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A Spatio-Topographical Assessment of Mobile Network Quality in Rocky Terrains: A Case Study of Dutsin-Ma Town

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The Research is aimed at identifying the spatial distribution and variation of mobile phones network quality in the study area which is dominated by irregular topography, inselbergs and rock outcrops. To achieve this aim, fifty (50) sampled areas were selected in Dutsin-Ma Town based on the nature of their rugged terrain and rocky landscape. Smart phones were used to collect Ultra-High Frequency (UHF) data using systematic grid sampling technique to determine the network strength of MTN, GLOBACOM, AIRTEL, and ETISALAT. A total of one hundred (100) structured questionnaires were also distributed to residents to obtain the necessary information to validate the results from users' perspective. The research found out that generally Dutsin-Ma is a not a town with good network as average (48%) and poor (36%) network quality dominates the area; only 16% of the areas have good network quality. From the questionnaire survey, majority (43%) of the respondents are using MTN because of its high quality and resistance especially in areas with rock outcrops. It was also found that areas around Motel, Gidan Ruwa, Hayin Gada, all of relatively moderate relief (512-578m) has the best Network; Unguwar Tsamiya, Dan Kauye and Tsohuwar Kasuwa have average Network while areas like Unguwar Alkali and Unguwar Wakaji have poor network quality. It was therefore concluded that network challenges in some areas have (in addition to other factors) a strong connection with elevation, rugged terrain and rocky landscape. However, in some few instances (Kadangaru and Makarantar Gabas), quality of some network like GLO and Airtel increases with altitude. It was also found that rugged terrains constitute a barrier to successful installation of masts in many locations. The research recommended adequate town and landuse planning that will ensure improved spatial distribution of masts for quality phone signals of all networks across Dutsin-Ma area.

Keywords: Elevation, Landscape, Network, Environment, Determinism, Possibilism

Introduction

Which integrates cellular phones into the Public Switched Telephone Network-PSTN (Zhang and Stojmenovic, 2005.) Apart from voice service, cellular telephony provides other services to the users like short messages services (SMS), Instant messaging (IM), multimedia messaging service (MMS), wireless internet, etc (Pashtan, 2006).

Original Article

Rappaport (1996) defined the quality of signals as set of technologies that work on a network to guarantee its ability to dependably run high priority applications and traffic under limited network capacity. Quality of service for network is an industry-wide set of standard and mechanism for ensuring high-quality performance for critical applications. It also refers to the performance of various communication services rendered which defines efficiency as determined by the level of users' satisfaction. Zhang and Stojmonvic (2005) gave some Tanzanian regulations clearly recommending measurement of the mobile network quality from time to time and comparing them with the norms so as to assess the level of performance.

While the threat to network quality is mainly perceived to be technical, the physical environment plays a critical role in that regard (Abdulazeez *et.al.* 2021). For example, communication system installations often take place over irregular terrains that can greatly affect and distort the expected network performances. Therefore, the terrain profile of a particular area needs to be taken into account when estimating the path loss since the transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is obstructed by buildings, rocks, hillsides or foliage (Sridhar, 2004) typically characteristic of the study area. Radio waves require direct line of sight from Base Station to Base Station (BS to BS).

Around Dutsin-Ma Town, there are hills and mountains which can create obstacles and prevent signal of one BS from reaching another BS or Base Station Controller (BSC). This problem potentially degrades quality of service and affects both network coverage and capacity. Secondly, there are apparent challenges to infrastructural network strength from service providers in Dutsin-Ma. It was understood that network infrastructure is available mainly in the center of most towns and urban areas, but not in the peripheries where communication is also key (Mishra, 2007). This research was carried out to analyze the spatial network quality in Dutsin-Ma Town to assess the impact of geographic factors on the network quality in the town.

