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2021/2022 Quarter 2:

Voice Quality of Service

Report

Free State Province

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY	7
2. INTRODUCTION.....	8
3. METHODOLOGY	10
3.1. EQUIPMENT TEST SETUP AND CONFIGURATION	11
3.1.1. SYSTEM USED.....	11
3.1.2. DEVICE DESCRIPTION	11
3.1.3. SHORT AND LONG CALL WINDOWS.....	11
3.2. ROUTE SELECTION	11
3.3. MEASUREMENT PARAMETERS AND TARGETS	12
3.3.1. PARAMETERS	12
3.3.1.1. CALL SETUP SUCCESS RATIO [%]	13
3.3.1.2. DROP CALL RATIO [%]	13
3.3.1.3. CALL SETUP TIME [S]	13
3.3.1.4. SPEECH QUALITY (MOS)	13
3.3.2. TARGETS.....	13
4. RESULTS AND ANALYSIS	15
4.1. ACCESSIBILITY, RETAINABILITY, CALL SETUP TIME AND QUALITY MEASUREMENTS	15
4.1.1. KPI RESULTS PER AREA.....	15
4.1.2. CALL ACCESSIBILITY (SHORT CALL)	16
4.1.3. DROP CALL RATIO (LONG CALL).....	17
4.1.4. CALL SETUP TIME (SHORT CALL)	18
4.1.5. POLQA MOS (LONG CALL)	19
4.1.6. RADIO TECHNOLOGY	20
4.1.7. CSFB	21
4.2. COMPARISON OF CURRENT RESULTS TO PREVIOUS RESULTS	22
5. CONCLUSION	23
6. APPENDICES	24
6.1. APPENDIX 1: MOBILE OPERATORS' FEEDBACK ON THE REPORT	24
6.1.1 VODACOM	24

6.1.2	MTN	24
6.1.3	CELL C.....	25
6.1.4	TELKOM.....	25
6.2.	APPENDIX 2: DETAILED TEST RESULTS PER PHASE	26
6.3.	APPENDIX 3 TECHNOLOGY MAPS	28
6.4.	APPENDIX 4 UMTS COVERAGE MAPS	29
6.5.	APPENDIX 5 UMTS QUALITY MAPS.....	30

List of Abbreviations

CD	Call Duration
CSFB	Circuit Switched Fall Back
CRR	Call Retention Ratio
CSSR	Call Setup Success Ratio
CST	Call Setup Time
DCR	Drop Call Ratio
GSM	Global System for Mobile Communications
HD	High Definition
ICASA	Independent Communications Authority of South Africa
IVR	Interactive Voice Response
KPI	Key Performance Indicator
LTE	Long-Term Evolution
LTE-A	Long-Term Evolution Advanced
R&S	Rohde & Schwarz
MOC	Mobile Originating Call
MOS	Mean Opinion score
POLQA	Perceptual Objective Listening Quality Analysis
WCDMA	Wideband Code Division Multiple Access
VoLTE	Voice over Long-Term Evolution

List of Figures

Figure 1. Free State Province Route Map with Population Distribution	8
Figure 2. Call Window Duration.....	11
Figure 3. CSSR KPI per Area	16
Figure 4. CSSR KPI Overall Results	16
Figure 5. DCR KPI per Area	17
Figure 6. DCR KPI Overall Results	17
Figure 7. Call Setup Time[s] per Area	18
Figure 8. Call Setup Time[s] KPI Overall Results	18
Figure 9. Speech Quality per Area	19
Figure 10. Speech Quality Overall Results.....	19
Figure 11. Serving Radio Technology per Area.....	20
Figure 12. Serving Radio Technology Overall Results.....	20
Figure 13. CSFB Results per Area.....	21
Figure 14. CSFB Overall Results	21
Figure 15. Radio Technology Maps	28
Figure 16. UMTS Coverage Maps	29
Figure 17. UMTS Quality Maps	30

List of Tables

Table 1. Test timelines for area covered	12
Table 2. Distance and Time driven per Area	12
Table 3. Summary of KPI Results per Area	15
Table 4 Comparison of previous results	22
Table 5. CSSR & Call Setup Time Phase 1 & Phase 2.....	26
Table 6. DCR & POLQA MOS Phase 1 & Phase2	27

1. Executive Summary

The Independent Communications Authority of South Africa (ICASA) contracted Metro Global Telecom Services (Pty) Ltd. (MetroTelworks) to conduct Quality of Service (QoS) measurements on the networks of mobile operators; Cell C, MTN, Telkom and Vodacom. The measurements were performed to monitor performance of mobile voice services offered by the operators in the Free State Province. The measurements were carried out between the 9th and the 28th of July 2021, covering a total distance of over 2519 kilometres for two phases of measurements.

The purpose of performing QoS measurements was to monitor and analyse the quality of mobile voice service as experienced by the end-user. The results were later benchmarked against the QoS standard set by the Authority. The measurements were conducted in areas and in circumstances where mobile voice service is likely to be accessed. These areas include towns, townships, farm areas, rural areas, and economic activity nodes. The sampled areas within the Free State Province were Bloemfontein, Botshabelo, Virginia and Welkom.

A vehicle equipped with Rohde and Schwarz Smart Benchmark II testing system equipped with 8 mobile phones was used to collect data in mobility conditions. The four Key Performance Indicators (KPIs) used to assess QoS are Accessibility, Retainability, Call Setup Time and Speech Quality. The Drop Call Ratio (DCR) KPI is used to measure a user's ability to successfully complete a call and Call Setup Success Ratio (CSSR) KPI measures a user's ability to make a phone call.

According to the End-User and Subscriber Service Charter Regulations of 2016, the average DCR should be less than 3% and the average CSSR should be greater than 98%. The average Call Setup Time must be less than 20 seconds and the score for the average Speech Quality must be greater than 3.

The results show that in terms of overall Call Setup Success Ratio, all four operators achieved more than 98% CSSR values, thus met the Accessibility target. All the operators achieved the overall Drop Call Ratio target of less than 3%, thus achieving the Retainability target. All operators met the Call Setup Time target of less than 20 seconds. Cell C is the only operator that didn't meet the Speech Quality Target of greater than 3.

2. Introduction

ICASA's mission is to regulate electronic communications, broadcasting, and postal services in the public interest. The Authority ensures the quality of service through its Quality of Service (QoS) monitoring activities. The Authority contracted Metro Global Telecom Services (Pty) Ltd. (MetroTelworks) to conduct drive testing in selected areas of the Free State Province. The test was focused on monitoring the cellular voice telephony service being offered by MTN, Vodacom, Cell C, and Telkom within the Free State Province of South Africa.

The QoS monitoring was conducted in areas that fall under the following District Municipalities: Lejweleputswa and Mangaung. The areas of interest that were selected within these municipalities were Bloemfontein, Botshabelo, Virginia and Welkom. The areas consist of major towns, townships, farm areas, rural areas, major road arteries, economic activity nodes and areas of previous complaints.

