ANACOM

ICP - Autoridade Nacional de Comunicações
Av. José Malhoa, nº12 - 1099-017 Lisboa
Portugal

Internet - http://www.anacom.pt
e-mail - info@anacom.pt
Telephone - +351 217211000
Fax - +351 217211001

The information is also available in Anacom's Internet website in:

http://www.anacom.pt/template12.jsp?categoryId=267743

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GSM / UMTS

Mobile Communication Systems

Quality of Service Assessment

Assessment of Voice (GSM) and Video-telephony (UMTS) Services, and Network Coverage (GSM and WCDMA) in the main Urban Agglomerations and Major Roads of the Autonomous Regions of the Azores and Madeira.

January 2008

ACRONYMS

CoDec	Codifier/De-codifier.
CPICH RSCP	Common Pilot Channel, Received Signal Code Power – Level of the signal received by a mobile terminal (WCDMA).
ETSI	European Telecommunications Standards Institute.
GSM	Global System for Mobile communications – Second generation (2G) Mobile Communications System.
ITU	International Telecommunications Union.
MOS	Mean Opinion Score – Quality rate quantifying the effort that it takes to understand an end-to-end type conversation. Its value is 0 (zero) when there is no communication and 5 (five) when the communication is perfect. Value "zero" never shows on the results since only situations where the connection was established and maintained during a given period are considered. "Five" also never shows on the results because CoDec7, used by mobile networks, renders impossible such high voice or video quality values (the voice or video quality reached with the usually used CoDec has MOS values lower than 4.5).
PESQ	Perceptual Evaluation of Speech Quality – Algorithm used in the analysis of the audio quality of a voice communication (Recommended by ITU: *ITU-T Recommendation P.862 (02/2001)*; *ITU-T RecommendationP.862.1 (11/2003)*).
ISDN	Integrated Services Digital Network – Technology used on the fixed access network.
RF	Radio Frequency.
RxLev	Received signal level, at a mobile (GSM) terminal.
Scanner	Measurement equipment that collects radio signal levels for each channel of a frequency band.
SQuad-LQ	SwissQual's speech quality algorithm for Listening Quality – Algorithm developed by SwissQual to analyse the audio quality of a communication.
UMTS	Universal Mobile Telecommunications System – Third generation (3G) Mobile Communications System.
VQuad	Objective Model for Video Quality Assessment – Algorithm used in the analysis of the video quality of a communication (developed by *SwissQual*)
WCDMA	Wideband Code Division Multiple Access – Technology used in the radio component of the UMTS communications systems.

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I EXECUTIVE SUMMARY

I.I GENERAL FRAMEWORK

In June and July 2007, Autoridade Nacional de Comunicações (ANACOM) carried out an assessment of the quality of mobile services – voice (GSM), video-telephony (UMTS) and network coverage (GSM and WCDMA) – provided by operators OPTIMUS, TMN and VODAFONE in the main urban agglomerations – Ponta Delgada, Angra do Heroísmo and Funchal – and major roads of the islands of the Autonomous Regions of the Azores and Madeira, by analysing technical parameters that translate the quality perception from the consumer's standpoint.

The methodology that was used in this study relies on field tests performed from the user's standpoint, by using an automatic measurement system that reflects the several features affecting the quality of the services (end-to-end measurements). On the other hand, measurements were carried out on equal terms regarding the three operators, namely at the same time, at the same locations and with the same parameters, thus making it possible to perform comparative analysis of the observed performances.

The main quality indicators were analysed, considering the user's perspective and the services under study:

1. Network Coverage – Availability of the GSM and WCDMA (UMTS) radio networks;
2. Service Accessibility (voice or video-telephony) – probability of success when setting up calls;
3. Call set up time (voice or video-telephony) – period of time that the network takes to establish the communication, after the correct sending of the request (targeted telephone number);
4. Call Termination Rate (voice or video-telephony) – Probability that a call has, after being successfully set up, to be maintained during a period of time, ending normally, i.e., according to the user's will;
5. Call Audio Quality (voice or video-telephony) – perceptibility of the conversation during a call;
6. Call Video Quality (video-telephony) – perceptibility of the communication's video feature.

Data collection took place on working days and during normal working hours, between 11 June and 30 July 2007. 9,076 test calls and 1,259,005 radio signal level measurements were made, standing for more than 83 hours of measurements along 3,269 kilometres.

The used sample provided global results, by operator, with a maximum error below 4.1% in the Azores

archipelago, and below 5.1% in Madeira, for a 95% confidence level.

In view of these services' penetration rate, of the diversity of the terminal equipment that is used, and given each user's subjective view itself, it is impossible to rigorously reproduce each consumer's conditions of interaction with the networks. In this context, the results of this study must thus be understood as an indicator of the networks' global behaviour. The transposition/extrapolation of these results to specific situations requires some prudence, at the risk that biased conclusions might be taken.