1.1 MATERIALS AND METHODS

1.1.1 Study Area Description

The study area is Dutsin-Ma Town in Dutsin-Ma Local Government Katsina State. Dutsin-Ma is located between latitude 12°09'18"N to 12°30'44"N and longitudes 7°20'48"E to 7°3'18"E. It is one of the oldest towns in central parts of Katsina State. Dutsin-Ma Local Government, its bordered by Kankia, Charanci and Matazu LGAs to the East, Safana LGA to the West, Danmusa LGA to the South and Kurfi LGA to the north (Fig 1.1a). The area is part of the tropical continental wet and dry Sahelian climate region (Koppens Aw) with total annual rainfall ranging from 700-800mm. The areas vegetation is *sudano-sahelian* types with predominantly grass and few scattered trees. (Ministry of land and survey Katsina, 2008; Abdulazeez *et.al.*, 2018).

1.1.2 Methodology

The study area (Fig 1a) was divided into 50 spatially distributed parts by imposing a grid on its map. The coordinates of the center of each grid were recorded and identified in the ground as a sample. Data collected include the Ultra High Frequency (UHF) for each point, Absolute (latitude and longitude) location, elevation, and inventory of physical features (Table A). User information on network quality was collected through questionnaire administration from at least two respondents which were selected using availability sampling technique.

The UHF is the International Telecommunication Union (ITU) designation for radio frequency ranging from 300-3000 Mhz denoting signal strength. Statistical Analysis was used to obtain average results of recorded UHF values

Original Article

taken for three different times of the day. Results of the data analyze were presented on graphs, charts, and frequency tables. Network quality maps for the four major telecommunication networks were processed in ArcGIS 10.1 and presented.

Before conducting sampling for the research, topography and elevation (Fig 1b) were considered to ensure comprehensive data collection. The varied terrain, characterized by rocky outcrops and undulating landscapes, required a stratified sampling approach to capture diverse network quality experiences. Elevation differences, impacting signal strength and propagation, were mapped and included in the sampling framework, ensuring that both high and low elevation areas were adequately represented. This approach enabled a thorough analysis of how the physical geography of Dutsin-Ma influences mobile network performance.