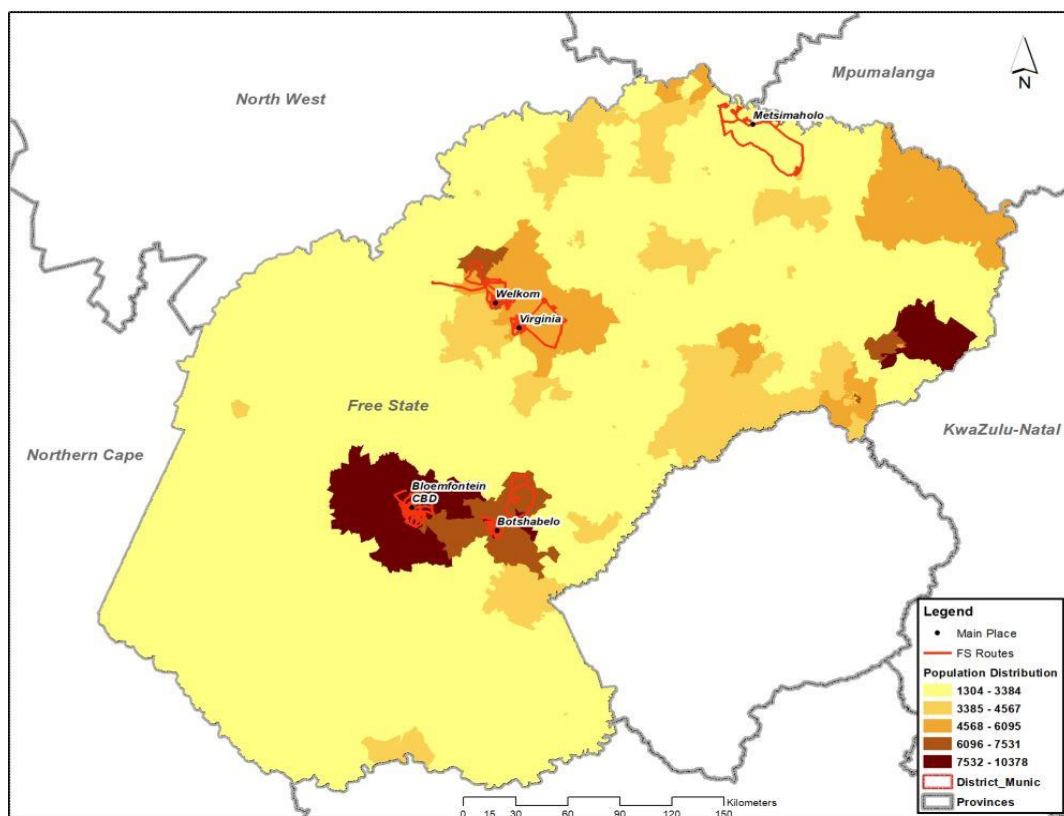


Figure 1. Free State Province Route Map with Population Distribution

QoS is defined as the collective effect of service performance that determines the degree of satisfaction a user derives from a service. It provides an indication of what a customer experiences when using a mobile network and is evaluated in terms of Call Accessibility, Call Setup Time, and Call Retainability and Speech Quality parameters.

- a) Call Accessibility is reported as a percentage and is a measure of the number of times a user can successfully establish a call as a ratio of the total calls attempted. It is measured using Call Setup Success Ratio (CSSR).
- b) Call Setup Time is the time interval from the instant a user initiates a mobile call request until a complete message indicating call disposition is received by the calling terminal. It is measured from the time a user presses the dial button until the user gets connected to the dialled party.
- c) Retainability is defined as the ability for a call to stay connected through to a normal call tear-down process, without abnormally disconnecting from the cell site that carries the call. It is measured using Drop Call Ratio (DCR).
- d) Speech Quality is the condition of conversational speech without noise and echo interference. It is measured using the Mean Opinion Score (MOS).

3. Methodology

A minimum of 120 test samples per network operator were collected except in the areas where services were limited on most part of the drive test route. A drive-test sampling methodology which provides a snapshot view of the mobile operator's quality of service was adopted. It provides a realistic picture of network performance from a user's point of view. The method adopted provides a snapshot of an operator's network performance on the selected routes and particular time of the day, which may not be a true representation of the mobile service provider's overall network performance, however, it is considered statistically relevant.

Voice test set-up consisted of two test scenarios namely, short calls, and long calls which are defined in this section. The short calls were used to measure Call Accessibility whilst the long calls were used to measure Call Retainability and Speech Quality. The Long call scenario required the use of two test mobiles per Operator i.e., call initiating side (A-side) and call receiving side (B-side). The Short call scenario required the use of a single test mobile for each Operator making calls to the Operators IVR system. This set-up results in three mobile devices per operator bringing the total number of devices used for the test to twelve with three for each Mobile Operator. The Call Windows were set up as follows: Call duration + 30 seconds, (for the setup and release phases) + 30 seconds (for the minimum pause interval after call termination). The call duration for the long call was set at 120 seconds bringing the total call window size to 180 seconds with the short call duration set at 10 seconds resulting in a total call window of 70 seconds. The audio quality of speech samples was evaluated using the HD-voice capable and ITU standardized POLQA wideband algorithm with 10 samples being recorded during each call.

The devices were set to select the best available technology whilst the test SIMs in use were not activated for Volte services. With this setup, in areas where operators had LTE, they performed Circuit Switched Fall Back (CSFB) calls.

Voice testing was done in two phases with a measurement window gap of at least seven days in between both measurements.

3.1. Equipment test setup and configuration

3.1.1. System used



The Test Equipment used was the Rohde & Schwarz SwissQual Benchmark II platform with Sony XZ Premium smartphones installed inside the car using the R&S Phone Mount Walls. 4 mobile devices were used for Short Call & 8 mobile devices were used for Long Call. The mobile devices were configured to automatically

select a mobile network and radio access technology.

3.1.2. Device Description

The Sony XZ Premium Smartphone was selected as the measurement User Equipment (UE) for Voice Services. It uses the Qualcomm Snapdragon 835 chipset and supports the following technologies: GSM, WCDMA, LTE and LTE-A.

3.1.3. Short and Long Call Windows

Figure 2 shows the call windows for the long and short calls as highlighted in the methodology section.

Short Call:



Long Call:



Test Scenar..	Value
Short Call	Call Duration = 10s
	Call Setup timeout = 30s
	Call Window = 70s
Long Call	Call Duration = 120s
	Call Setup timeout = 30s
	Call Window = 180s
	POLQA (WB)

Figure 2. Call Window Duration

3.2. Route selection

Measurement routes were selected so that they would reflect end user distribution at different geographical locations in areas where people live and use mobile phones i.e.-

major towns, townships, farm areas, rural areas, major road arteries, economic activity nodes and areas of previous complaints. The selected four areas in which the QoS measurements were conducted are within the two district municipalities as indicated in Table 1.

Table 1. Test timelines for area covered

Routes and Dates			
District	Area	Dates	Phase
Lejweleputswa	Welkom	9/7/2021 - 10/7/2021	Phase 1
		21/7/2021 - 22/7/2021	Phase 2
	Virginia	12/7/2021 - 13/7/2021	Phase 1
		22/7/2021 - 23/7/2021	Phase 2
Mangaung	Bloemfontein	14/7/2021 - 16/7/2021	Phase 1
		26/07/2021 - 27/07/2021	Phase 2
	Botshabelo	14/07/2021-17/07/2021	Phase 1
		27/07/2021 - 28/07/2021	Phase 2

Table 2. Distance and Time driven per Area

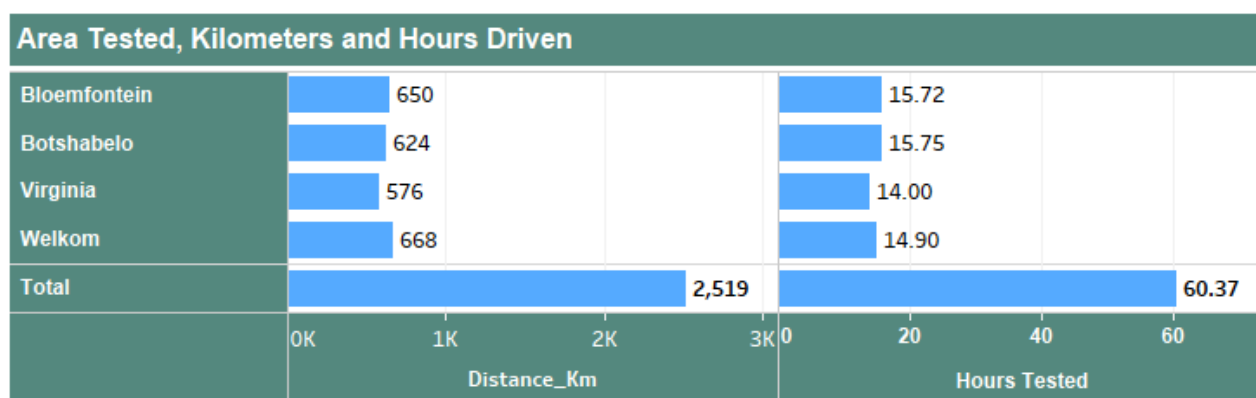


Table 2 shows the total distance covered in each area for two phases and active measurement duration.

