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Design and planning of a 5G fixed wireless network

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ABSTRACT

This research explains how to design and plan fixed wireless access connections in an urban setting using 5th generation (5G) technology in a multi-user urban scenario. Although the antennas used had a high gain, the 28 GHz carrier frequency proved incompatible with the connections due to path loss. The additional loss due to foliage led to a drop in the receiver sensitivity to -84 dBm. The loss due to weather conditions resulted in lower received signal strength. The lower frequency of 3.5 GHz performed better and is recommended to establish successful communication over multi-kilometer distances. As a result, this study demonstrates how vulnerable high 5G carrier frequencies are to typical path loss impairments.

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1. INTRODUCTION

Fixed wireless networks and technologies are well-known prospective broadband connectivity alternatives in various applications. They have a vast range and may provide consumers with fast speeds. They also offer the benefit of low deployment costs. Fixed wireless networks may be scaled to suit future demands. Fixed wireless network installation can be challenging, especially where current wire-line services are highly competitive. To effectively construct and develop such networks, it is necessary to consider economic, technical, and radio-based constraints while analyzing the business case for such networks.

The application of automated planning and modeling in wireless communications network design has risen in popularity, particularly in mobile telephony, namely global system for mobile communication (GSM) [1], [2] and universal mobile telecommunications service (UMTS) [3]–[6], but also in general broadband fixed wireless access (BFWA) [7], worldwide interoperability for microwave access (WiMAX) [8], [9], and WLAN [9]–[16]. Although automated planning approaches, such as mathematical programming techniques [2], [11], are often used in constructing and designing individual networks, they also play an essential role in studying a wide range of economic and technological challenges. For example, Mom *et al*. [12] assesses the influence of mast height on the infrastructure demands and profitability of 28 and 40 GHz fixed wireless networks, whereas [13] used automated planning to study commercial aspects impacting the growth of 3.5 GHz BFWA networks in rural areas.

Because they attempt to generate near-optimal network designs in a fraction of the time required by a human planner, their regular usage enables an operator to correctly assess the impact of changing technologies, topologies, frequency bands, [17]–[20] and so on in actual realistic circumstances. Unlike human planning methodologies, automated systems can evaluate many different network topologies in a short time while considering several objectives [21]–[25]. This article outlines a step-by-step technique for improving the performance of any deployed fixed wireless network. Fixed wireless networks have technological constraints such as interference, area coverage, service, and availability. The 28 GHz and 3.5 GHz links are among the situations mentioned in this paper.

2. RESEARCH METHOD

Step one: install a receiver at Maitama, Abuja, Nigeria (9.09°N, 7.47°E). In this area, many base stations serve the region. The location is set up with a 28 GHz transmitter with a power of 1 W. The site and its surroundings are depicted in Figure 1, while Table 1. Shows the receiver sites and their corresponding coordinates and elevation.

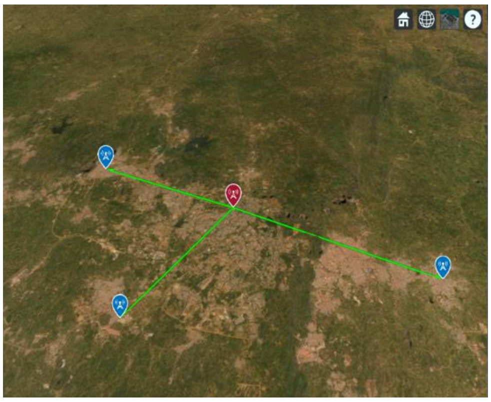


Figure 1. Light of sight (LOS) link achieved

Table 1. Coordinates and elevation for receiver sites

Receiver site	Kubwa	Lugbe	Masaka
Latitude	9.153978855103317	8.966829378713781	9.005487785609986
Longitude	7.321673936953184	7.377978869061242	7.679416249493409
Elevation (m)	444	403	1115

Step two: set up the sites for receiving signals and mark them on a map. Each reception site corresponds to the physical location of a customer's terminal. Table 1 shows the receiver sites and their coordinates and elevation. Step three: install antennas on buildings at reception sites, assuming 6 m utility poles for the Kubwa and Lugbe locations and a 15 m antenna pole for the Masaka location. As shown in Figure 2, the base station's antenna height is extended until line-of-sight is obtained with all receiving sites.

Step four: Make an 8-by-12 antenna array out of turnstile antenna pieces to generate a highly directed beam. This technology employs multi-user multiple input, multiple outputs (MU-MIMO) to realize the 5G concept. Priority is given to estimating input impedance and radiation patterns utilizing electric and magnetic fields. The far-field radiation may be computed in many steps, beginning with the vector potential A, as illustrated in (1):

$$\vec{A} = \iiint_V \mu \vec{J} \frac{e^{-j\beta\vec{R}}}{4\pi\vec{R}} dV \tag{1}$$

Where: $\vec{J}$ is the current source density and $\vec{R}$ is the vector distance, hence:

$$\vec{H} = \frac{1}{\mu} \nabla \times \vec{A} \tag{2}$$

$$\vec{E} = \frac{1}{j\omega\varepsilon} \left(\nabla \times \vec{H} \times \vec{J}\right) \tag{3}$$