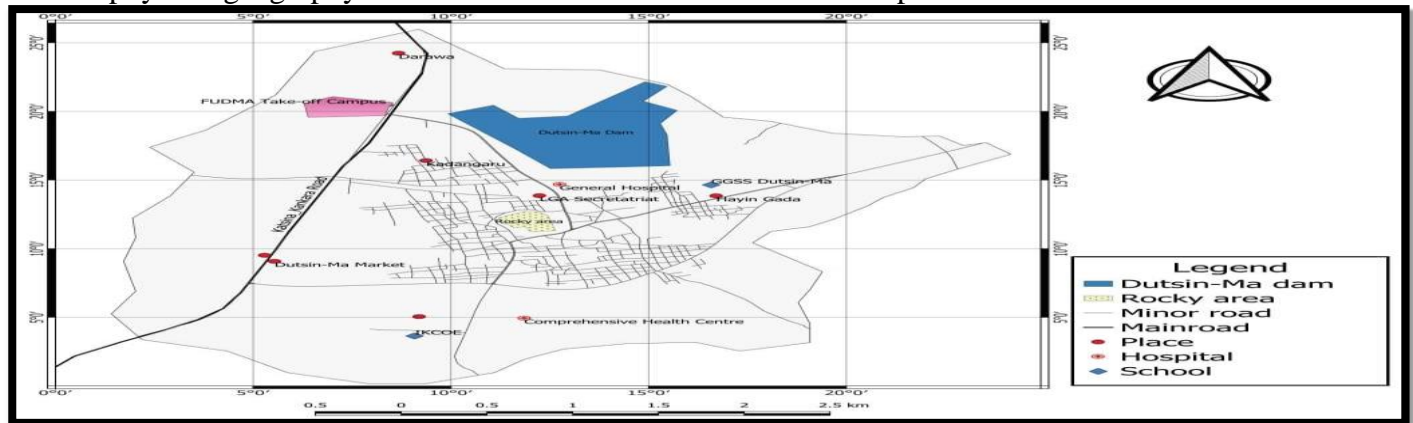


Fig 1a: Map of Dutsin-Ma Town, the Study Area

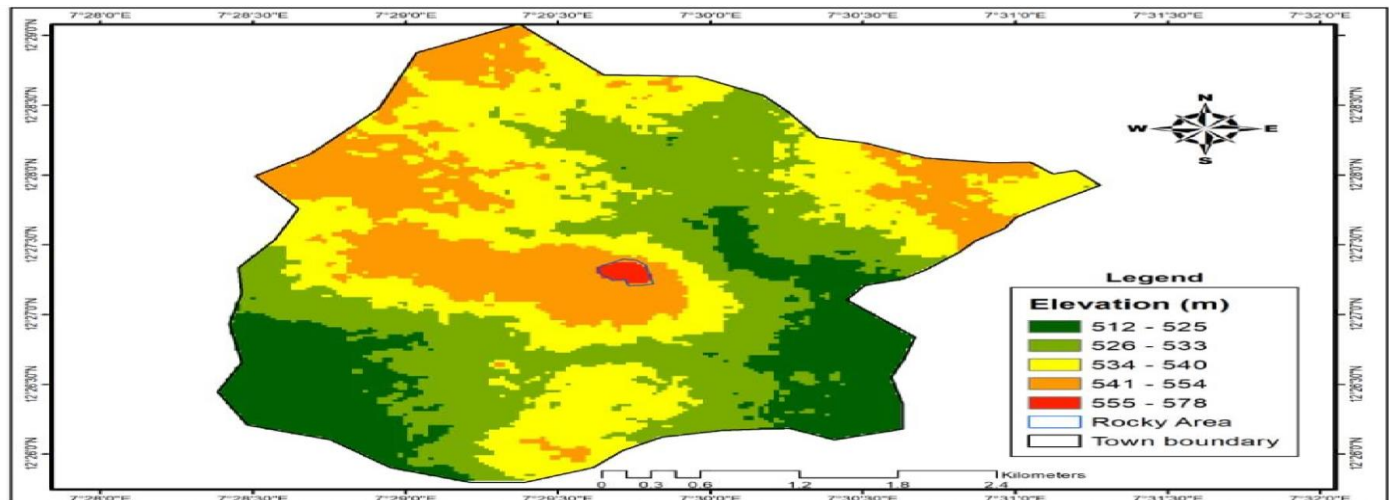


Fig 1b: Map of Dutsin-Ma, the Study Area with elevation

1.2 RESULTS AND DISCUSSION OF FINDINGS

From table A, it can be analyzed that generally Dustisn-Ma is a not a town with good network as average (48%) and poor (36%) network quality dominates the area; only 16% of the areas have good network quality. While the elevation range of the town is 512-578m (Figure 1b), the average is about 535m above sea level. Most cellphone masts transmit their signals horizontally not vertically, with the exception of a few that transmit signals sporadically in all directions, therefore, network quality in many cases is likely to decrease with altitude (Colpaert,

Original Article

2018). Furthermore, at high altitudes, atmospheric conditions may cause signal delays due to the earth's curvy shape (Karanja *et.al.*, 2023).

Table A: Average Mobile Network Quality Across 50 Sampled Location in Dutsin-Ma Town. 1.2.1 Demography of Network Users

The age distribution shows that 34% of the users fall within the age of less than 25 years old; 36% falls within the age range 25-34; 20% falls within the age range of 35-44, 4% falls within the age range of 45-54; 2% falls within the age range of 55-64 and 15% falls within the age of 64 years to above. This shows that the population of network users is dominated by the youth which are very active with communication.

The sex distribution of the respondent reveals that 64% are male while 36% are female. From the questionnaire survey, 57 % of network users have a qualification beyond secondary school meaning they are at least educated enough to understand the dynamics of network quality.

1.2.2 Major Networks Used in Dutsin-Ma Town

Table 1 shows the major, primary or first choice network used by the respondents indicating a clear preference for MTN (43%) and Airtel (36%). Globacom users (9%) and Etisalat (12%) following by a distance. This implies that majority of the network users of Dutsin-Ma Town are using MTN as their preferred network.