3.3. Measurement parameters and targets

3.3.1. Parameters

3.3.1.1. Call Setup Success Ratio [%]

The Call Setup Success Ratio (CSSR) is the percentage of calls that are successfully set up as a percentage of the total call attempts. The formula to calculate CSSR is shown below:

$$\text{CSSR} = Y/X * 100$$

Where, Y represents the calls that are established, and X is the total number of call attempts.

3.3.1.2. Drop Call Ratio [%]

Dropped Call Ratio (DCR) is the proportion of incoming and outgoing calls, which, once correctly established and therefore having been assigned a traffic channel, are dropped, or interrupted prior to the deliberate completion by the user. The formula to calculate DCR is shown below:

$$\text{DCR} = D/S * 100$$

Where, D = number of dropped calls and S = number of successful calls established

3.3.1.3. Call Setup Time [s]

Call Setup Time is the time interval from the instant a user initiates a network connection request until a complete message indicating call disposition is received by the calling terminal. It is measured from the time a user presses the dial button until the user gets connected to the dialled party.

3.3.1.4. Speech Quality (MOS)

Speech quality on call basis is an indicator representing the end-to-end speech transmission quality of the mobile telephony service. This parameter computes the speech quality on the basis of completed calls. Measurement made use of the POLQA Algorithm which compares the reference signal received from the transmitting side against an equivalent sample on the receiving side.

3.3.2. Targets

According to the End User and subscriber Service Charter Regulations of 2016, the following voice parameters' targets are defined as follows:

1. Call Setup Success Ratio – Average Call Setup Success Ratio must be greater than 98%.
2. Call Setup Time Ratio – Average Call Setup Time must be less than 20 seconds.
3. Drop Call Ratio – Average Drop Call Ratio must be less than 3%.
4. Speech Quality – Average Speech Quality of MOS must be greater than 3.

4. Results and Analysis

This section provides a summary of the mobile operators' performance results based on the drive test route in the following test areas: Bloemfontein, Botshabelo, Virginia and Welkom.

4.1. Accessibility, Retainability, Call Setup Time and Quality Measurements

4.1.1. KPI Results per Area

Table 3 shows KPI results per area. Detailed results are provided in the Appendix 1 and Appendix 2.

Table 3. Summary of KPI Results per Area

		Bloemfontein	Botshabelo	Virginia	Welkom
Call Setup Success Ratio - [%]	MTN	99.55%	98.02%	98.99%	98.39%
	Vodacom	99.73%	99.46%	99.60%	99.43%
	Cell C	99.37%	96.66%	98.79%	97.45%
	Telkom	99.73%	98.02%	98.79%	99.15%
Drop Call Ratio [%]	MTN	0.00%	0.00%	0.00%	0.37%
	Vodacom	0.35%	0.35%	0.00%	0.00%
	Cell C	0.71%	0.35%	0.00%	0.37%
	Telkom	0.00%	1.82%	1.19%	1.12%
Call Setup Time [s]	MTN	3.30	3.24	3.34	3.44
	Vodacom	3.66	3.27	3.43	3.71
	Cell C	3.70	3.84	3.86	3.96
	Telkom	3.63	3.97	3.85	3.69
POLQA MOS	MTN	3.55	3.55	3.57	3.58
	Vodacom	3.71	3.71	3.54	3.60
	Cell C	2.81	2.79	2.80	2.81
	Telkom	3.04	3.03	3.00	3.04

4.1.2. Call Accessibility (Short call)

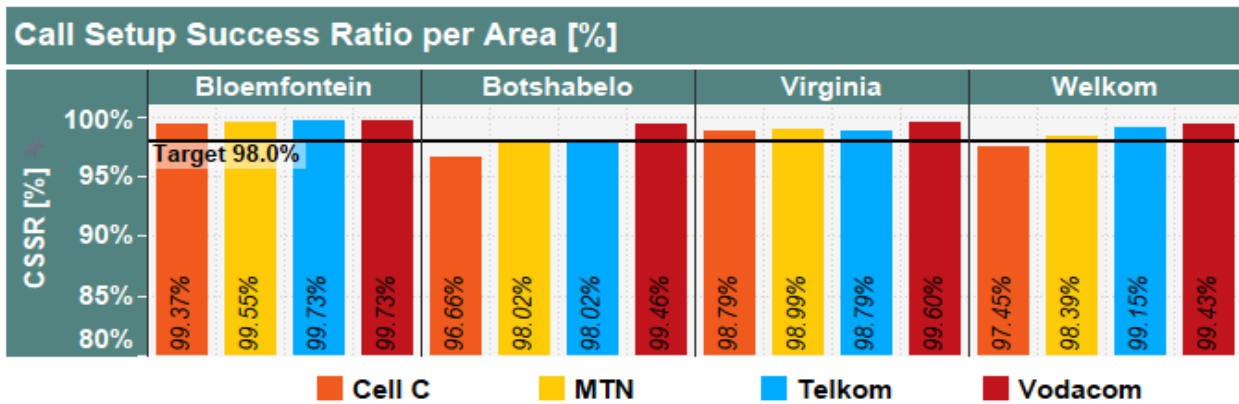


Figure 3. CSSR KPI per Area

Figure 3 shows MTN, Vodacom and Telkom met 98% CSSR target in all areas. Cell C met the CSSR target only in Bloemfontein and Virginia.

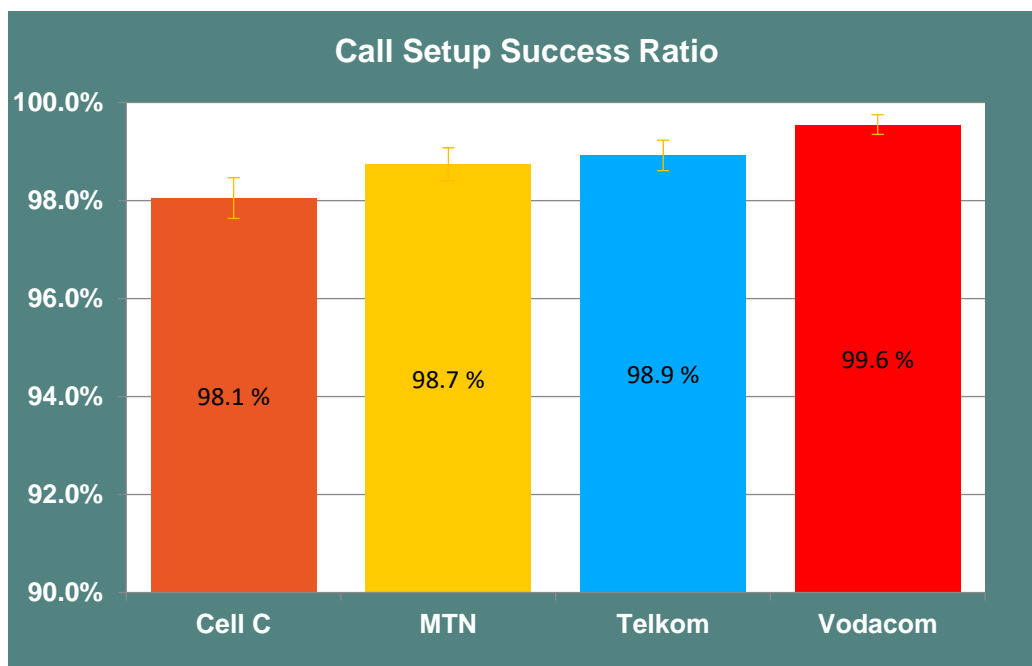


Figure 4. CSSR KPI Overall Results

Figure 4 shows Vodacom's overall CSSR is the highest followed by Telkom, MTN and Cell C. There is statistical significance difference recorded between MTN, Vodacom and Cell C. There is no statistical significance difference recorded between MTN and Telkom as well as MTN and Cell C. There was statistical significance difference between Vodacom, MTN, Cell C and Telkom as well as between Cell C and Telkom.

