Experimental Study on the Impact of Weather Conditions on Wide Code Division Multiple Access Signals in Nigeria

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***Abstract*—In cellular network activities, before a site is integrated it is expected that each cell of the site meets the Nigerian Communication Commission (NCC) standard of ≥98% for both service accessibility and call completion rate which in turn depicts a ≤2% in both blocked call rate (BCR) and dropped call rate (DCR). It is suggested that weather conditions have a very strong negative effect on the performance of wideband code division multiple access (WCDMA) network as it could lead to signal attenuation or change the polarization. In this paper, we study the impact of weather conditions on WCDMA network in Nigeria. To achieve this, network samples (log-files) were collected weekly during a driving test in Enugu State Nigeria for a period of five years for both rainy and dry seasons, in which blocked and dropped calls were extracted. Results show that during adverse weather conditions, BCR and DCR rise greater than 8% and 4% respectively. Although with a slight relationship between the weather conditions, the weather condition during the dry season has a better-blocked call rate of 8.76% in comparison with the rainy season with 12.89%. Calls tend to drop more during the dry season. From the outcome of the experiment, a model was developed for predicting an unknown network call statistics variables.**

Keywords-blocked call; cellular; dropped call; dry season; rainy season; weather; WCDMA

I. INTRODUCTION

In cellular networks, trying for optimization is considered a constant. One of the major reasons for constant optimization is the weather. Often, weather conditions affect major key performance indicators (KPI) such as accessibility and retainability used by operators and subscribers to assess network performance. During various weather conditions, it is expected for the WCDMA cellular network to maintain its performance and meet the Nigerian Communication Commission (NCC) threshold of both BCR and DCR ≤2%. This paper studies the impacts of weather conditions on WCDMA network and compares them. GSM signal strength varies with respect to weather parameters. Tropospheric delays such as humidity, pressure and temperature affect the strength of the transmitted signal [1]. Distance estimation based on the received signal strength of a wireless radio is susceptible to radio propagation conditions, particularly during periods of precipitation [2]. Movement of mobile station (MS) affects the signal received from the base transceiver system (BTS). Decreased signal reception conditions, if the channel is exposed to rain, occur. Rain attenuation as color noise affects signal quality, mainly 3G network signal transmission, and can be grouped into drizzling rain, straight form, medium, heavy convective and storms, have the effect of their own in the process of signal transmission. [3].

Many wireless sensor networks operating outdoors are exposed to changing weather conditions, which may cause severe degradation in system performance. Therefore, it is essential to explore the factors affecting radio link quality in order to mitigate their impact [4]. There is a relationship between atmospheric conditions and speech quality [5]. Since the cellular GSM networks are one of the most commonly used communication technologies today, the quality of speech in these networks is a topic of great significance. Many advances and approaches have been introduced in the field of speech quality during the last decade, most of them focusing on IP networks, where speech quality is influenced by every single network node through which the communication passes. There is a bond between speech quality in GSM networks and weather conditions and a greater bond between rain density and speech quality [6]. The most classical approach of determining rain attenuation for radio-wave frequency has been to theoretically determine the specific attenuation. At frequency over 10GHz, rain and precipitation can influence the attenuation a lot. The effect of atmospheric attenuation between the source and destination over wireless communication is of major concern and proper site visit and control method are required so that the performance can be increased [7]. Rainfall is a natural phenomenon whose temporal and geographical distribution varies widely. Wireless communications suffer losses in network quality during rainfall which can affect the regional communication for a while. Growing concerns of climatic change also encourage the study of the effects of natural phenomena like rainfall on other measurable parameters

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[8]. The link availability of outdoor radio systems is often affected by atmospheric conditions such as rain and snow. The effects of rainfall on wireless transmissions are particularly noticeable at data rates. As the rate of rainfall increases, more disruption is caused to the outdoor link [9]. Some dependencies between weather conditions and receive level were studied in [10]. There is a relationship between refractivity from rainfall and propagation of the GSM radio signal as greater refractivity means lower signal quality and vice versa [11]. The GSM technology is the most widely utilized communication standard which it is now coming to its bandwidth limitations especially in big cities and densely populated areas. Under such circumstances, even a minor weather change could be a decisive factor causing changes in the quality of service [12]. Attenuation in tropical regions is underestimated by existing prediction methods based on experimental data from temperate climates [13]. Sunny and rainy weather conditions have first-order main effects on user equipment [14]. The significance here is that various forms of precipitation such as rain, snow, cloud and fog absorb and scatter electromagnetic energy leading to attenuation in its signal strength. Harmattan precipitation intensity may be so great that visibility at ground level is reduced to less than a hundred meters while inflicting attenuation significantly [15]. Certain combinations of the constituents in weather can cause radio signals to be heard hundreds of miles beyond the ordinary range of radio communications. Tropical weather has significant effects on radio signal where the highest correlation values for each factor are 0.70756 for solar radiation, 0.6285 for humidity, 0.4344 for wind speed, 0.3850 for rain rate, and 0.3339 for temperature [16]. Terrestrial and Earth-space links operating at bands higher than 10GHz inevitably suffer severe signal degradation due to rain fade, particularly in the tropics [17]. This study focuses on ascertaining and comparing the impact of various weather conditions on WCDMA network.