Table 1: Primary Network of residents

SN	NETWORK	FREQUENCY	PERCENTAGE %
1.	MTN	43	43
2.	GLO	09	9
3.	AIRTEL	36	36
4.	ETISALAT	12	12
Total		100	100

Source: Fieldwork, 2022 Table 2 shows the results for respondents' second choice network. MTN is the most popular secondary network of users as well with 41% followed by Airtel with 30%. This indicates that MTN and Airtel Networks relatively have the best spatial coverage in the town.

Table 2: Secondary (Other) Network(s) used by the Respondents

SN	NETWORK	FR EQUENCY	P ERCENTAGE %
1.	MTN	36	36
2.	GLO	16	16
3.	AIRTEL	28	28
4.	ETISALAT	10	10
Total		100	100

Source: Fieldwork, 2022.

1.2.3 Location-Based Network Quality According to Users

The detail of network quality in specific areas of Dutsin-Ma Town (Table A) is being presented in maps and tables based on recorded UHF values and customer satisfaction which varied across different telecommunication networks. Data collected from Network users returned a result of 71% for Danrimi as the best location to make calls in the town; 20% preferred Unguwar Tsamiya and 9% opted for Abuja Road. Incidentally, all three locations are within the center of the town which has a relatively flat terrain and favourable topography. Although, close to

Original Article

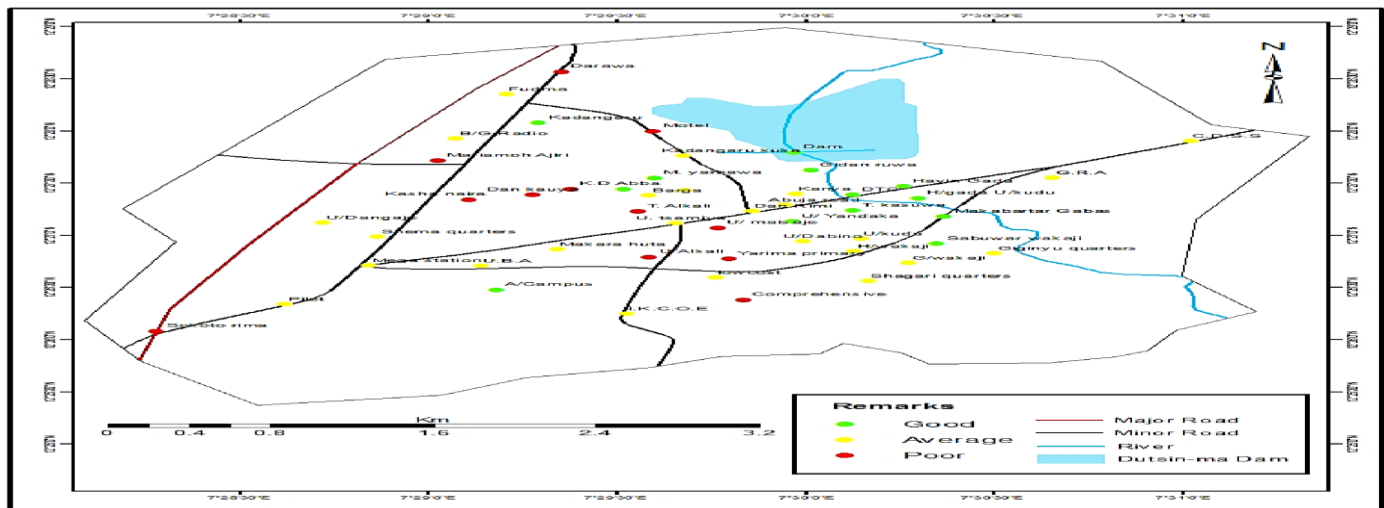


Figure 4: Spatial Quality of Glo Network in Dutsin-Ma Town

The Quality of Etisalat Network in Dutsin-Ma Town is good in Danrimi, Gidan Ruwa and Makabartar Gabas, it is average in IKCOE, Makara-Huta and Low cost. The network is poor in Sokoto Rima, Mega Station and Tudun Alkali areas of Dutsin-Ma Town (Fig 5). The eastern side of the town with relatively flat terrain has better Etisalat network quality.