The technical and methodological options of this study directly influenced its results and must be taken into account when analyzing the results, namely the following ones:

- Tests were exclusively based on a technical solution (equipment + software) and performed in a totally automatic way, thereby setting homogenous conditions for the monitoring of the three operators and eliminating the subjectivity inherent to the human user;
- It used NOKIA 6680 terminal equipment;
- Tests were carried out in moving vehicles and with outdoor antennas (without gain);
- Call duration, both for voice and video-telephony, was 120 seconds;
- Voice tests were made with manual selection of the 2G (GSM) infrastructure, while video-telephony tests were made with automatic selection of the 2G or 3G (GSM/UMTS) infrastructure;
- Coverage indicators, particularly WCDMA coverage, do not take into account networks' loads (number of simultaneous users and type of services used);
- The new measurement systems call on the most recent testing techniques and implement new reckoning algorithms; therefore, the results produced are not directly comparable with those of the studies carried out on these regions in previous years;
- The results of the study only reflect the behaviour of the networks on the locations and moments of the measurements;
- On the other hand, operators are permanently improving their networks. The technical interventions necessary for these improvements can cause momentary degradations of the service in the geographic area of intervention.

I.II MAIN RESULTS AND CONCLUSIONS

The performance of the mobile communications systems analysed in this study present important differences among the analysed operators, technologies and types of locations.

One of the features that contributed to the observed differences is the fact that operator OPTIMUS does not have a WCDMA coverage in the Azores archipelago, and that its GSM coverage is only available in 5 of the 9 islands. Operators TMN and VODAFONE also do not have WCDMA coverage in the islands of Flores and Corvo.

In general, GSM coverage is wider than WCDMA coverage. However, for both technologies, there are large areas with poor or even non-existent radio coverage, especially in major roads.

The voice service presents good performances in urban areas. In major roads there is a degradation of this service, particularly regarding the *Service Accessibility* and the *Call Termination Rate* indicators. In the Azores' major roads, OPTIMUS' *Service Accessibility* is below 50%.

The performance of the video-telephony service stands below the one recorded for the voice service, namely the *Service Accessibility* indicator, due to the existence of large areas without WCDMA radio coverage. The lowest levels are recorded in major roads; in the Azores, they are even below 50%, for operators TMN and Vodafone, and null for operator OPTIMUS.

GSM and WCDMA Networks Coverage

Mobile networks' coverage present important differences among the analysed operators, technologies and type of locations.

In urban agglomerations (Figure 1 and Figure 2), the mobile networks of TMN and VODAFONE present good coverage levels. Results obtained for WCDMA are still good, although below the GSM ones.

On its hand, operator OPTIMUS presents different results in the urban agglomerations of both analysed autonomous regions. In the Autonomous Region of Madeira (Figure 2), it presents levels that are close to those observed for operators TMN and VODAFONE, both for GSM and WCDMA. In the Autonomous Region of the Azores (Figure 1), for GSM, results stand below those recorded by the two other

operators, although still good. For WCDMA, there is no coverage both in Ponta Delgada and in Angra do Heroísmo.

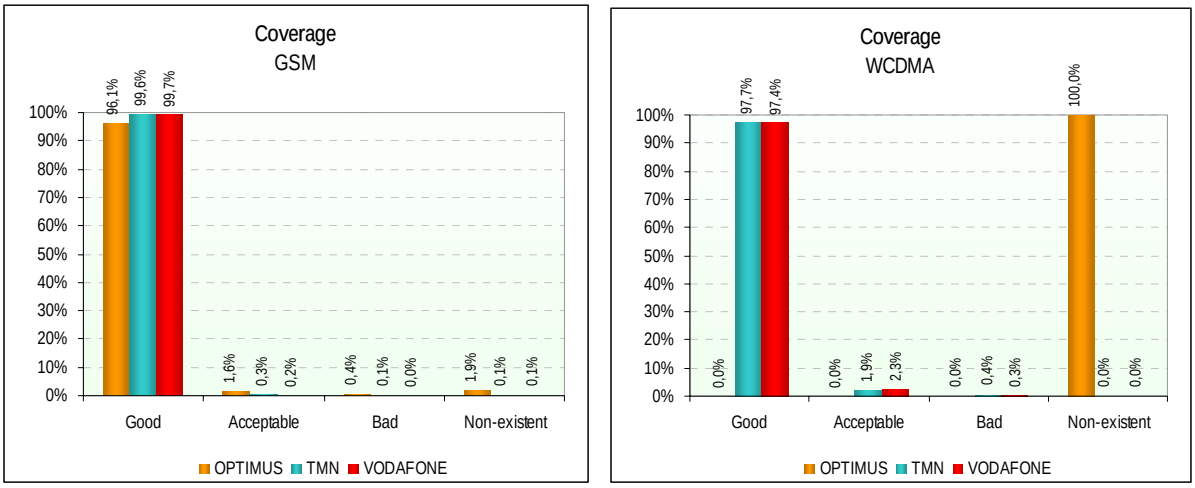


Figure 1 – *Coverage* indicator, on the Urban Agglomerations of the A. R. of the Azores.

