

Research Article

Multi-Parametric Analysis of the Coverage and Quality of Service (QoS) of 3G/4G Networks in the Sub-Saharan Environment: The Case of the Republic of Guinea

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Abstract

Guinea, like many countries in sub-Saharan Africa, faces persistent challenges in terms of mobile network coverage and quality of service (QoS). Despite these difficulties, the penetration rate of mobile telephony and internet access continues to increase. This article aims to analyze the coverage and quality of service of 3G/4G networks in Guinea, as well as to assess user satisfaction in this context. To do this, an online survey was conducted among a sample of 384 users of the Guinean mobile network. The responses were analyzed automatically via Google Forms, while Excel and Atlas software allowed for an in-depth comparison of the results. The observations from the comparison survey also confirm the data published by the ARPT. The analysis of the main results reveals that, although the orange operator has rolled out 4G in the eight administrative regions, coverage remains insufficient in most regions of the country. The quality of voice calls remains average and frequent interruptions are reported. In addition, 67.2% of respondents say they have difficulty accessing online services. Overall, satisfaction with network coverage, internet connection and value for money for calls and packages appears to be low. Mobile network users therefore recommend significant improvements in all these aspects.

Keywords

Network Coverage, Quality of Service, User Satisfaction, 3G/4G Mobile Networks

1. Introduction

The rapid evolution of information and communication technologies (ICTs) has had a profound impact on economic

growth and social inclusion across sub-Saharan Africa [1]. Mobile phones, starting from a situation of scarcity in many

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developing countries, are now ubiquitous in all regions of the globe. Indeed, the mobile phone penetration rate in Africa is 98.7% [2], in Guinea, this rate increased from 100% to 103% between 2022 and 2023, with a penetration rate of 52% in 2022 to 56% in 2023 for the internet and from 20% to 24% for Mobile Money [3]. Sub-Saharan Africa is a region where international internet connection is underdeveloped [4], mobile broadband (3G or 4G) is the main and often the only way to connect to the internet [5]. In Guinea, as in many sub-Saharan African countries, the development of mobile networks has improved access to the internet and digital services, which thus offers new economic and social opportunities [6]. Even though substantial changes are taking place in the technological development of mobile phones, Africa still faces problems with telecommunications infrastructure [2]. This leads to a deficit in the coverage and quality of service (QoS) of mobile networks offered to users, especially in rural or underserved areas. More than 870 million people in sub-Saharan Africa are still unconnected and at risk of being excluded from the emerging digital economy [6]. The challenge is to enable users to be covered by a high-speed mobile network with good QoS in order to strengthen user loyalty and the provision of high value-added services. In the literature, various works have been carried out on this issue, highlighting a plurality of methodological approaches and results. The work of Mohamed Abdelatif BOUSLAH and Mohamed DJEBBOURI with a survey and the SPSS MINITAB and AMOS V22 software showed the positive and significant impact of the quality of mobile telephony services on customer satisfaction in Algeria [7]. In the same vein, a check was carried out on the coverage and QoS of mobile networks in Côte d'Ivoire in the locality of (LOMO), with the Driver test tools, the results revealed the presence of insufficient 2G coverage of the operators MOOV, MTN and ORANGE, non-existent 3G/4G coverage and poor performance of voice service in 2G by the three operators [8]. Dr. NGUEBANG TAZANGMO Hervé Francis with a field survey and SPSS and AMOS software, showed that mobile phone customers are not satisfied with the QoS offered by mobile phone operators and that the handling of complaints influences the relationship between the perceived quality and the overall satisfaction of mobile phone customers in the Cameroonian context [9]. Still for the performance of digital services, HiTEK under the instruction of the ARPT, in the QoS report of mobile telephony and internet service providers in the Republic of Guinea, with Nperf software for ISPs and (Tems Paragon, Tems Pocket) for mobile telephony, the results showed that fixed and mobile operators offer overall satisfactory coverage and quality of service in dense urban areas, But much work remains to be done in rural areas and on roads [10]. The aim of this article is to make a multiparametric analysis of the coverage and Quality of Service (QoS) of 3G/4G networks in the Sub-Saharan environment (Guinea). On this, we used Google Forms, Excel, Atlas Guinea software.

2. Materials and Methods

The Republic of Guinea is a coastal country located in the western part of the African continent, halfway between the Equator and the Tropic of Cancer (7°30' and 12°30' north latitude and 8° and 15° west longitude). It is bordered to the west by Guinea-Bissau and the Atlantic Ocean, to the north by Senegal and Mali, to the east by Côte d'Ivoire and to the south by Sierra Leone and Liberia and covers an area of 245,857 km² [11], it has an estimated population of 13,622,399 inhabitants with a density of 55 inhabitants per km² in 2023 [12]. Guinea is subdivided into 4 natural regions, including eight administrative regions, these eight regions bear the name of the city that is the capital: Conakry, Boké Kindia, Mamou, Labé Faranah, Kankan and Nzérékoré

To allow us to have a more global idea of the 3G/4G mobile network, we conducted a survey on the mobile network starting from October 03 to November 19, 2024 in the 8 administrative regions, on a sample of 384 individuals. The software (Google Forms and Excel) allowed us to create online survey forms, collect and analyze data in graphical form through specific questions on coverage and QoS. The Atlas Guinea tool allowed us to provide mapping on network coverage. In order to effectively achieve the objectives, we analyzed the following parameters: Gender and age of respondents, operators and technology used for internet connection, quality of coverage and services, user satisfaction, disparity and mapping of coverage, difficulty in accessing online services and recommendations for service improvement.