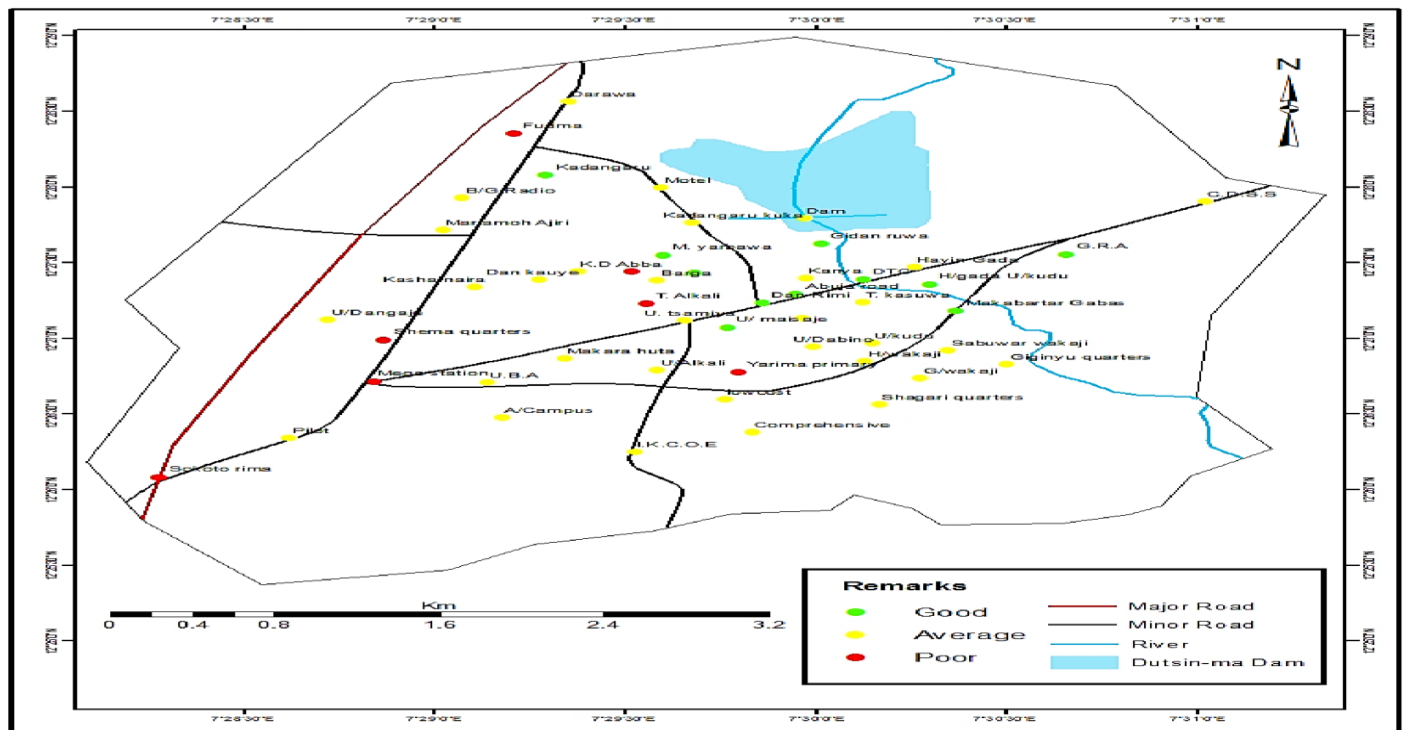


Figure 5: Spatial Quality of Etisalat Network in Dutsin-Ma Town

1.2.3 Geographical Impediments to Network Quality According to Users

Original Article

Table 3 shows the percentage of the major physical impediment to network quality in Dutsin-Ma Town. Rocks and boulders constitute 73% while weather conditions go with 19% of the physical impediment toward network quality. This clearly shows that the nature of terrain or landscape of Dutsin-Ma Town has significant influence the network strength of the study area.

Table 3: Physical impediments to Network Quality in Dutsin-Ma Town.

SN	PHYSICAL IMPEDIMENT	FREQUENCY	PERCENTAGE %
1.	Rocks	73	73
2.	Weather	19	19
3.	Vegetation	8	8
4.	Others (specify)	00	00
Total		100	100

Source: Fieldwork, 2022.

