in any of the parameters or items of the 5G network. At 9:00 am, the upload speed was 15.7 ms, and this changed at 9:30 am to 11.4 ms. The download then changed to 13.3 ms, 4.34 ms, 7.66 ms, 12.1 ms at 11:30 am, etc. The upload speed also changed from 9:00 am from 2.97 ms, 0.85 ms, 3.92 ms, 0.68 ms, 2.72 at 11:00 am, etc. The ping, which is the time taken by the signal to travel from the source to the server or destination back to the source, also displayed the variation as the time passed by. At 9:00 am, the ping was 32 ms, and this changed to 50 ms at 9:30 am, 31 ms at 10:00 am, 31 ms at 10:30 am, 32 ms at 11:00 am, etc. In the case of SINR, the values of SNR were 30 dB, 29 dB, 32 dB, 29 dB, 28 dB, 31 dB, 29 dB, …. with the highest being 47 dB, and this value was recorded at 4:30 pm. In other words, the SNR changes as the upload and download speed, ping, and jitter are changing. Also, the average atmospheric components; temperature, pressure, and relative humidity also experienced changes half hourly. The temperature, pressure, and relative humidity were observed to have shown almost half-hourly variation, even though some did not change at some points. It was observed that the temperature increased with time from morning to noon, then decreased towards the evening; the atmospheric pressure decreased with time from morning to noon and later started increasing towards the evening period. In the case of relative humidity, the values were high in the morning and evening compared to the noon period. The reason for some higher values in the daytime is because the work is in the rainy season month of September in the study area, Abuja metropolis, in which it rains at some point while sunny at some points or on some days.

Table 1: Data of average signal strength parameters of 5G network signal of Abuja metropolis and atmospheric components measured between September 2 and 7, 2024.

S/N	Time	Download (ms)	Upload (ms)	Ping (ms)	Jitter (ms)	SNR (dB)	Temp (^{o}c)	Pressure (hPa)	RH (%)
1	9:00	15.7	2.97	32	6	30	23	1015	94
2	9:30	11.4	0.85	50	30	29	23	1015	94

3	10:00	13.3	3.92	31	4	32	21	1015	97
4	10:30	4.34	0.68	31	9	29	25	1014	78
5	11:00	7.66	2.72	32	8	28	25	1014	83
6	11:30	12.1	2.22	31	5	31	25	1014	83
7	12:00	6.02	0.98	33	4	29	25	1013	89
8	12.30	13.4	3.50	35	7	30	25	1013	89
9	1:00	10.4	2.47	32	12	35	26	1012	78
10	1:30	8.3	2.4	32	46	35	23	1012	83
11	2:00	5.83	1.42	31	46	35	21	1012	97
12	2:30	4.67	0.76	36	12	31	26	1012	83
13	3:00	7.50	1.64	39	7	36	26	1011	83
14	3:30	10.2	1	48	4	34	24	1011	97
15	4:00	8.4	2.16	31	14	32	21	1011	97
16	4:30	7.25	13.7	32	11	47	21	1012	99
17	5:00	9.16	15	38	13	38	21	1013	98
18	5:30	10.2	10.2	37	9	40	20	1014	98

Figure 1 shows the graphical representation of the 5G network speed (upload and download) and quality (SINR). The figure shows that there was a variation in the speed of the 5G network in the Abuja metropolis. In other words, there were variations in the upload and download speeds of the signal, though the speed of the download was higher than the speed of the upload. In the same way, the SNR showed a half-hourly variation even though it is not in a regular form. From the figure, it can be observed that the SNR increased slightly from the beginning at 9:00 am through the day, even as it had some fall in-between until it reached the peak around 4:30 pm (number 17) before it fell and started rising again. This implies that the signal quality was high in the morning at some point, became better at some points in the afternoon, and became "much better" in the evening.