4.1.3. Drop Call Ratio (Long call)

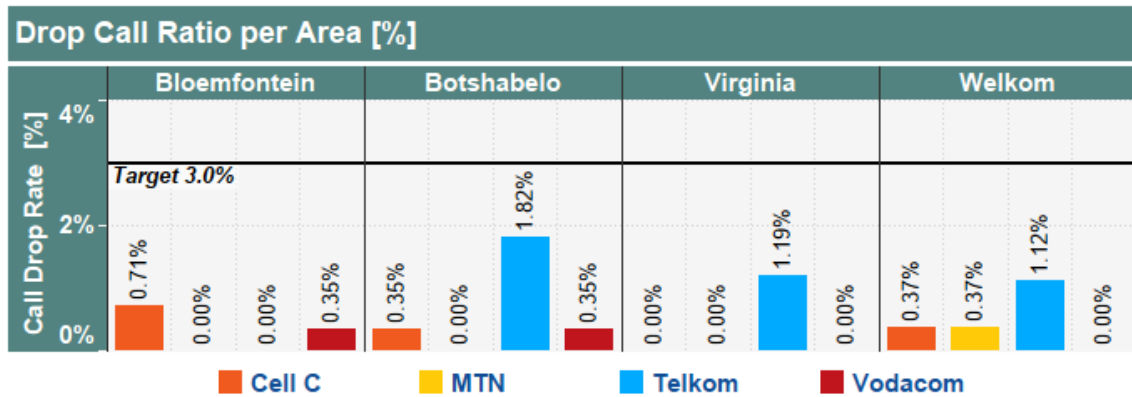


Figure 5. DCR KPI per Area

Figure 5 shows all the operators' DCR KPI results per area. All four operators met the target in all the tested areas. Figure 6 shows that MTN's overall DCR is the lowest followed by Vodacom, Cell C and Telkom in an ascending order. There is no statistical significance difference recorded between MTN, Vodacom and Cell. There is statistical significance difference between Telkom and MTN.

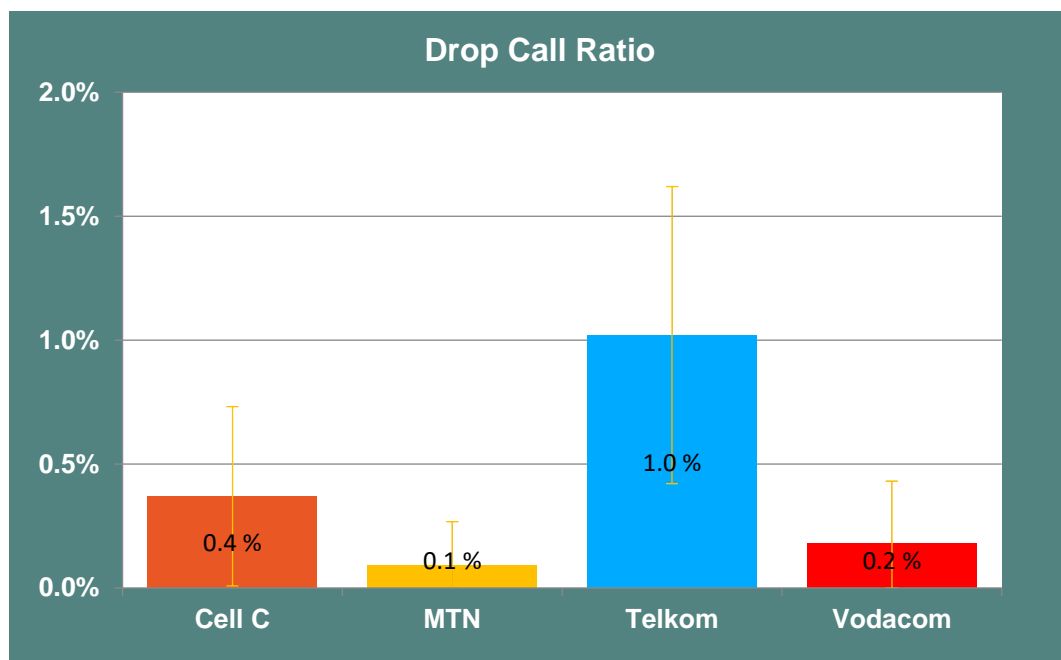


Figure 6. DCR KPI Overall Results

4.1.4. Call Setup Time (Short call)

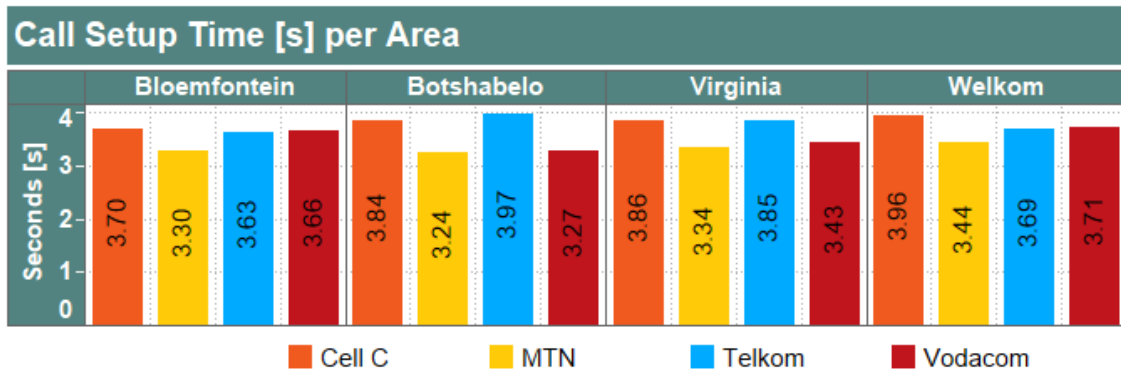


Figure 7. Call Setup Time[s] per Area

Figure 7 shows all operators met the Call Setup Time target of less than 20 seconds in the tested areas as per the End-User and Subscribers Service Charter Regulations of 2016.

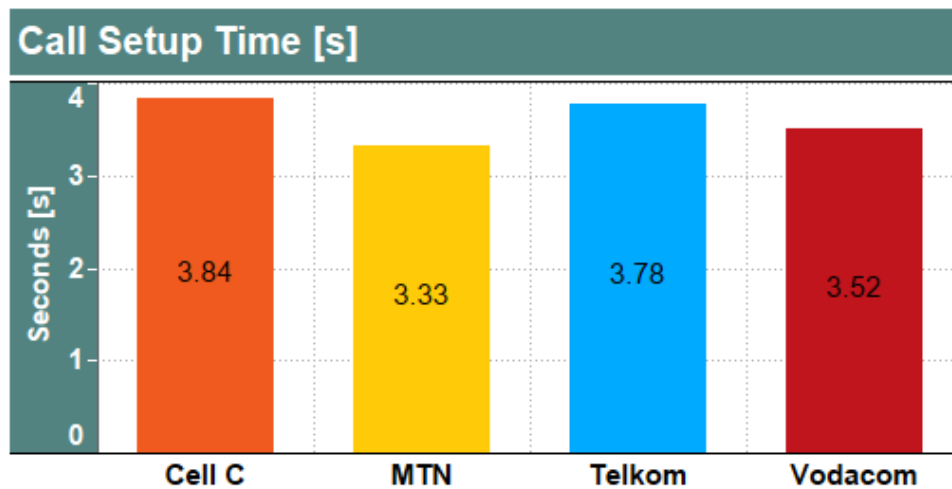


Figure 8. Call Setup Time[s] KPI Overall Results

Figure 8 shows the overall Call setup time results for the Free State Province. MTN had the lowest overall Call Setup Time, followed by Vodacom, Telkom, and Cell C.