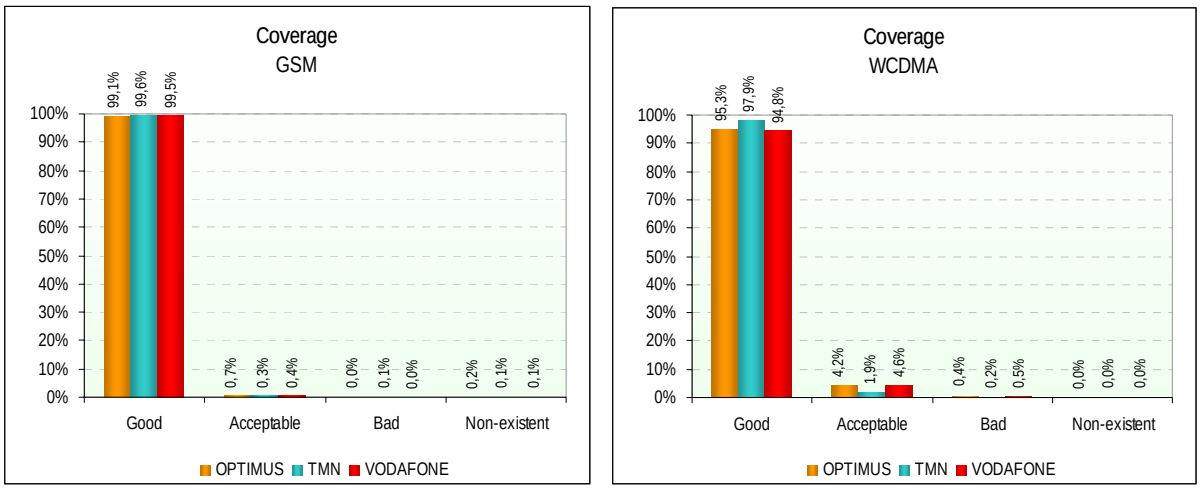


Figure 2 – *Coverage* indicator, on the Urban Agglomerations of the A. R. of Madeira.

Major roads (Figure 3 and Figure 4) present large areas with poor or no coverage at all, especially in the Azores and for the WCDMA technology.

For GSM, operator OPTIMUS presents the lowest performances, with good coverage levels around 41%, in the Azores archipelago, and 83.2% in the Madeira archipelago. For WCDMA, the worst coverage levels are recorded in the Azores archipelago. Operator OPTIMUS is not present on any of the islands and TMN and VODAFONE are not present on the Flores and Corvo islands. TMN's and

VODAFONE's good coverage levels stand at 60% and 41.7%, respectively. In the Madeira archipelago, the good coverage levels for operators OPTIMUS and TMN are close to 80%, while for VODAFONE they stand at 56%.

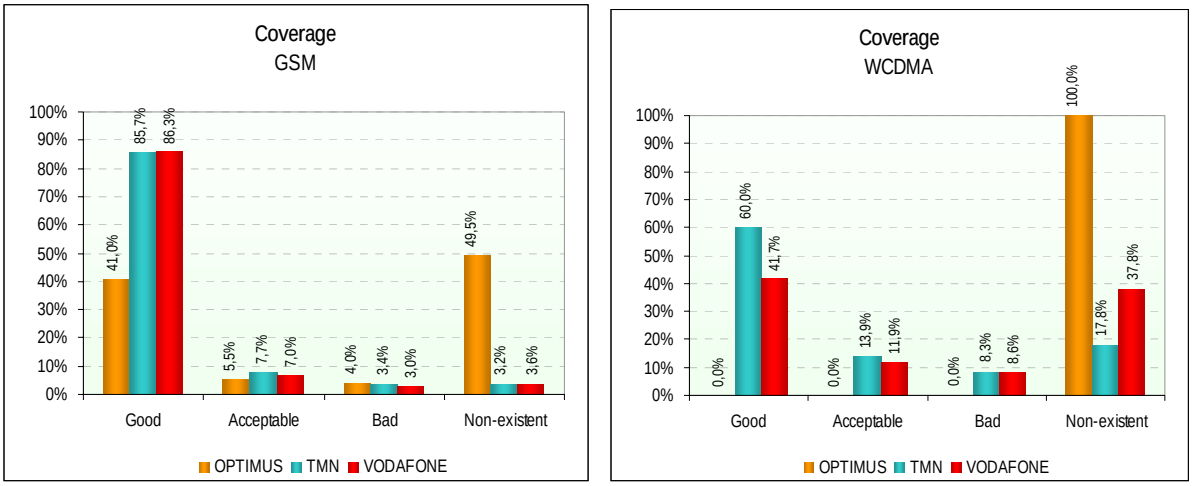


Figure 3 – *Coverage* indicator, on the Major Roads of the A. R. of the Azores.