Table 4 shows some human impediments to network quality in Dutsin-Ma Town. Inadequate masts constitute 81%, large population goes with 8% and remoteness goes with 3%. This implies that apart from elevation and terrain, inadequate masts contribute to the poor network quality of some places in Dutsin-Ma Town.

Table 4: Human Geographical Impediments to Network Quality

SN	HUMAN IMPEDIMENT	FREQUENCY	PERCENTAGE %
1.	Large population	08	8
2.	Inadequate masts	81	81
3.	Remoteness	03	03
5.	Buildings	8	8
6.	Other(s) specify	00	00
Total		100	100

Source: Fieldwork, 2022.

Table 5 shows the best time to which network is at its best to Network users. About 80 % of the respondents reveal that the network is at its best in the night while 26% prefer morning. This shows that the network users prefer to use network at night because of its stability and less congestion.

Original Article

Table 5: Temporal Dimension of Network Quality

SN	TIME	FREQUENCY	PERCENTAGE%
1.	Morning	24	24
2.	Afternoon	4	4
3.	Evening	4	4
4.	Night	68	68
Total		100	100

Source: Fieldwork, 2022.

From those interviewed, 97% of the respondents believe that rugged terrains and rocky landscape has effect on the network quality of Dutsin-Ma Town, while 3% of the respondents do not share this belief. Meanwhile, 26% of the respondent believe rocky landscapes constitute barriers to the erection of telecommunication mast, whereas 74% think the rocky landscape blocks free distribution of signals. About 12% of the respondents observed that increase in population has resulted in more pressure of network quality and 88% of the respondents suggest that it is the same increase in population that has attracted the installation of more masts in the area instead.

Table 6 shows the most significant types of network problems in Dutsin-Ma Town. The main problem according to the respondents is poor connectivity with 55%, unclear sound while making calls goes with 17%, poor internet service has 17%, complete shut down and breakage goes with 2% and 1% respectively. This shows that poor connectivity is the worst problem affecting network quality of Dutsin-Ma Town.

Table 6: Major Network problem in Dutsin-Ma Town.

SN	NETWORK PROBLEM	FREQUENCY	PERCENTAGE%
1.	Poor connectivity	55	55
2.	Unclear sound	17	17
3.	Poor internet service	17	17
4.	Complete shutdown	02	02
5.	Breakage	01	01
Total		100	100

Source: Fieldwork, 2022**1.3 FURTHER DISCUSSION OF FINDINGS**

Apart from other socio-economic factors, the quality or strength variation of Network quality is partly due to the nature of rugged terrain and rocky landscape of Dutsin-Ma Town. The research shows that some of the samples that are close to the rocky areas have poor Network quality. This factor is clearly similar to the research work of Mtaho and Ishengoma (2011) in the Analysis of quality service in Tanzania cellular Network which identifies the geographical terrain as one of the main factors that led to the Network quality variability in a particular area. This

Original Article

is also partly due to differences in quality of network infrastructure between MTN, AIRTEL, GLO and ETISALAT.

The spatial network quality can be seen in the maps of Dutsin-Ma Town of MTN, Airtel, Glo and Etisalat Network shown in Figures 2, 3, 4 and 5 respectively. This was supported by the result of network quality across Dutsin-Ma Town which was gotten from respondents through questionnaires.

Finally, it was observed that the elevation or the nature of landscape in Dutsin-Ma Town have great influence on network quality across Dutsin-Ma Town, this is because the areas surrounded with high elevated lands tends to be poor in all the networks, while the areas surrounded by moderate elevated lands tend to be average and lastly the areas surrounded- by low elevation tend to be good in term of network quality for MTN, GLO, AIRTEL, and Etisalat.

1.4 CONCLUSION

Geography is a critical factor in physical and human development. Communication is an important aspect of human development which requires not only the right infrastructure but careful environmental planning to achieve the maximum results. Based on the study carried out, it is therefore recommended that the GSM operators be advised to consider geographical factors in making any efforts to improve their quality of service to enhance mobile communication performance within and outside the study area.

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