II. EXPERIMENTAL SETUP

A. Method

The drive test method was used to characterize the network [18]. The experimental setup uses the Testing Equipment for Mobile System (TEMS) V13.0 software installed on a laptop, a TEMS mobile phone, a GPS and a power inverter. Voice calls were made for 120secs on the MTNN network by the mobile phone. The test covered the Enugu metropolis in Enugu State, Nigeria for a period of 5 years, covering both rainy and dry seasons.

B. Network Characterization Parameter

Although the experimental technique reports many parameters, the parameters of interest are BCR and DCR. BCR explains the rate at which the user equipment (UE) is unable to access the network when a call is attempted. It is expressed as:

$$\%BCR = \frac{100*\beta_{bc}}{\beta_{ca}} \quad (1)$$

where β_{bc} is the number of blocked calls and β_{ca} the number of successful calls. DCR is the rate at which established calls ends abruptly without the knowledge of both call originator and terminator:

$$\%DCR = \frac{100*\beta_{dc}}{\beta_{ce}} \quad (2)$$

where β_{dc} is the number of is dropped calls and β_{ce} is the number of successful calls.

C. Network Characterization Results

Table I shows the call statistics and radio environment results for the five year period.

TABLE I. CALL STATISTICS KPI RESULT FROM NETWORK CHARACTERIZATION.

Year	Weeks	Rainy season		Dry/Harmattan season	
		BCR	DCR	BCR	DCR
2015	Wk1	7.14	3.66	7.43	2.06
	Wk2	3.19	3.12	2.1	2.27
	Wk3	1.01	2.6	1.01	3.07
	Wk4	3.04	1.96	2.23	2.98
	Wk5	10.25	3.9	3.75	2.43
	Wk6	5.54	2.88	3.29	2.7
	Wk7	5.1	2.11	3.02	1.97
	Wk8	3.87	3.04	1.98	2.45
2016	Wk9	3.47	4.1	2.56	5.7
	Wk10	5	3.72	9.41	5.32
	Wk11	16.75	8.62	2.19	3.14
	Wk12	8.96	5.46	4.98	9.42
	Wk13	12.85	5.47	3.46	6.81
	Wk14	17.19	8.18	2.27	5.12
	Wk15	24.35	11.3	11.21	7.07
	Wk16	22.13	2.63	13.75	7.73
2017	Wk17	23.35	7.47	13.81	9.94
	Wk18	10.43	4.37	8.21	5.59
	Wk19	14.29	4.7	13	4.84
	Wk20	21.55	4.05	31.87	8.77
	Wk21	29.53	3.91	3.34	2.52
	Wk22	30	5.84	8.98	5.83
	Wk23	35.22	7.5	12.39	8.38
	Wk24	30.15	5.7	12.44	7.37
2016	Wk25	2.46	4.65	16.53	5.45
	Wk26	1.69	3.36	4.76	4.27
	Wk27	2.91	1.72	1.27	1.28
	Wk28	29	4	5.06	2.67
	Wk29	24.63	5.91	31.76	7.47
	Wk30	23.08	4.39	31.3	4.5
	Wk31	6.59	7.27	7.73	8.98
	Wk32	3.01	2.35	4.88	2.65
2017	Wk33	5.05	5.7	6.93	5.53
	Wk34	10.11	3.45	9.91	3.73
	Wk35	16.92	5.47	9.04	12.31
	Wk36	17.54	5.35	10.11	5.75
	Wk37	7.07	6.65	12.37	6.67
	Wk38	5.91	4.05	8.74	5.71
	Wk39	8.38	5.2	4.88	3.82
	Wk40	7.11	6.11	6.34	4.07

III. RESULTS AND ANALYSIS

A. Blocked Call Rate Analysis

First, a correlation test is performed on the BCR results for both rainy and dry seasons to ascertain their nature of relationship existing between them. The correlation test is denoted with r_s ranges from -1 to 1 [19].

$$r_s = \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \quad (3)$$

The result (r_s=0.453) shows there is a slight positive relationship between the BCR for both rainy and dry seasons, such that a rise in rainy season BCR leads to a rise in dry season BCR: $\mu_{rainyBCR} = 12.8955$, $\mu_{dryBCR} = 8.7573$. A statistical approach for testing the hypothesis is used to ascertain if there is a difference in population means between the BCR during the rainy and dry seasons.

Hypothesis:

$H_0: \mu_r - \mu_d = 0$

$H_1: \mu_r - \mu_d \neq 0$ (4)

Decision Rule:

Accept H_0 if $t_{cal} < t^{(\alpha)}_{(n_r+n_d-2)df}$, otherwise reject.