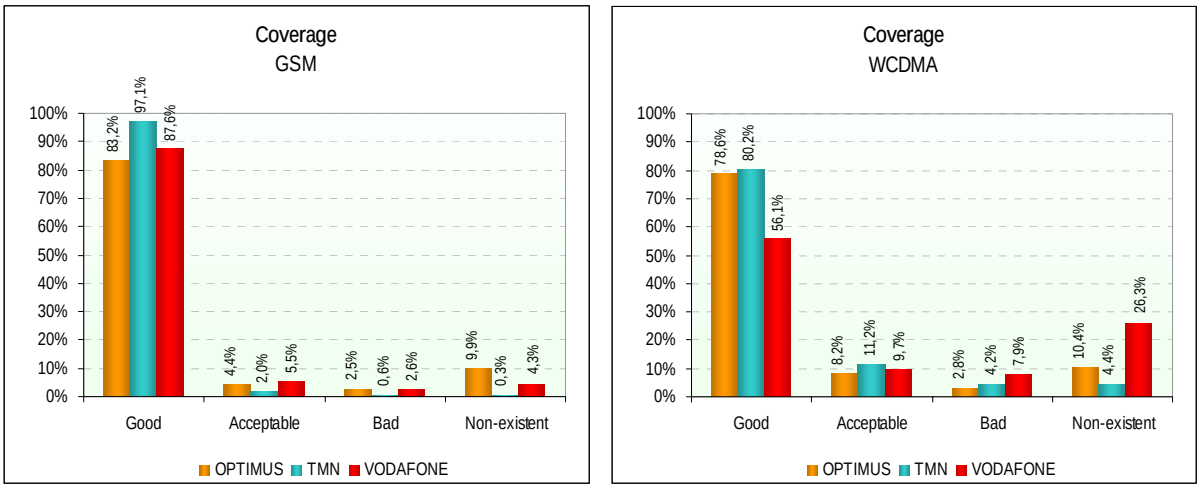


Figure 4 – *Coverage* indicator, on the Major Roads of the A. R. of Madeira.

Voice Service (GSM)

The voice service, regarding the *Service Accessibility* and *Call Termination Rate* indicators, presents different performances between the analysed urban agglomerations and major roads.

On urban agglomerations, both in the Azores and in the Madeira archipelago, these indicators present good levels (Figure 5 and Figure 6). The lowest value was recorded by TMN in Funchal, with a 95% *Call Termination Rate*.

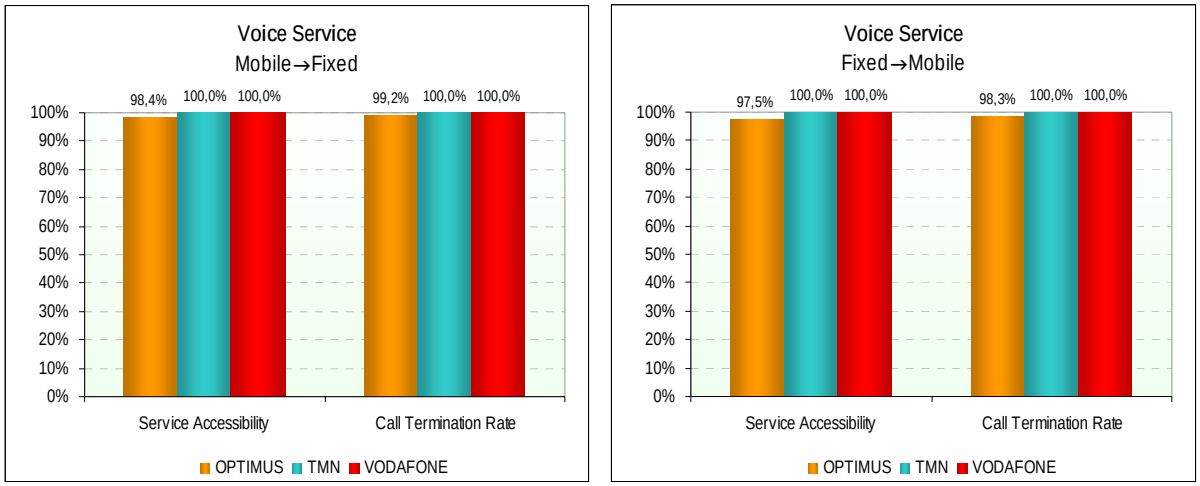


Figure 5 – *Service Accessibility* and *Call Termination Rate* indicators, on the Urban Agglomerations of the A. R. of the Azores.