The sample size depends on the size of the national population, the confidence level (Z), the margin of error (e) and the estimated proportion (P). For a so-called infinite population (> 10,000 population), $n_{nationale}$ [13]. The national sample size is determined by equation (1) [13].

$$n_{nationale} = \frac{Z^2 \cdot P \cdot (1-P)}{e^2} \quad (1)$$

The distribution of the sample of 384 individuals was carried out in proportion to the estimated population of the eight administrative regions of Guinea in 2023. Table 1 presents the population of each region, its relative share in the national population and the corresponding number of respondents for each region. Equation (2) represents the size of the regional sample [14].

$$n_x = \left(\frac{N_x}{N_{nationale}} \right) \cdot n_{nationale} \quad (2)$$

n_x : Sample size for region x

$n_{nationale}$: Calculated national sample size

N_x : Population size of the region

$N_{nationale}$: size of the national population

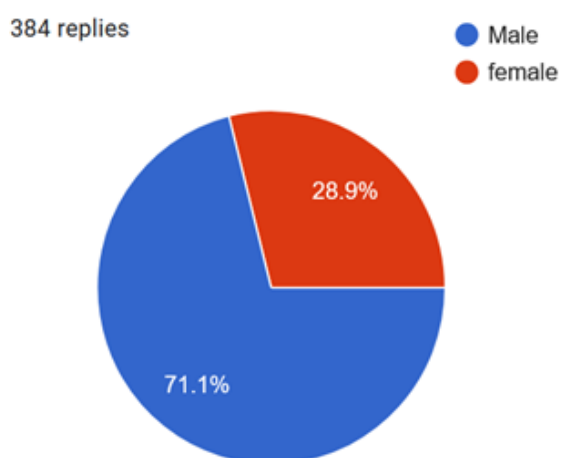
Table 1. Regional Sample Size.

Regions administrative	Regional population Nx	Nx rate (%)	Sample size nx
Conakry	2 152 715	15.80%	60
Bok é	1 403 758	10.30%	40
Kindia	2 022 428	14.85%	57
Mamou	947 236	6.95%	27
Lab é	1 286 939	9.45%	36
Faranah	1 220 364	8.96%	34
Kankan	2 543 364	18.67%	72
Nz é & kor é	2 045 595	15.02%	58
Total	13 622 399	100%	384

3. Results and Discussion

3.1. Analysis of Respondent Information Metrics

The analysis of these parameters is to know the gender and age of the 384 respondents, the operator and the mobile network technology used by the respondents for the Internet connection. The analysis of figures 1 and 2 shows the results on the gender and age of the respondents.

**Figure 1.** Gender.

The results show that the majority of respondents were men (Figure 1), their number reached 273 or 71.1%. In Figure 2, it

was noted that the majority of respondents are between 18 and 40 years old, i.e. a rate of 85.7%.

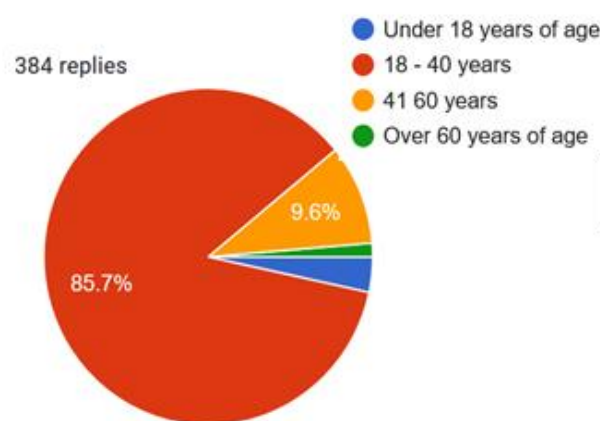
**Figure 2.** Age.

Figure 3 shows the analysis of the operators and generations used for the internet connection.

Regarding Figure 3, we observe that for 3G, the operator Cellcom has a user rate of 6.77%, compared to 4.95% for Orange and 3.91% for MTN. As far as 4G is concerned, it is the operator Orange that dominates with 83.85%, while Cellcom and MTN record 0% and 0.52% respectively. This high rate for Orange in 4G suggests that there is little competition between mobile operators, with users mainly favouring network performance.

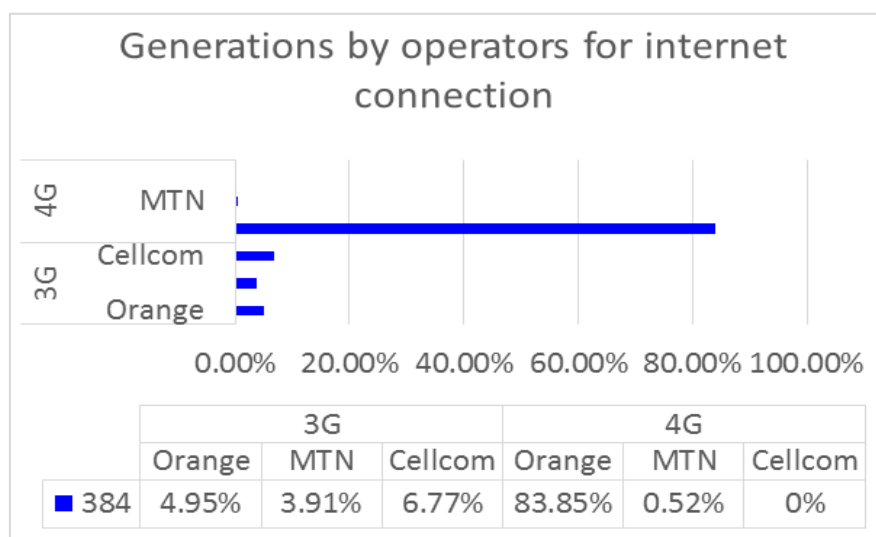


Figure 3. Mobile network operator and generation used.

The analysis in **Figure 4** shows the mobile network services used by the respondents.