4.1.5. POLQA MOS (Long call)

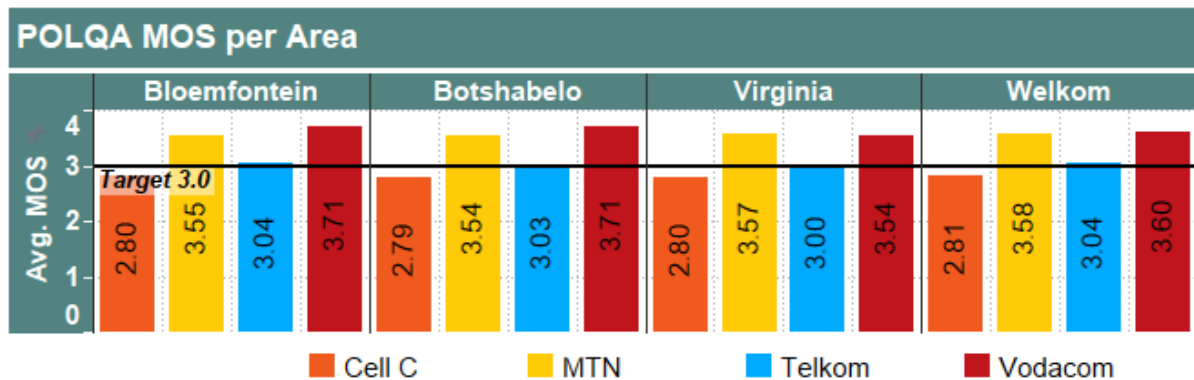


Figure 9. Speech Quality per Area

Figure 9 depicts speech quality results per tested area. MTN, Vodacom and Telkom achieved an average MOS of at least 3 in all the tested areas, thus, meeting the Speech Quality target. Cell C failed to meet the target for Speech Quality in all the tested areas.

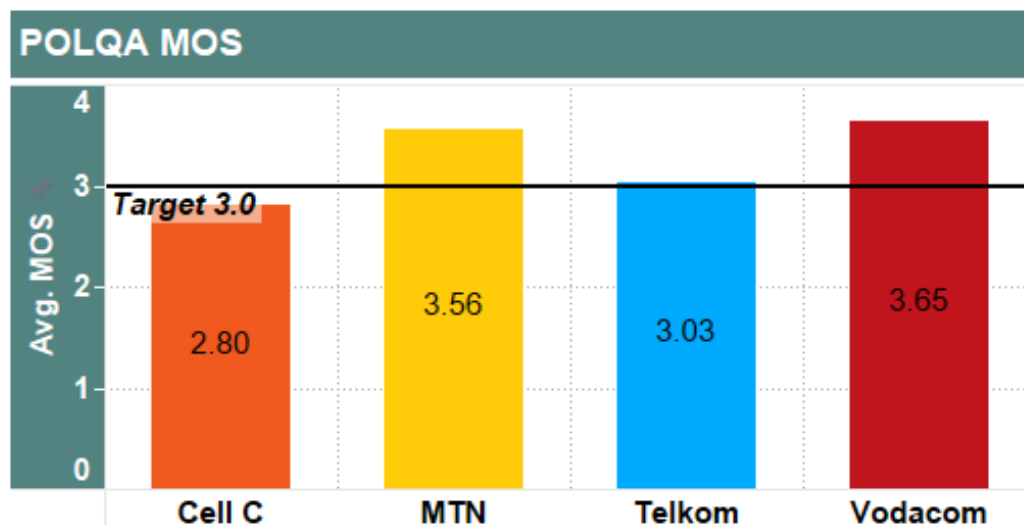


Figure 10. Speech Quality Overall Results

Figure 10 shows the overall Voice Quality scores for each Operator for the Free State Province. Vodacom achieved best Speech Quality followed by MTN, Telkom and Cell C in descending order. Cell C failed to meet the speech quality target of a score of 3.

4.1.6. Radio Technology

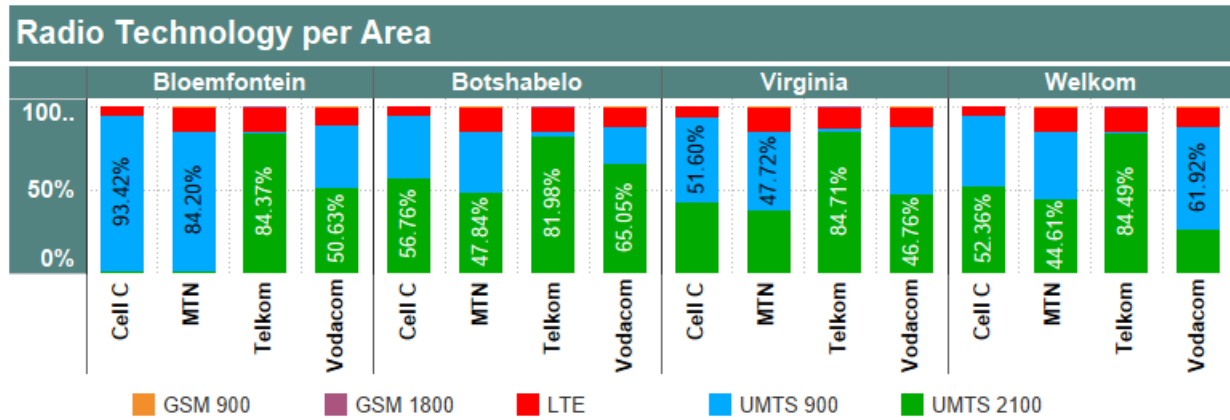


Figure 11. Serving Radio Technology per Area

Figure 11 shows the distribution of the serving technology per area. Bloemfontein showed the highest presence of UMTS 900 for MTN and Cell C.

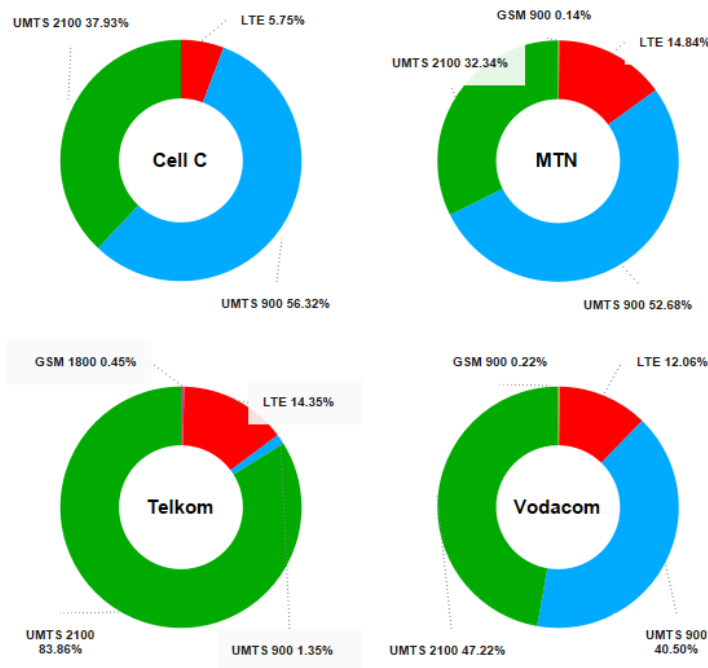


Figure 12. Serving Radio Technology Overall Results

Figure 12 shows the distribution of the overall serving radio technology during the drive test. All operators' serving technology was mainly on UMTS technology, Vodacom, MTN and Cell C had significant distribution on UMTS 900 technology. Telkom samples showed

significant presence of most samples on UMTS 2100. MTN has the highest LTE presence followed by Telkom, Vodacom and Cell C in a descending order.

4.1.7. CSFB

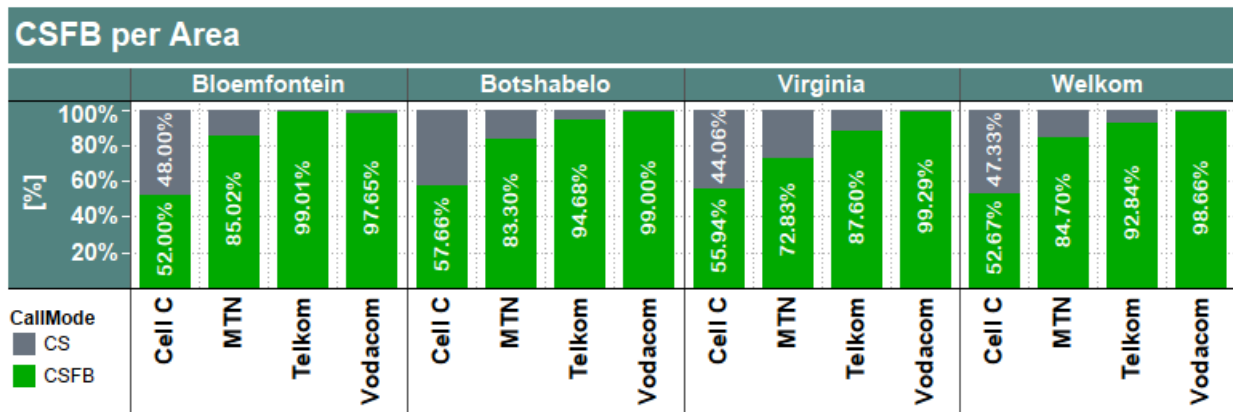


Figure 13. CSFB Results per Area

Figure 13 shows the breakdown of CS/CSFB calls per route. Vodacom has the most CSFB samples in all the areas. This is also an indication that the operator has significant LTE coverage in all the areas.