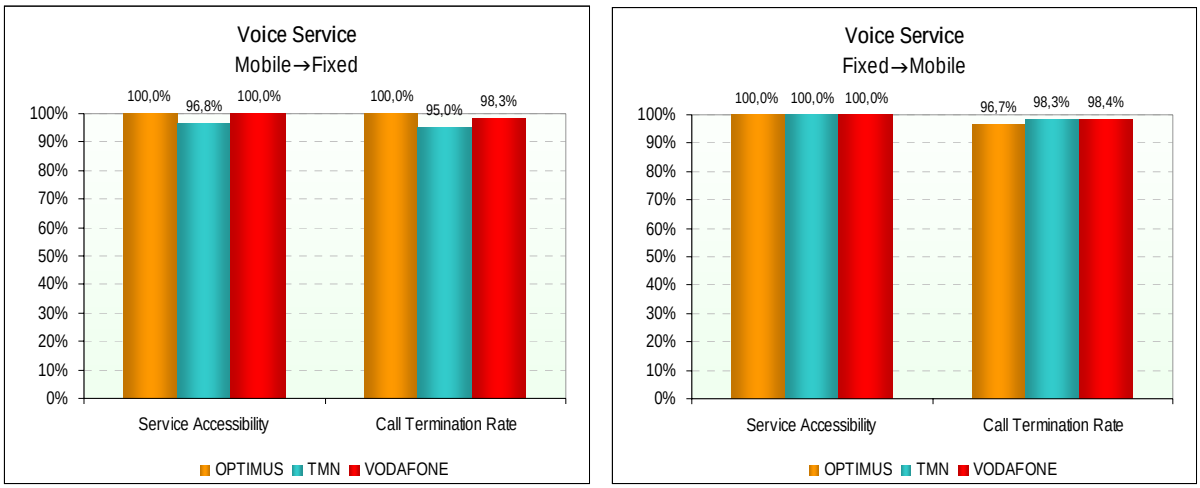


Figure 6 – *Service Accessibility* and *Call Termination Rate* indicators, on the Urban Agglomerations of the A. R. of Madeira.

In major roads there is a general degradation of these indicators, mainly caused by the numerous areas where mobile networks have poor or no radio coverage (Figure 7 and Figure 8). The highest

degradation is recorded by operator OPTIMUS in the Autonomous Region of the Azores, with a *Service Accessibility* below 42%.

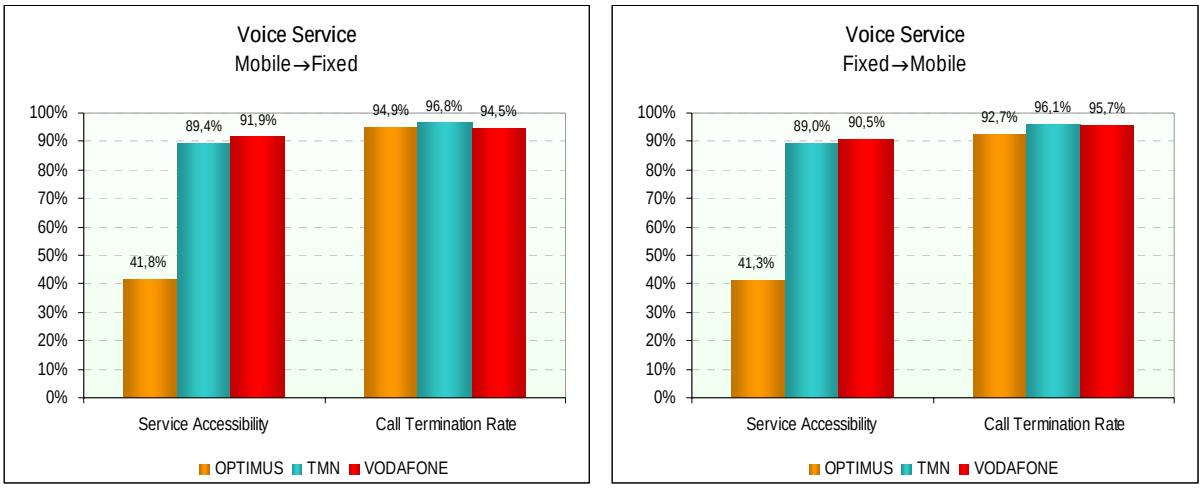


Figure 7 – *Service Accessibility* and *Call Termination Rate* indicators, on the Major Roads of the A. R. of the Azores.