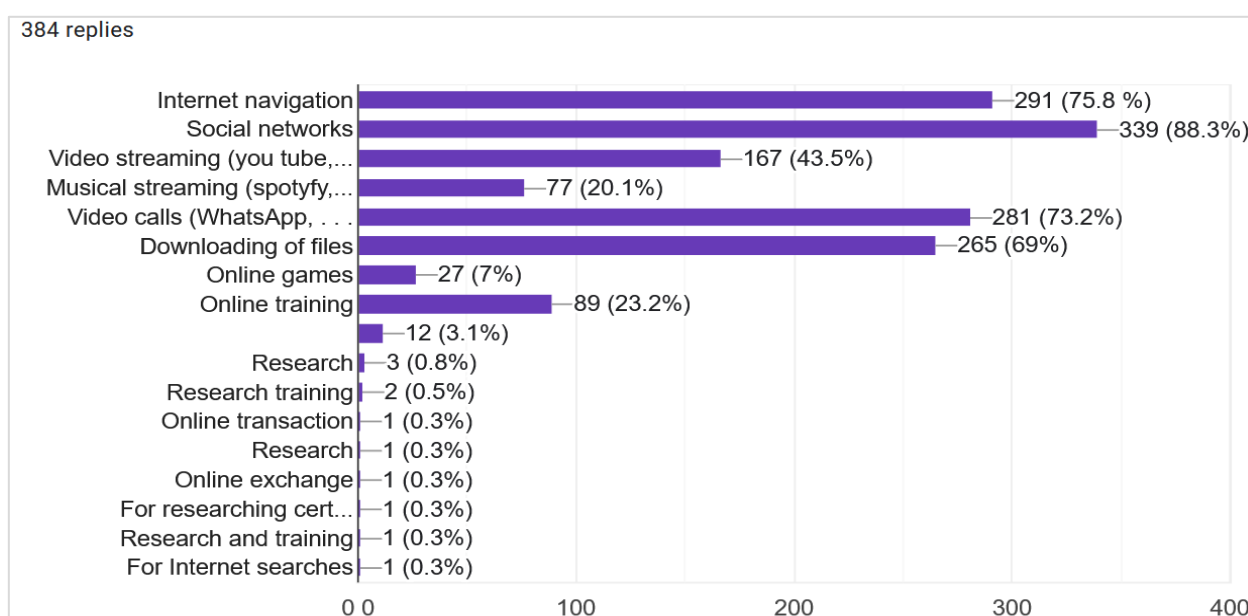


Figure 4. Services used for the 3G/4G network.

Taking into account the multiple-choice questions for **Figure 4**, the results reveal that users largely prefer social networks, with a usage rate of 88.3%. This is followed by Internet browsing (75.8%), video calls (73.2%), data download speed (69%) and video streaming (43.5%). These figures clearly demonstrate that all mobile network services are being used, but to different degrees.

3.2. Analysis of Parameters Concerning the Quality of the Area Covered and the Service

For the analysis of the quality of coverage and services, the objective is to evaluate network coverage, by identifying the presence or absence of uncovered areas, to assess the quality of voice calls, to identify the frequency of call interruptions and the use of the internet connection.

Figures 5 and 6 show the analysis of the covered and white areas.

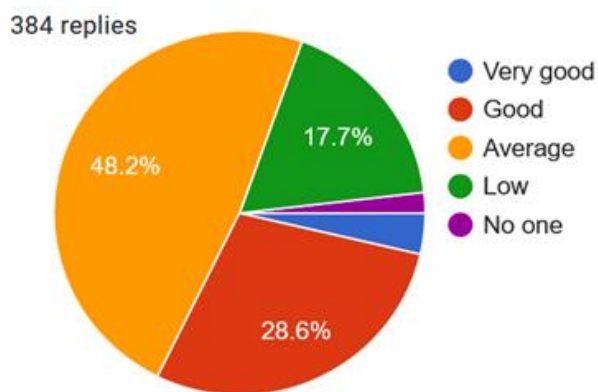


Figure 5. Area covered.

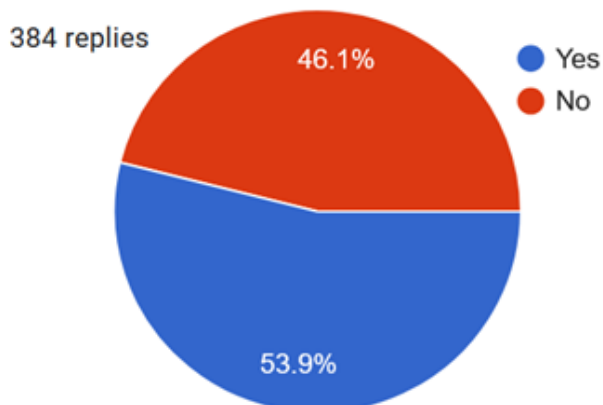


Figure 6. White area.

Figure 5 shows mobile coverage rates, with only 3.6% of areas having very good coverage, 28.6% good coverage and 48.2% average coverage. These first two rates, being lower than the average coverage area of 48.2%, indicate a limited level of satisfaction with national mobile coverage. In addition, Figure 6 reveals that 53.9% of the areas studied are without network coverage, which confirms and reinforces the hypothesis formulated from Figure 5 concerning the significant extent of uncovered areas across the territory.

Looking at the mobile network coverage maps in the Republic of Guinea (Figure 20), focusing only on 4G, the most widely used technology for internet connection, shows that Orange has a national coverage rate of 17%, followed by MTN with only 0.1%. As for Cellcom, it has not deployed a 4G network.

Bringing together all the results relating to network coverage, it is clear that mobile operators face persistent challenges in ensuring satisfactory national coverage.

Analysis of Figures 7 and 8 shows the quality of voice calls.

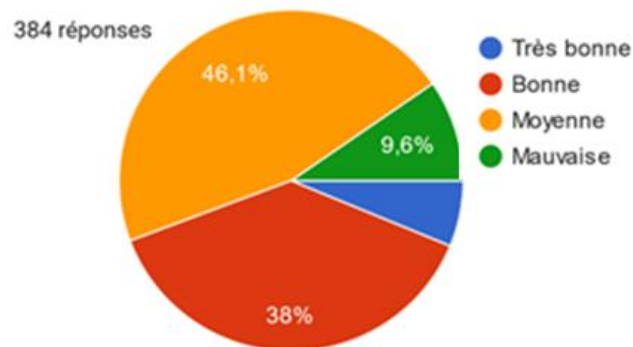


Figure 7. Voice Calls.