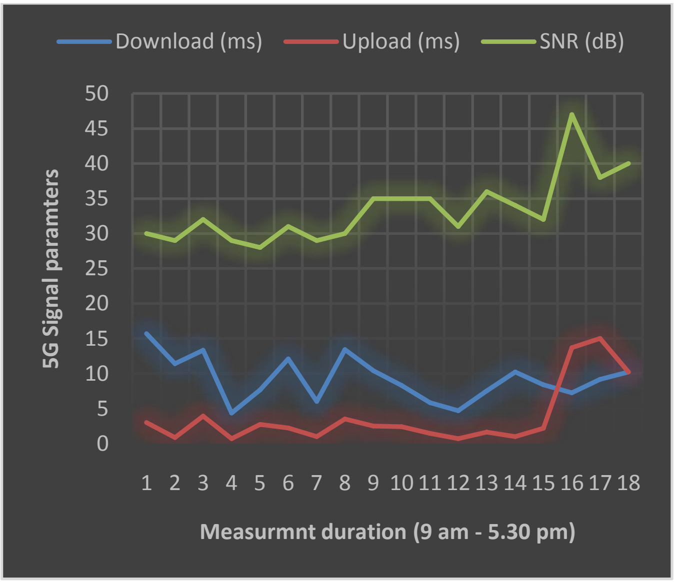

Figure 1: Graphical representation of the 5G network speed (upload and download) and signal quality (SNR)

Table 2 shows the result of the correlation analysis of the 5G signal strength and atmospheric components. The coefficients of correlation between atmospheric temperature and the download and upload speeds, ping, jitter, and SNR were -0.14, -0.10, -0.51, 0.005, and -0.24. This means that temperature is inversely related to upload and download speed, ping, and SNR except jitter. It implies that when the atmospheric temperature increases, the upload and download speeds, ping, and SNR of the 5G network decrease. The signal strength reduces when the temperature is high. Atmospheric pressure varied positively with download and upload speeds, and inversely proportional with upload and download speeds, and SNR. In other words, as the pressure increases, the upload and download speeds, ping, and SNR will decrease. In the case of relative humidity, it is directly proportional to the download and upload speeds, ping, Jitter, and SNR. This is shown in the coefficient of correlation values as 0.28, 0.52, 0.26, 0.06, and 0.42. It implies that as the relative humidity increases, these features of 5G network will increase. This positive correlation or relationship is possibly because, when the relative humidity or amount of moisture is high, it will reduce temperature, which causes a decrease in these parameters.

Table 2: Result of correlation analysis of the 5G signal strength and atmosphericcomponents

Correlation coefficients					
	Download	Upload	Ping	Jitter	SNR (dB)
Temp	-0.14	-0.10	-0.51	0.05	-0.24
Pre	0.48	0.05	-0.05	-0.17	-0.38
RH	0.28	0.52	0.26	0.05	0.42

CONCLUSION

The investigation of 5G network signal strength variation with atmospheric parameters has been done. The research made use of an experimental research method that involves the measurement of 5G network speed and quality with QualiPoc 5G software as well as some atmospheric parameters such as temperature, pressure, and relative humidity with a portable digital thermometer, barometer, and hygrometer, from 9:00 a.m. to 5:30 p.m. daily from September 2 to September 7, 2024. The result showed that the speed and quality of the 5G network in the Abuja metropolis are influenced by atmospheric parameters such that temperature is inversely proportional to the upload and download speed, ping, and SNR except jitter, atmospheric pressure is directly proportional to the download and upload speeds, and inversely proportional with upload and download speed, and SNR, while the relative humidity is directly proportional to the download and upload speeds, ping, jitter, and SNR. This is shown in the correlation coefficients as -0.14, -0.10, -0.51, 0.05, and -0.24 for temperature with the download and upload speeds, ping, jitter, and signal quality (SNR), respectively; 0.48, 0.05, -0.05, -0.17, and -0.38 for pressure with the download and upload speeds, ping, jitter, and signal quality (SNR), respectively; and 0.28, 0.52, 0.26, 0.05, and 0.42 for the download and upload speeds, ping, jitter, and signal quality (SNR), respectively. It can be concluded from the results that there is a relationship between the 5G network signal in the Abuja metropolis and the atmospheric condition.

RECOMMENDATION

In this work, the experiment was conducted in one week in the first week of September in 2024 to obtain the data used for the research work. It is recommended that a longer duration of the experiment be done in the same place to determine a more refined nature of the relationship.

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