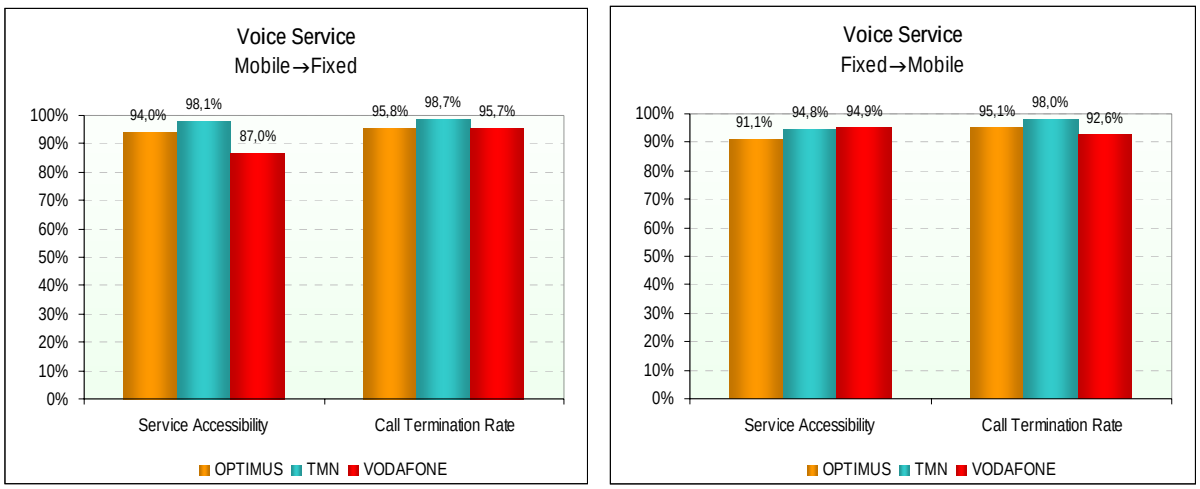


Figure 8 – *Service Accessibility* and *Call Termination Rate* indicators, on the Major Roads of the A. R. of Madeira.

The networks of operators OPTIMUS, TMN and VODAFONE show good average voice call set up times, regardless of the analysed locations (Figure 9, Figure 10, Figure 11 and Figure 12).

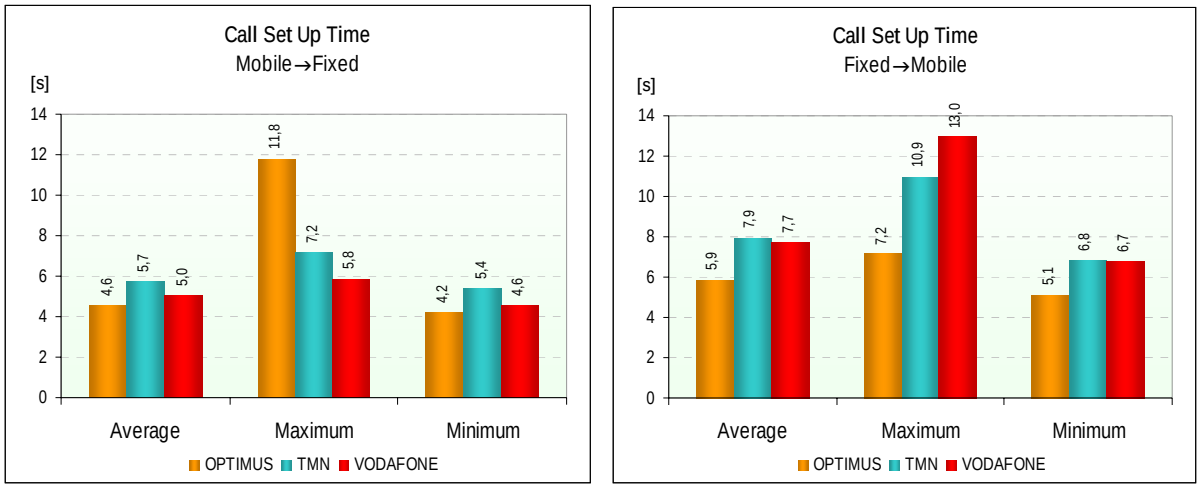


Figure 9 – *Call Set Up Time* indicator, on the Urban Agglomerations of the A. R. of the Azores.