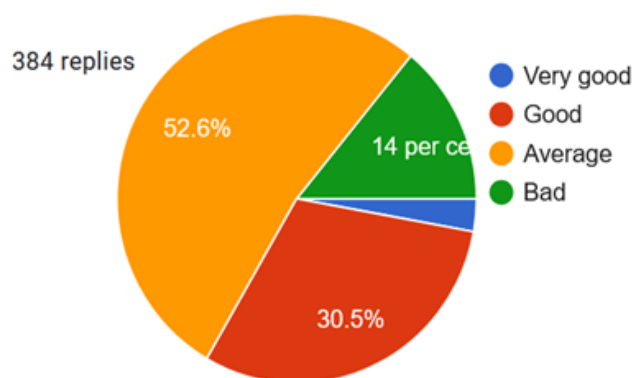


Figure 8. Voice calls when it rains.

The results in Figure 7 show the rates of 6.3%, 38% and 46.1% respectively, the very good, good and average quality of voice calls in normal times, these first two rates being lower than the third, indicates that, operators offer an average quality of voice calls to the users of these networks. Based on Figure 8, the results show that the rates of 2.9% and 30.5%, which correspond to "very good" and "good" voice call quality in rain, respectively, are an indicator of QoS evaluation in these weather conditions. These values, which are lower than the average rate of 52.6%, indicate that operators offer average voice call quality during rainy periods.

The analysis of figures 9 and 10 shows the frequency of call interruption and use of internet connection.

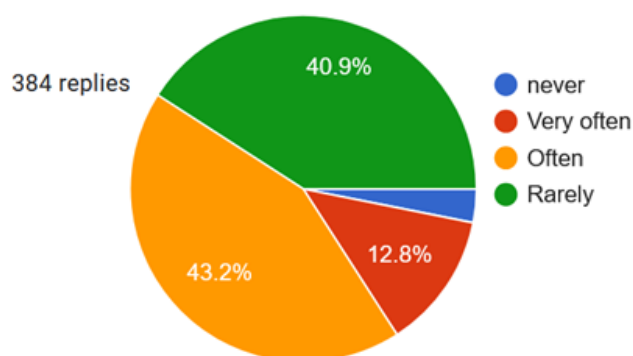


Figure 9. Call Drop Frequency.

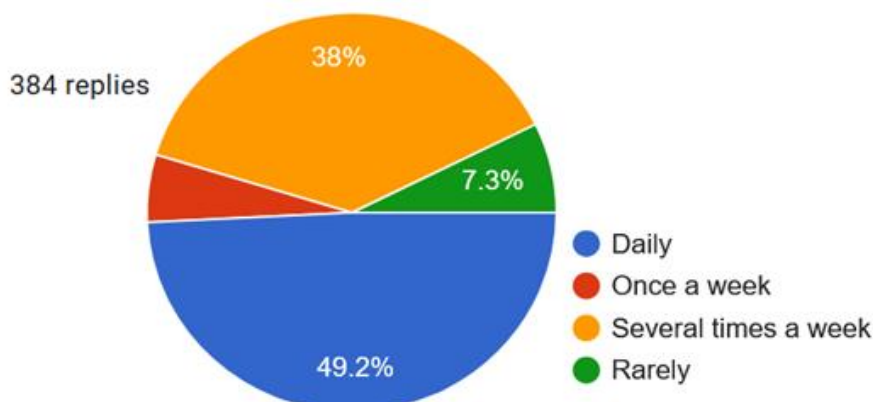


Figure 10. Frequency of Internet use.

The analysis in Figure 9 highlights the rates of 12.8% and 43.2% of interruption of subscriber communications respectively (very often and often), these rates express an inconvenience during the communication. This requires decision-making for future improvement. With regard to Figure 10, it should be noted that the rates of 38% and 49.2% respectively expressing the frequency of use of the connection daily and several times a

week is an indicator that evaluates the degree of use of the Internet connection in the Republic of Guinea. This shows that the majority of users access the Internet frequently, a sign of a gradual integration of digital technology into everyday life. However, the significant proportion of those who connect little or rarely suggests the existence of obstacles, such as cost, quality of connection or network coverage.

3.3. Analysis of User Satisfaction Metrics

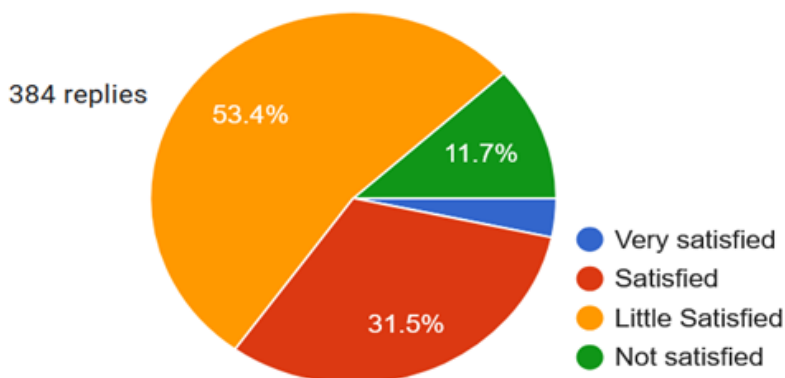


Figure 11. Satisfaction with coverage.

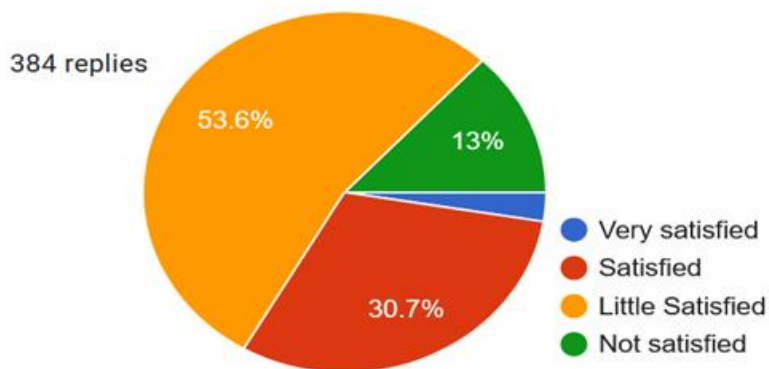


Figure 12. Internet connection satisfaction.