Test Statistic:

$$t_{cal} = \frac{(\mu_r-\mu_d)}{\sqrt{\frac{s_r^2}{n_r}+\frac{s_d^2}{n_d}}} \sim t^{(\alpha)}_{(n_r+n_d-2)df} \quad (5)$$

$$t_{cal} = 2.796 > t^{(\alpha)}_{(n_r+n_d-2)df} = 1.664 \quad (6)$$

Conclusion: There's a statistical significant difference between the blocked call rate for the rainy and dry seasons. The graph in Figure 1 shows that the rate of blocked calls during rainy season is higher than the dry/Hammattan season. This result is obvious in weeks 21, 23 and 25 respectively.

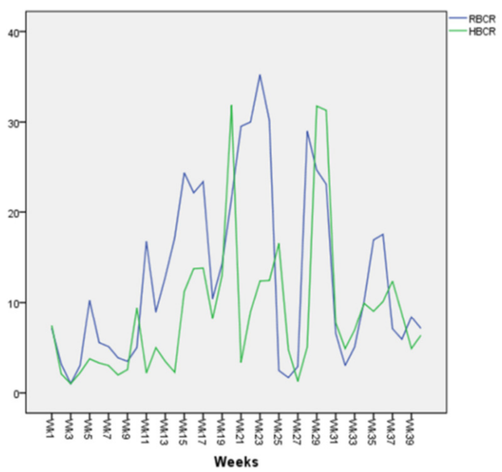

Fig. 1. Rainy and dry season BCRs

B. *Drop Call Rate Analysis*

Applying (3)-(5) the DCR we get r_s=0.524. With r_s there is a slight positive correlation between the DCRs of both rainy and dry seasons: $\mu_{rainyDCR} = 4.798$ and $\mu_{dryDCR} = 5.2085$, $t_{cal} = -1.129 > t^{(\alpha)}_{(n_r+n_d-2)df}$=1.664.

Conclusion: There's no statistical significant difference between the DCRs of rainy and dry seasons. The graph in Figure 2 shows that there is a statistical equal rate of dropped calls during rainy and dry/Hammattan seasons. All through the test period, the average marginal difference (AMD) of the DCR was $-1 \leq AMD_{DCR} \leq 1$.

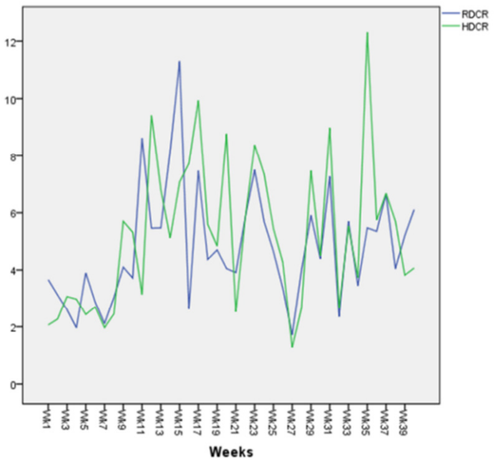

Fig. 2. Rainy and dry season DCRs

C. *Comparative KPI Analysis*

Friedman test is a non-parametric test of hypothesis approach for repeated measure analysis of variances which is used when the same parameter has been measured under different conditions on the same subjects [20].

Hypothesis**:**

$H_0: R_{RBCR} = R_{HBCR} = R_{RDCR} = R_{HDCR} = 0$

$H_1: R_{RBCR} = R_{HBCR} \neq 0$ (6)

Decision Rule:

Accept H_0 if $\alpha_{value} > \alpha_{sig}$ and reject if otherwise [20].

$$Fr_{cal} = \frac{12\sum_{i=1}^{k} R_i^2}{nk(k+1)} - 3n(k+1) \sim Fr^{(\alpha)}_{(n,k)df} \quad (7)$$

$\alpha_{value} = 0.05 > \alpha_{sig.} = 0$

Conclusion: There's no statistical significant difference between the BCR and DCR for rainy and dry seasons.

D. *Multiple Linear Regression*

Multiple linear regression is a statistical approach that models the relationship between two or more explanatory variables and a response variable by fitting a linear equation to the observed data [20]. All the values of the independent variable x are associated with the values of the dependent variable Y. The model is expressed as:

$$Y_i = \beta_0 + \beta_1 x_{i1} + .. + \beta_p x_{ip} + e_i \quad (8)$$

$$Y_i = 2023.437 - 0.084x_1 + 0.756x_2 + 0.415x_3 + 0.555x_4$$

where Y_i =years, x_1 =rainy BCR, x_2 =dry BCR, x_3 =rainy DCR and x_4 =dry DCR. The above linear regression model can be used for prediction.

IV. CONCLUSION

In cellular network activities in Nigeria, before site integration, it is expected that each cell of the site meets the NCC standard of ≥98% for service accessibility and call completion rate which in turn depicts a ≤2% in the BCR and

DCR. These results are achieved during seasonal changes. This paper points out the impact of varying weather conditions on WCDMA network performance. The results showed that during adverse weather conditions, the BCR and DCR rise greater than 8% and 4% respectively. Although with a slight relationship between the weather conditions, the weather conditions during the dry season have a better BCR of 8.76% than the rainy season with 12.89%. Calls tend to drop more during the dry season. A regression model was developed for predicting unknown network call statistics variables. Optimization actions that will protect against the effects of weather conditions on service accessibility and retainability should be considered in future studies.

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