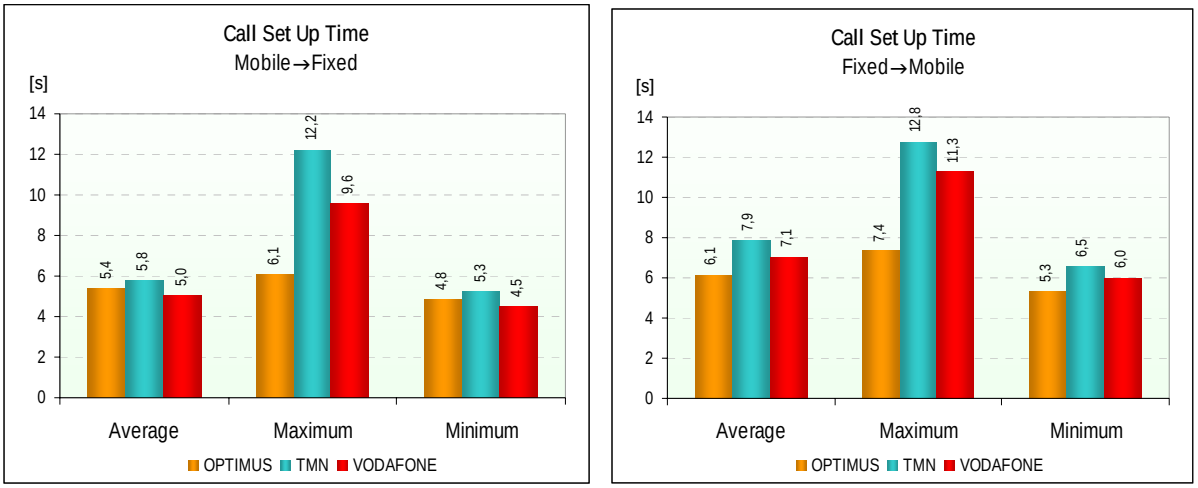


Figure 10 – *Call Set Up Time* indicator, on the Urban Agglomerations of the A. R. of Madeira.

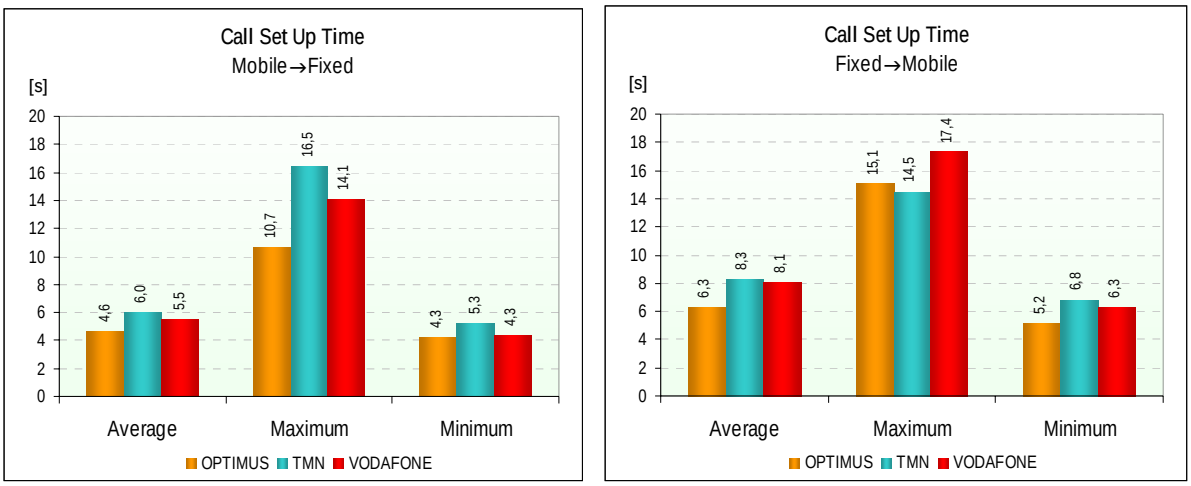


Figure 11 – *Call Set Up Time* indicator, on the Major Roads of the A. R. of the Azores.

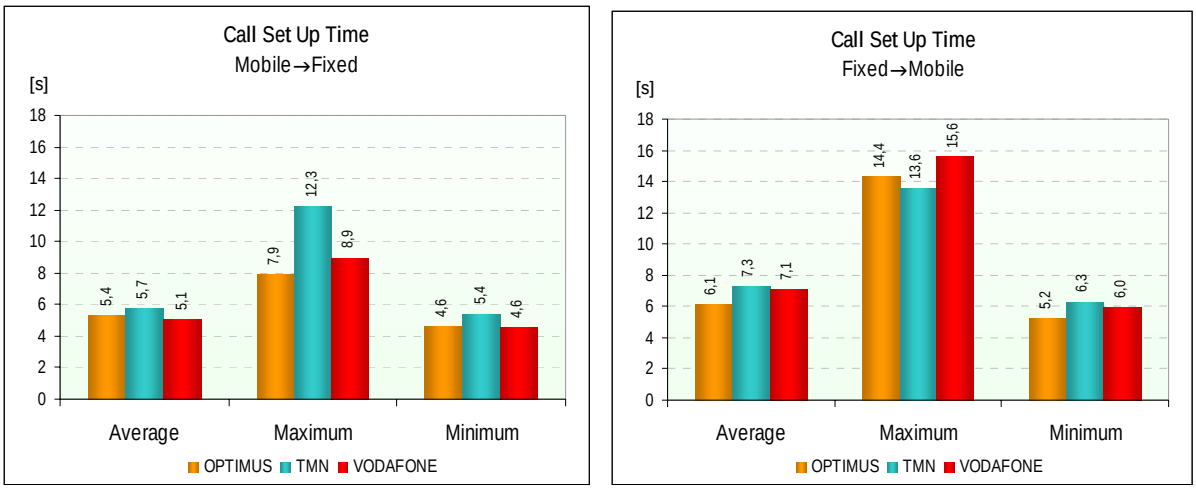


Figure 12 – *Call Set Up Time* indicator, on the Major Roads of the A. R. of Madeira.