The study of the analysis of parameters concerning user satisfaction aims to know the degree of satisfaction with network coverage, internet connection and the quality/price ratio of calls and internet packages.

Figures 11 and 12 show the satisfaction analysis on the coverage and internet connection.

The results in Figure 11 show that the rates of 3.4% and 31.5% respectively express the very good and good coverage of the mobile network in normal times, is an indicator that assesses the degree of satisfaction of the respondents. These rates being lower than 53.4% of respondents who are not very

satisfied, indicates an overall low level of user satisfaction with network coverage.

In addition, Figure 12 shows that 2.6% of users are very satisfied and 30.7% are satisfied with the internet connection. This rate being lower than 53.6% of respondents who are not very satisfied, implies that the majority of users are not very satisfied with the quality of the internet connection. This means that mobile network operators face a lot of challenges in delivering a better internet connection.

Figure 13 shows the satisfaction analysis on the quality/price ratio of calls and packages.

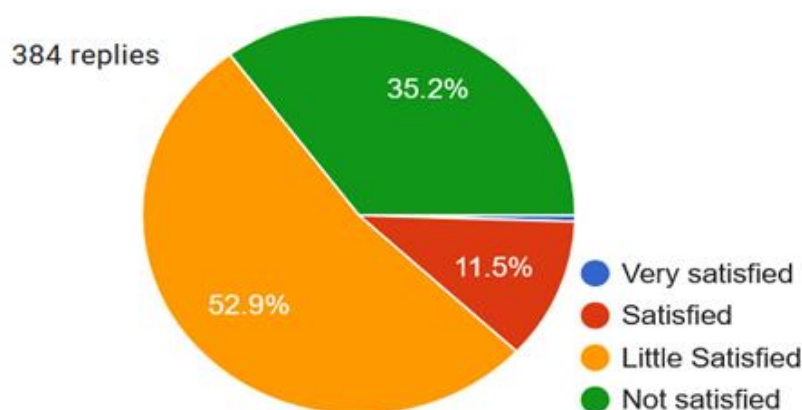


Figure 13. Satisfaction with quality and price.

The rates of 0.5% and 11.5% in Figure 13 represent respondents who are very satisfied and satisfied with the quality/price ratio of calls and packages, respectively. This rate, which is almost insignificant, indicates that users are

not satisfied with the price compared to the quality of service offered by the operators. This requires decision-making for a future improvement in the quality of services in relation to price.

3.4. Analysis of Parameters Related to Difficulties in Accessing Online Services and Recommendations for Network Improvement

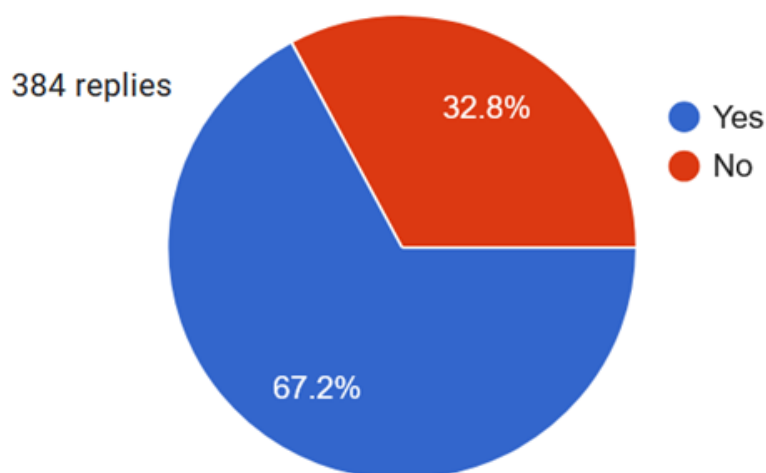


Figure 14. Difficulty accessing services.

384 replies

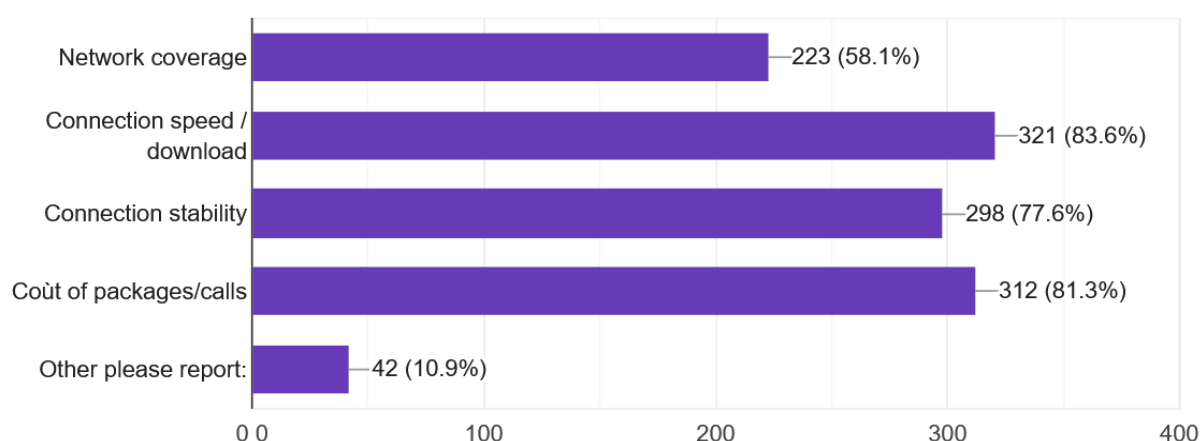


Figure 15. Aspects of the network to be improved.

The purpose of this analysis is to identify difficulties in accessing services and areas of the network that need to be improved. The results of the analysis are presented in Figures 14 and 15.

The result in Figure 14 highlights the difficulty of accessing online services, i.e. a rate of 67.2% compared to 32.8% who say they do not encounter any difficulty in accessing online services. The first rate being higher, shows that users have serious difficulties in accessing online services. This outcome is up to telephone operators and authorities to make decisions to improve online services. Concerning Figure 15 where the questionnaires were multiple choice, the results show that most respondents want an improvement in all aspects of the

network, the coverage rate is 58.1%; connection and download speed at 83.6%; the stability of the connection at 77.6% and the costs of calls and plans at 81.3%. This is sufficient proof that mobile network users want an improvement throughout the network chain.