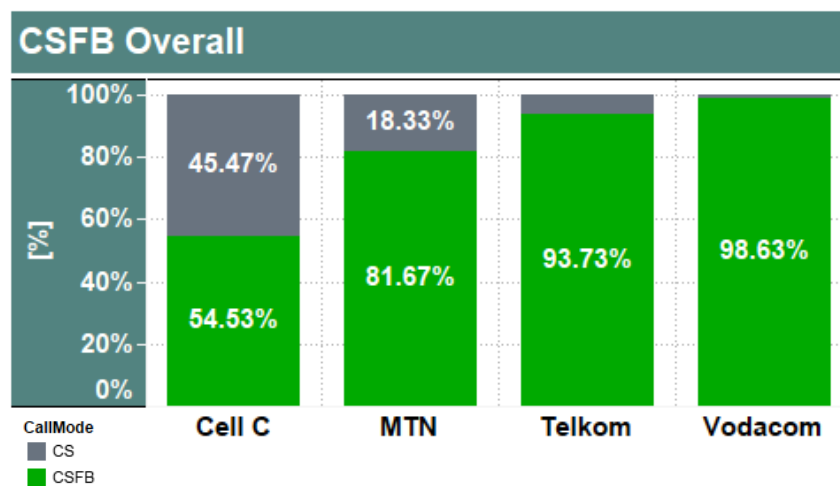


Figure 14. CSFB Overall Results

Figure 14 shows percentage of calls that were attempted on traditional networks as well as the ones initiated on LTE network and fell back to UMTS/ GSM.

4.2. Comparison of current results to previous results

Bloemfontein was previously monitored in the financial year 2014/2015, along with Welkom. Botshabelo was previously monitored in the financial year 2017/18, and Virginia in 2018/19. The aim of conducting the recent QoS measurements in these areas was to assess the level of improvement that the operators promised in the previous financial years. The results show that there is consistent good performance from all operators in Bloemfontein and Virginia.

In Botshabelo, Vodacom is the only operator that shows improvement in terms of Accessibility. In terms of Retainability, all operators show a significant improvement.

In Welkom, Vodacom is the only operator that shows improvement in terms of Accessibility; all operators met the then target of 95%. In terms of Retainability, Vodacom and Cell C show an improvement

It must be noted that the target for Accessibility was 95% in 2014/2015, this is before the revision of *End-User and Subscriber Service Charter Regulations of 2016* which became effective on 1 April 2016. Table 4 below summarises the previous and current results. Telkom was not yet included in the measurements during the financial year 2014/15.

Table 4 Comparison of previous results

Route	Financial Year	Accessibility (%)				Retainability (%)			
		Cell C	MTN	Telkom	Vodacom	Cell C	MTN	Telkom	Vodacom
Bloemfontein	2014/15	98,67	99,44	-	93,03	2,74	1,71	-	0,32
	2021/22	99,37	99,55	99,73	99,73	0,71	0,00	0,00	0,35
Botshabelo	2017/18	97,26	98,96	99,30	97,41	2,98	2,11	1,92	1,62
	2021/22	96,66	98,02	98,02	99,46	0,35	0,00	1,82	0,35
Virginia	2018/19	91,91	99,50	95,95	96,60	2,92	1,00	1,15	2,73
	2021/22	98,79	98,99	98,79	99,60	0,00	0,00	1,19	0,00
Welkom	2014/15	97,96	99,73	-	95,97	0,70	0,00	-	1,11
	2021/22	97,45	98,39	99,15	99,43	0,37	0,37	1,12	0,00

5. Conclusion

This section provides the summary and key findings of all measurements. The results illustrate a snapshot of the mobile network performance and customer experience within the measured time and location context.

The results indicate that the end-user's Quality of Service and operators' network performance varies significantly per area tested.

After benchmarking the operators, the results show that in terms of areas tested:

- **Worst Performing Area:** MTN, Cell C and Telkom failed to meet CSSR target in **Botshabelo**. Cell C also failed to achieve the target in Welkom.
- **Best Performing Area:** Bloemfontein and Virginia are the areas where all operators achieved most of the targets, with only Cell C failing to achieve the MOS target.
- All operators (Vodacom, MTN, Telkom and Cell C) met the DCR target in all tested areas.
- All operators met the Call Setup Time target of less than 20 seconds in all the tested areas.
- MTN, Vodacom and Telkom achieved an average MOS of at least 3 in all the tested areas, thus, meeting the Speech Quality target. Cell C failed to meet the target for Speech Quality in all the tested areas.

The tests provided a view of potential hotspot areas where there was a concentration of failures from more than one mobile network operator:

- In Botshabelo there was a concentration of failures along the Thaba Nchu Road where most of MTN and Cell C failures occurred.

In terms of the Overall results, the following was observed:

- **Call Setup Success Ratio (CSSR):** Overall results show that all four operators achieved more than 98% CSSR values, thus they have met the Authority's Accessibility target.
- **Drop Call Ratio (DCR):** MTN, Vodacom, Cell C and Telkom met the overall Drop Call Ratio target of less than 3% and thus met the Authority's Retainability target.

- **Speech Quality (MOS):** MTN, Vodacom and Telkom achieved the overall speech quality target of MOS score of more than 3, thus meeting the Authority's Speech Quality target.
- **Call Setup Time (CST):** All operators achieved the overall Call Setup Time target of less than 20 seconds.

The results for the areas which were monitored in the previous financial years compared to current results shows:

- There is CSSR performance improvement in Bloemfontein and Virginia.
- In Botshabelo, Vodacom is the only operator that shows improvement in terms of Accessibility.
- There is DCR performance improvement in all tested areas: Bloemfontein, Botshabelo, Welkom and Virginia from all four operators.

6. Appendices

6.1. Appendix 1: Mobile operators' feedback on the report

A detailed report was shared with the mobile operators in order for them to share their plans and remedial actions to address issues of poor performance. The improvement plans and remedial actions are provided below.

6.1.1 Vodacom

Vodacom provided feedback and network improvement plans that are in place. Vodacom indicated that the root cause of all the failures in in some of the areas were caused by several sites that were out of service (power failure) during trialling, due to vandalism and the sites that were on air were experiencing congestion due to reduced capacity. All sites that were out of service have since been resolved and quality improved in the areas affected.

The solutions proposed in order to address the challenges are as follows:

- a) Energiser 3 project (Site hardening and backup power installation), to be implemented in quarter 4 of 2022 Financial Year.
- b) Two new sites to increase capacity and close coverage gaps in the area, to be implemented in quarter 4 of 2022 Financial Year.
- c) Omni sites Sectorisation to improve quality of coverage, implemented in December 2021.
- d) LTE Footprint extension through L900 configuration in the area, implemented in December 2021

6.1.2 MTN

MTN acknowledged the poor coverage patches in the Free State network, resulting in lower Call Accessibility performance.

- The call setup failure and dropped calls experienced during testing were mainly due to poor coverage in the area. On one site, antenna optimization solution will be implemented to improve coverage. MTN indicated that they already planned a site on one location, which will be built in 2022 to improve coverage in the area.