The power radiated is expressed in (4):

$$p_{rad} = \frac{1}{2} R_e \iint_S \vec{E} \times \vec{H} \times dS \tag{4}$$

As shown in (4), the power given to an antenna is the sum of the radiated power plus the power wasted due to ohmic losses. The dissipative impedance R_A of the antenna is made up of radiation resistance R_R and ohmic losses R_{ohmic}. The near field also stores energy, represented by the reactive component of the antenna input impedance, j_{xa}. The antenna's total impedance, indicated by Z_A, is derived by combining the impedances in (6).

$$P_{in} = P_r + P_{ohmic} = \frac{1}{2} R_A |I_A|^2 = \frac{1}{2} R_r |I_A|^2 + \frac{1}{2} R_{ohmic} |I_A|^2 \tag{5}$$

$$Z_A = R_r + R_{ohmic} + jX_A \tag{6}$$

The time average stored power P_{st} is given in (7):

$$P_{st} = j2\omega \left(W_{m_{Average}} - W_{e_{Average}} \right) \tag{7}$$

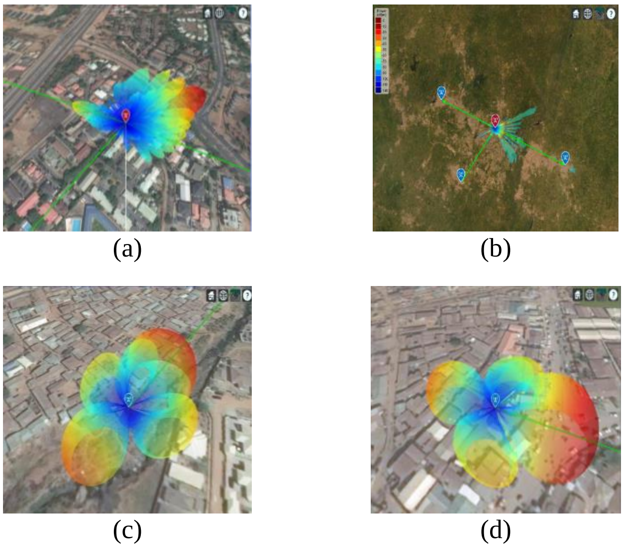
Step five: make a three-by-three rectangle array using a reflector-backed vertical dipole antenna unit. Draw the radiation pattern on the map by pointing the array toward the base station at each receiver position. Step six: create a single beam to broadcast to all receiver locations simultaneously while fulfilling receiver sensitivity requirements.

Step seven: weissberger's model estimates route loss due to vegetation, while the gas and rain propagation models provided in [2], [3] are used to evaluate signal strength due to weather. The estimated signal intensity drops below the receiver sensitivity. Step eight: we redesign the MU-MIMO system for the 3.5 GHz band to achieve lower path loss and higher signal strength.

3. RESULTS AND DISCUSSION

An antenna height of 265 m was required to achieve a light of sight between the three (3) locations with a signal strength of -94.45 dBm, -94.12 dBm, and -79.78 dBm for Kubwa, Lugbe, and Masaka. Path loss due to foliage for the 28 GHz link was 22.74 dB bringing the signal strength for Kubwa, Lugbe, and Masaka to -121.26 dBm, -122.93 dBm, and -105.70 dBm. Figures 2(a)-(d) show the beam and pattern across the receiver sites.

From Figures 2(a)-(d) the transmitter site beam alongside the beam pattern for Kubwa, Lugbe, and Masaka are shown. The single beam generates radiation lobes toward the three receiver sites. The results show that the signal strength drops at each receiver site with the simultaneous transmission but still meets the receiver sensitivity. The signal strength at Kubwa, Lugbe, and Masaka dropped to -98.52 dBm, -100.18 dBm, and -82.96 dBm, respectively. Path loss due to foliage depth of 25 m was 22.74 dB and 12.59 dB for the 28 GHz and 3.5 GHz links, respectively. This affected the signal strength of the 28 GHz links more than the 3.5 GHz link. The signal strength for the 28 GHz link further dropped to -154.99 dBm, -155.34 dBm, and -146.38 dBm for Kubwa, Lugbe, and Masaka areas when passed through atmospheric gases.



(a) (b) (c) (d)

Figure 2. Beam pattern structure for (a) transmit beam pattern for base station site, (b) base station power level in dBm, (c) beam pattern for Kubwa receiver site, and (d) beam pattern for Masaka receiver site

4. CONCLUSION

This study shows how to leverage 5G technology to plan a fixed wireless access connection over terrain in a multi-user urban context. Despite beam shaping and high gain antennas, the 28 GHz carrier frequency is incompatible with the links due to route loss. The addition of vegetation loss reduces the signal intensity below the receiver sensitivity, and the introduction of meteorological loss further reduces it. A lower frequency of 3.5 GHz is necessary to establish effective communication over multi-kilometer distances. As a result of this study, 5G carrier frequencies are exposed to common route loss problems.

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