3.5. Disparity in Coverage Across the Eight Administrative Regions

In this part, we analyzed the results of network coverage by administrative region, either from the survey (Figure 16) or from the ARPT data (Figure 17), then we proceeded to the discussion.

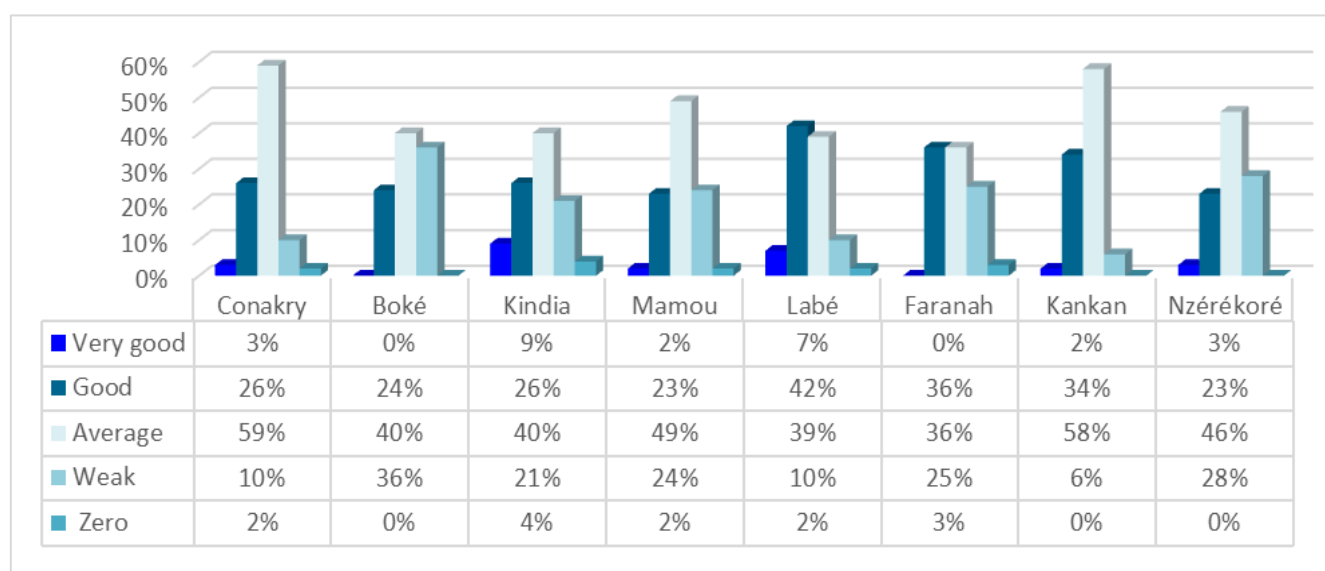


Figure 16. Quality of coverage by region.

The analysis presented in Figure 16 shows that the quality of mobile network coverage in the eight regions studied is

average overall. It should also be noted that the majority of respondents use 4G, with the operator Orange as the main

provider of the internet connection. Comparing these results with those in Figure 17, we can see that Orange is the only operator to have deployed 4G throughout the country, although coverage rates remain low in most regions. Only the orange operator in the Conakry region has achieved a coverage rate of 76%, in accordance with the specifications where

the threshold is set at 70%, followed by the Labé region which is at 57%.

In summary, the results in Figures 16 and 17 clearly show that despite the national deployment of 4G by Orange, the quality of network coverage remains insufficient in the majority of Guinea's regions.

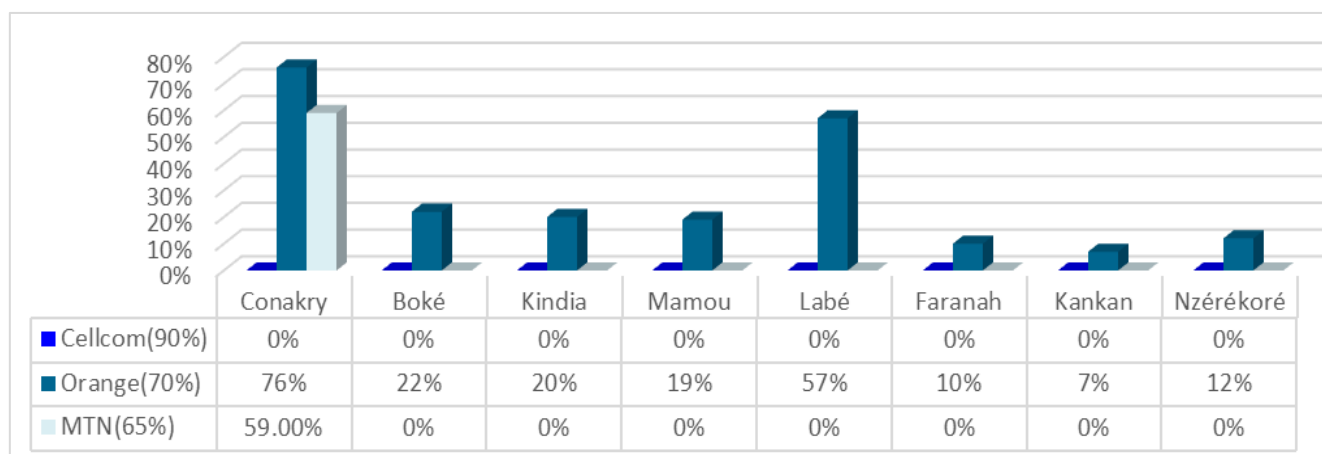


Figure 17. 4G coverage rate by region.