6.1.3 Cell C

Cell C indicated that their response includes the highlights of the report taking into account the network coverage of Cell C and MTN under the commercial national roaming agreement. Cell C also stated that they will engage with their Roaming Partner, with regards to 3G and 4G coverage in the tested areas and investigate site availability and performance in the area. The preliminary investigation of the low MOS score points to a configuration mismatch between the RAN (Radio Access Network) and Core networks. Cell C will further engage with the Roaming Partner to resolve the issue.

6.1.4 Telkom

Telkom's response to the report indicated that it views the Authority test results as very significant and use them as additional input to further improve the quality of the mobile network.

Furthermore, Telkom indicated that they will be engaging with their roaming partners to resolve issues and improve customer experience. It is also mentioned that during the Authority's drive tests, ten (10) sites were affected by vandalism. Repairs have been underway to address this issue.

There are twenty-six (26) new sites at different stages of rollout within the tested areas. Twenty-two (22) of these sites are in site acquisition phase (nineteen in Bloemfontein, two in Botshabelo and four in Welkom) and expected to be in service by the second quarter of 2022/2023 financial year, pending approval of site leases by site owners. There are three sites on a re-planning phase in Bloemfontein and one site on a "Lease Agreement" phase.

6.2. Appendix 2: Detailed Test results per Phase

Table 5. CSSR, Call Setup Time Phase 1 and Phase 2

		Bloemfontein		Botshabelo		Virginia		Welkom		Grand Total
		Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	
Call Attempt	Cell C	548	561	563	545	497	491	528	530	4263
	MTN	550	563	565	547	498	491	526	530	4270
	Telkom	550	564	565	547	498	490	526	530	4270
	Vodacom	550	563	565	547	497	491	526	530	4269
Call Failed	Cell C	4	3	15	22	3	9	13	14	83
	MTN	2	3	14	8	4	6	9	8	54
	Telkom	2	1	15	7	6	6	2	7	46
	Vodacom	3	0	5	1	2	2	2	4	19
Call Setup Success Rate [%]	Cell C	99.27%	99.47%	97.34%	95.96%	99.40%	98.17%	97.54%	97.36%	98.05%
	MTN	99.64%	99.47%	97.52%	98.54%	99.20%	98.78%	98.29%	98.49%	98.74%
	Telkom	99.64%	99.82%	97.35%	98.72%	98.80%	98.78%	99.62%	98.68%	98.92%
	Vodacom	99.45%	100.00%	99.12%	99.82%	99.60%	99.59%	99.62%	99.25%	99.55%
Call Setup Time	Cell C	3.71	3.70	3.85	3.84	3.86	3.85	3.94	3.97	3.84
	MTN	3.28	3.31	3.24	3.25	3.38	3.29	3.51	3.38	3.33
	Telkom	3.66	3.61	4.04	3.89	3.81	3.88	3.68	3.71	3.78
	Vodacom	3.62	3.69	3.26	3.28	3.41	3.46	3.72	3.70	3.52

Table 6. DCR and POLQA MOS Phase 1 and Phase2

		Bloemfontein		Botshabelo		Virginia		Welkom		Grand Total
		Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	
Call Completed	Cell C	138	142	143	140	122	127	132	135	1079
	MTN	142	147	147	140	126	128	135	134	1099
	Telkom	140	146	134	135	125	124	131	134	1069
	Vodacom	141	144	146	141	126	126	132	136	1092
Call Dropped	Cell C	1	1	1	0	0	0	0	1	8
	MTN	0	0	0	0	0	0	0	1	9
	Telkom	0	0	3	2	2	1	2	1	22
	Vodacom	0	1	0	1	0	0	0	0	7
Drop Call Rate [%]	Cell C	0.72%	0.70%	0.69%	0.00%	0.00%	0.00%	0.00%	0.74%	0.37%
	MTN	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.74%	0.09%
	Telkom	0.00%	0.00%	2.19%	1.46%	1.57%	0.80%	1.50%	0.74%	1.02%
	Vodacom	0.00%	0.69%	0.00%	0.70%	0.00%	0.00%	0.00%	0.00%	0.18%
POLQA MOS	Cell C	2.79	2.81	2.80	2.77	2.80	2.81	2.80	2.83	2.80
	MTN	3.55	3.54	3.56	3.53	3.56	3.58	3.58	3.57	3.56
	Telkom	3.04	3.04	3.02	3.03	3.01	2.99	3.04	3.05	3.03
	Vodacom	3.73	3.70	3.70	3.72	3.58	3.50	3.65	3.56	3.65