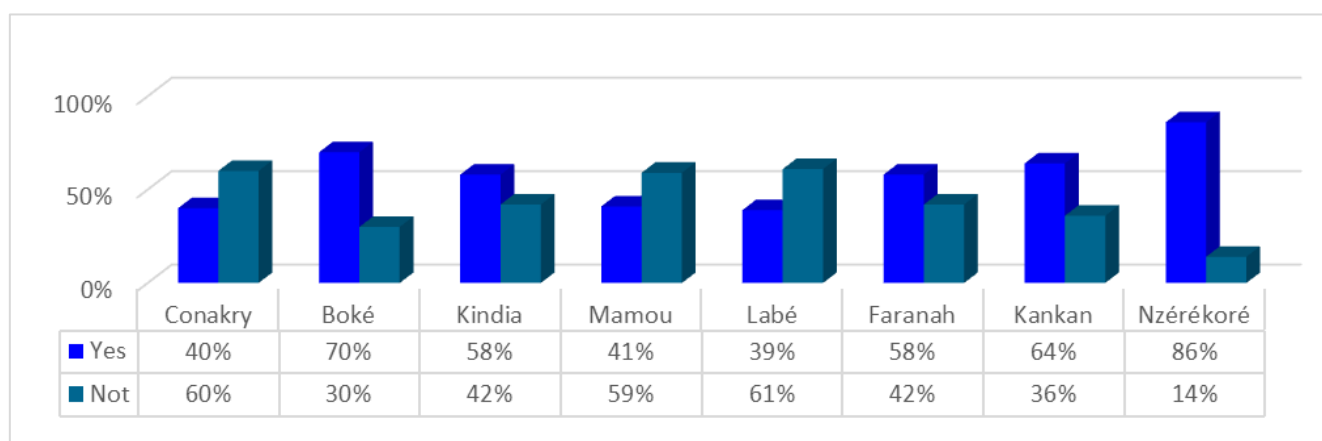


Figure 18. White area by region.

In Guinea, the coverage threshold for technologies is set as follows: the operator Cellcom must reach at least 90% for 3G/4G; Orange must ensure at least 80% coverage with 3G and 70% with 4G; finally, MTN must achieve a minimum threshold of 65% for both technologies [16]. It appears that only the operator Orange has deployed 3G/4G in the eight regions. On the other hand, MTN has only deployed 3G and part of the 4G in Conakry, while Cellcom has only deployed 3G in a few localities in the country [16].

In Figure 18 we present the analysis of the disparity of white areas by region resulting from the survey.

The results presented in Figure 18 show that the majority of respondents in the regions of Conakry, Mamou and Labé say

that they do not encounter white zones (areas without network coverage) in their locality, with proportions of 60%, 59% and 61% respectively. On the other hand, in the other regions, these rates are less than 50%. Referring to Figure 19 (data from the ARPT), we can observe a consistency of the results or the localities of Conakry and Labé. For the Mamou region, this situation varies depending on the specific locality and the generation of the network used by the respondents. In conclusion, these results reinforce the observations from Figures 16 and 17.

Figure 19. shows, by region, the rate of 4G white zones according to ARPT data.

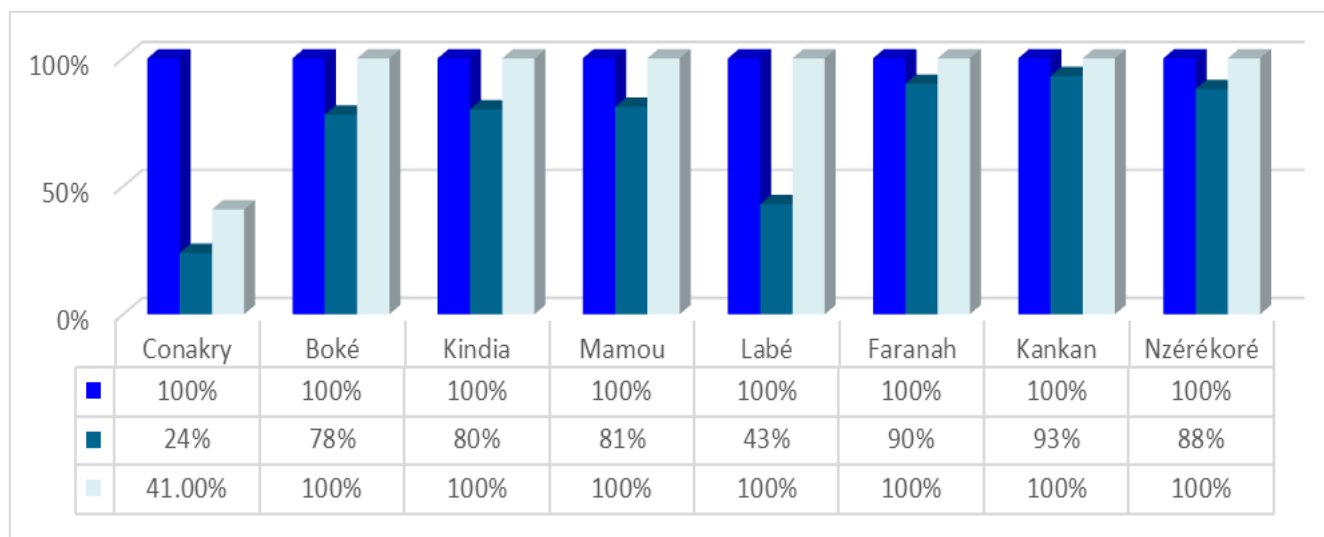
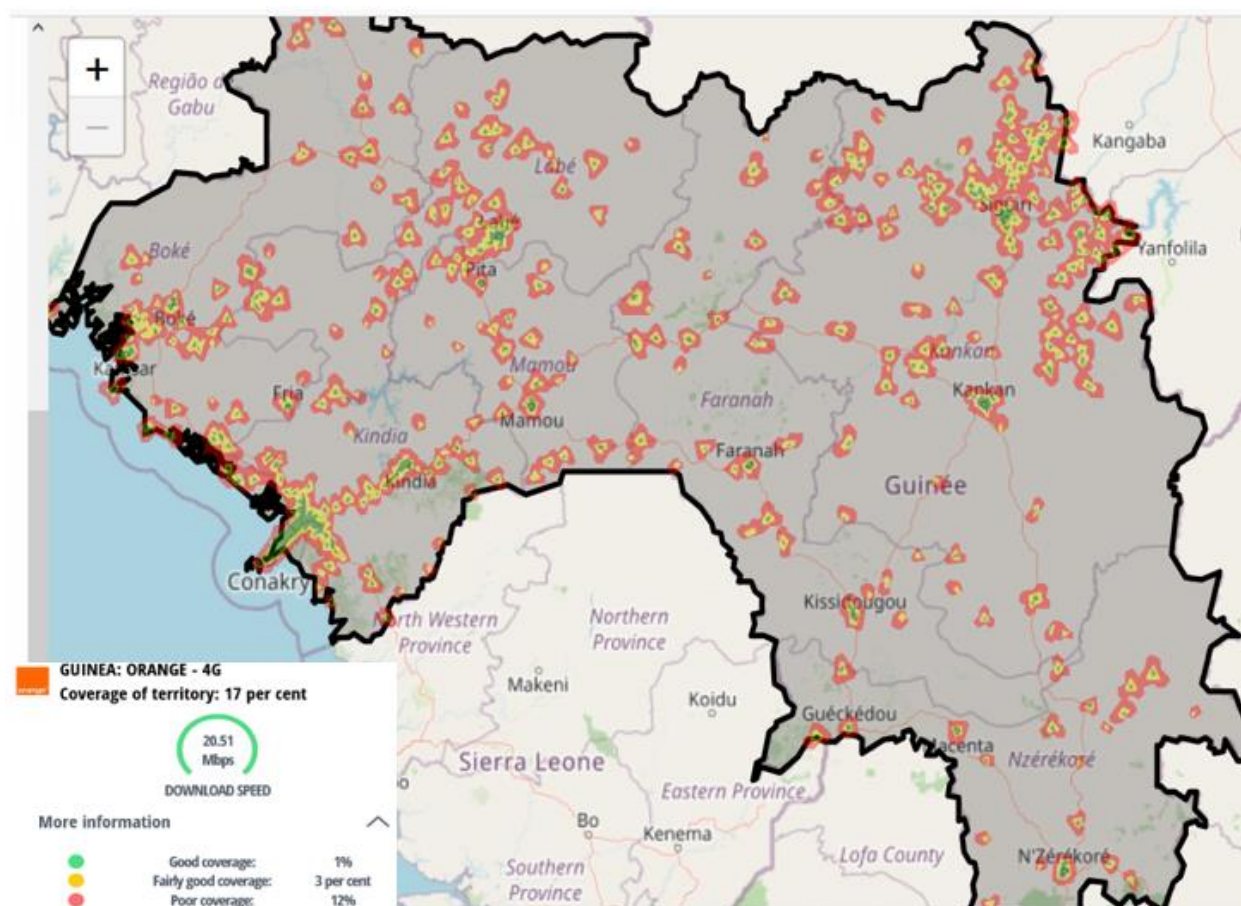