6.3. Appendix 3 Technology Maps

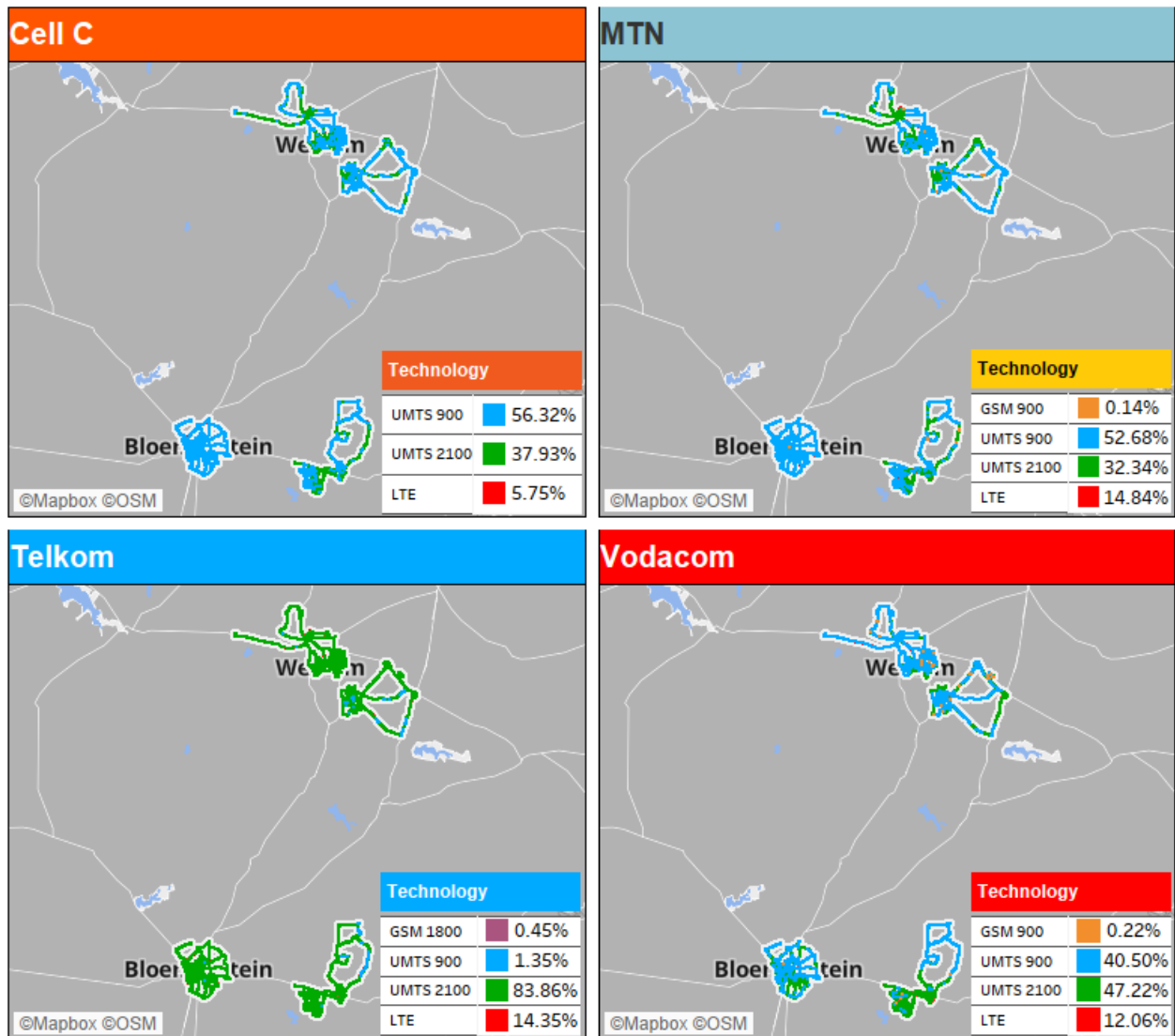


Figure 15. Radio Technology Maps

6.4. Appendix 4 UMTS Coverage Maps

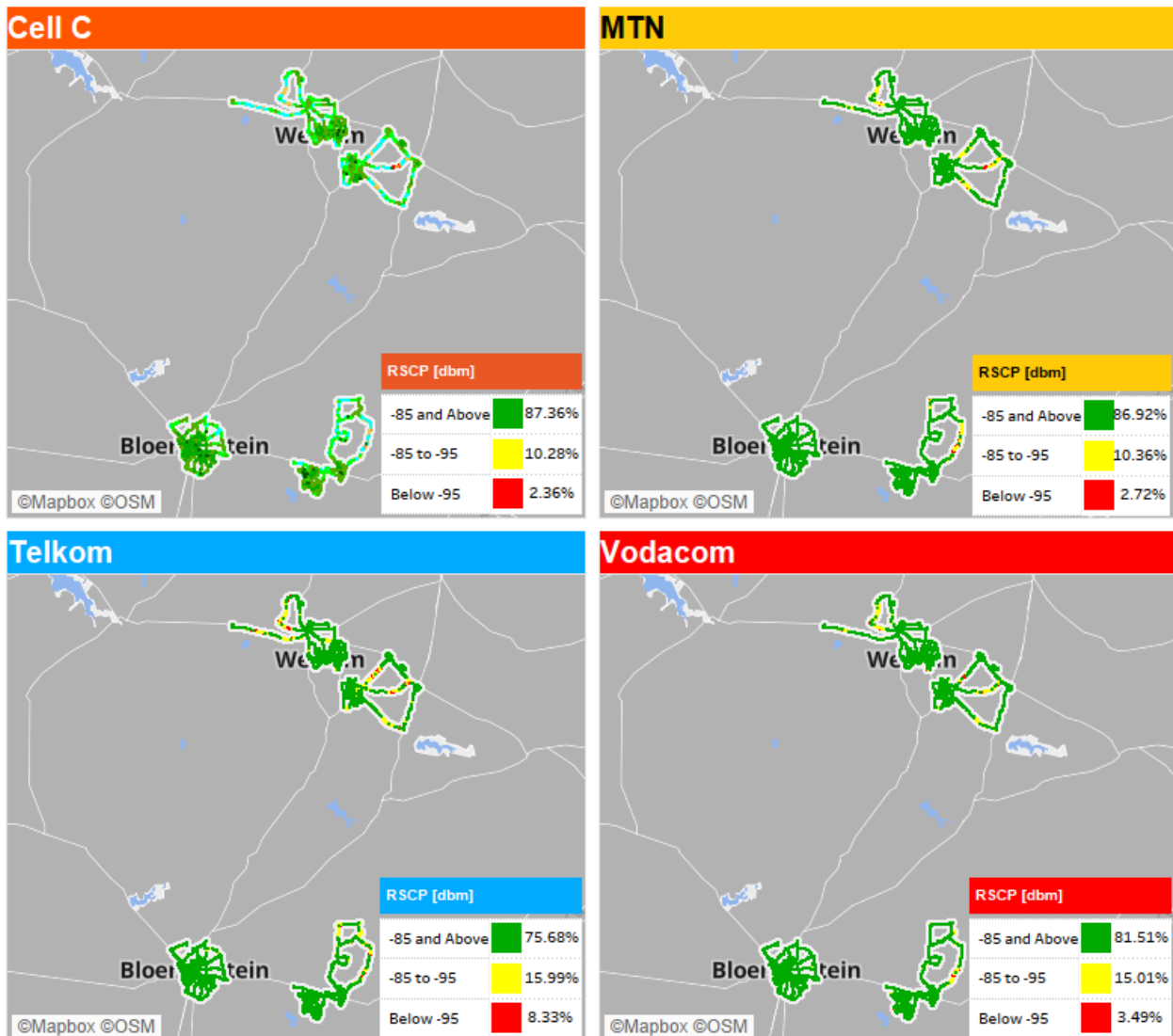


Figure 16. UMTS Coverage Maps

6.5. Appendix 5 UMTS Quality Maps

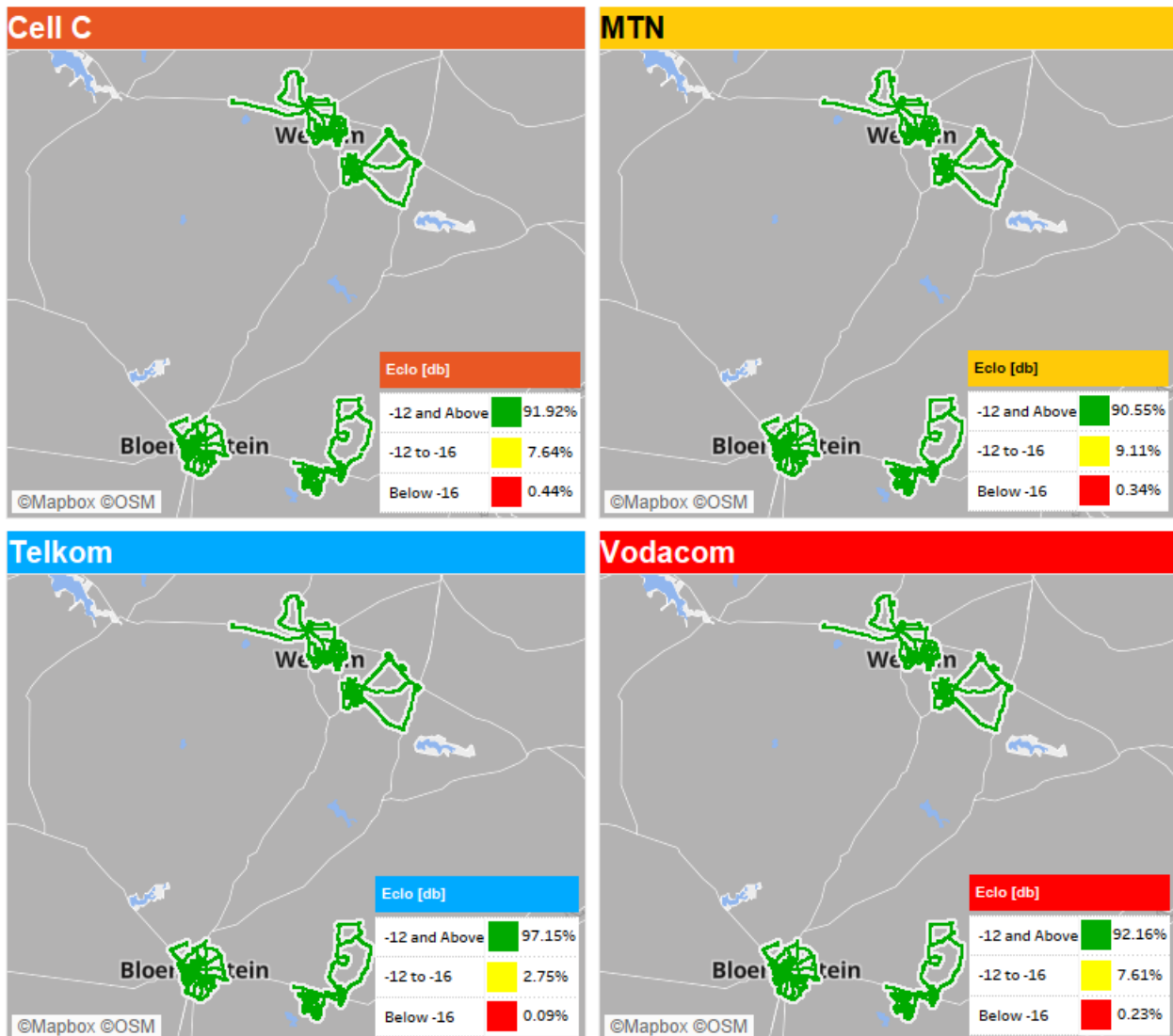


Figure 17. UMTS Quality Maps