Figure 19. 4G white zone rate by region.

Figure 20 shows the coverage mapping and white area of the 4G network in Guinea (ARPT).



a) The operator Cellcom



b) The operator Orange



c) The operator MTN

Figure 20. 4G network coverage map in Guinea [15].

On these maps, the good coverage in green indicates that the user of the mobile network can make calls, browse the Internet and exchange SMS inside and outside buildings. On the other hand, the yellow colour, which corresponds to fairly good coverage, indicates that the mobile network user can make calls, browse the Internet and exchange text messages outside buildings in most cases, and in some cases inside buildings.

And in red poor coverage, which indicates that the mobile network user may not have a signal, but communications are not guaranteed [15]. It turns out that, for the operator Orange, the rate of poor coverage (12%) is higher than good coverage (1%) and fairly good coverage (3%). On the other hand, the operator MTN recorded only 0.03% good coverage, 0.04% fairly good coverage and 0.05% poor coverage. This indicates that, despite a wider presence of the 4G mobile network for Orange, there is a considerable gap between the regulatory obligations set by the ARPT and the reality observed on the ground. While, for MTN, extremely low rates reflect either geographically limited coverage or a network performance well below expectations.

4. Conclusion

The objective of this study was to carry out a multi-parametric analysis of the coverage and quality of service (QoS) of 3G/4G networks in sub-Saharan Africa: the case of the Republic of Guinea. This study provides a detailed view of the network coverage as well as the QoS offered to subscribers. The measurements were carried out using Atlas tools, supplemented by data collection and analysis via Google Forms and Excel.

The results indicate that mobile operators provide overall satisfactory coverage in the capital Conakry, although the quality of service is considered average at the national level. Of the 100% of respondents, 71.1% were men aged mainly between 18 and 40 years old. Orange dominates the market with a subscriber rate of 88.80%, ahead of MTN and Cellcom. 4G technology is the most widespread, used by 84.38% of respondents. In terms of service usage, subscribers mostly use all available services: 88.3% for social networks, 75.8% for internet browsing, 73.2% for video calls and others.

However, the quality of network coverage remains insufficient in the majority of Guinean regions. The quality of voice calls is only average and frequent interruptions are reported. The rate of 67.2% reflects a difficulty in accessing online services. As a result, user satisfaction with network coverage, internet connection, and value for money remains low. Mobile network users recommend an overall improvement in the various aspects of the network.

These results should enable users to be better informed about the performance of their mobile networks and motivate operators to improve the quality of their services. The Postal and Telecommunications Regulatory Authority (ARPT), under the vigilance of the political authorities, must continue to

monitor the quality of service offered to mobile network subscribers to ensure compliance with the minimum coverage and quality thresholds defined in the specifications. The prospects for this research are to optimize the 4G mobile network with a view to migrating to 5G.

Abbreviations

ARPT	Regulatory Authority for Posts and Telecommunications
ISP	Internet Service Providers
N/A	Not Applicable
QoS	Quality of Service
SMS	Short Message Service
ICT	Information and Communication Technologies
3G	3rd Generation
4G	4th Generation
5G	5th Generation

Conflicts of Interest

The authors declare no conflicts of interest.

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