Normally ended voice calls (120 seconds duration) present good average *Audio Quality*, both on urban areas and on the major roads of the Azores and Madeira archipelagos. TMN shows the best performance, although differences between operators are not significant (Figure 13, Figure 14, Figure 15 and Figure 16).

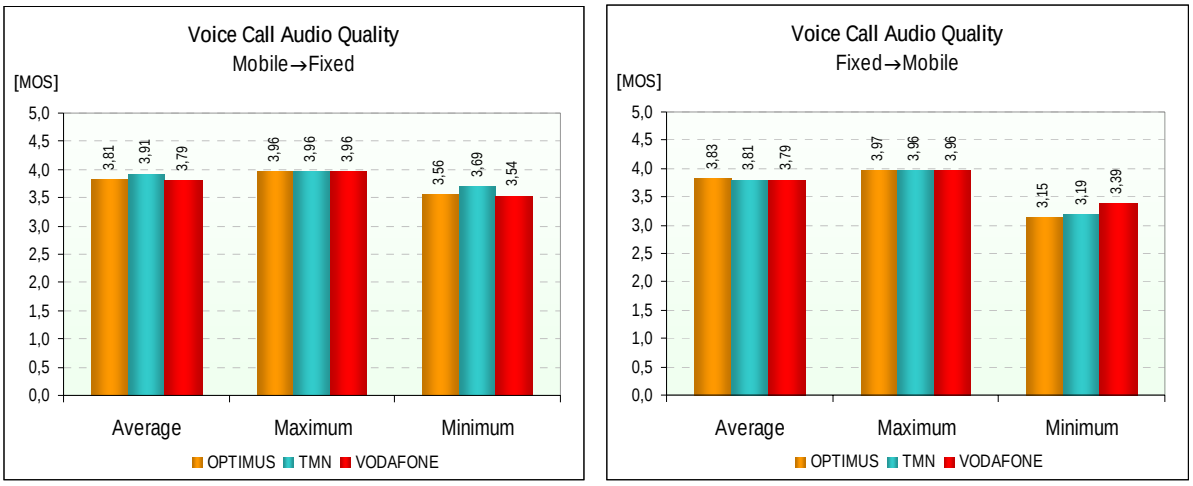
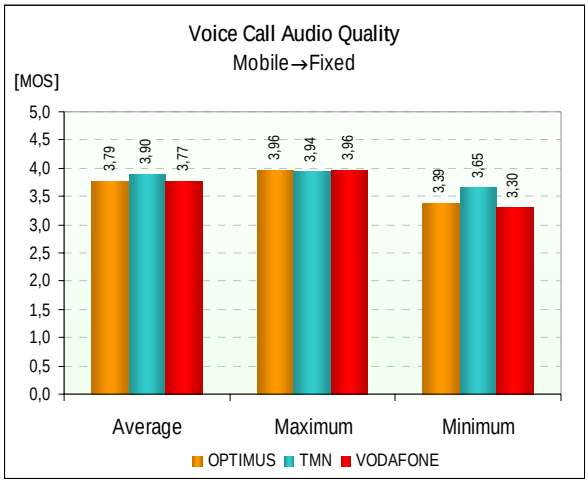


Figure 13 – *Call Audio Quality* indicator, on the Urban Agglomerations of the A. R. of the Azores



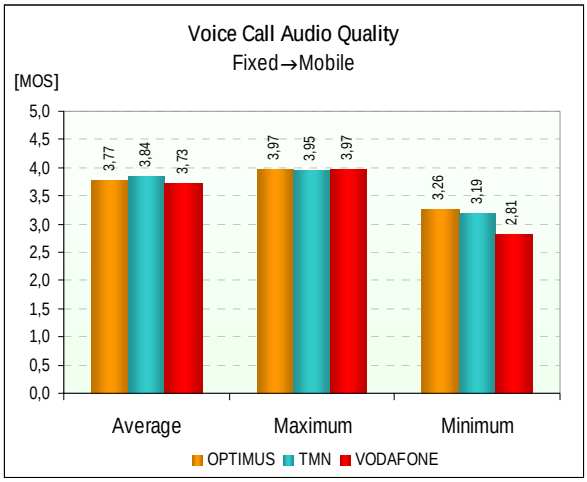
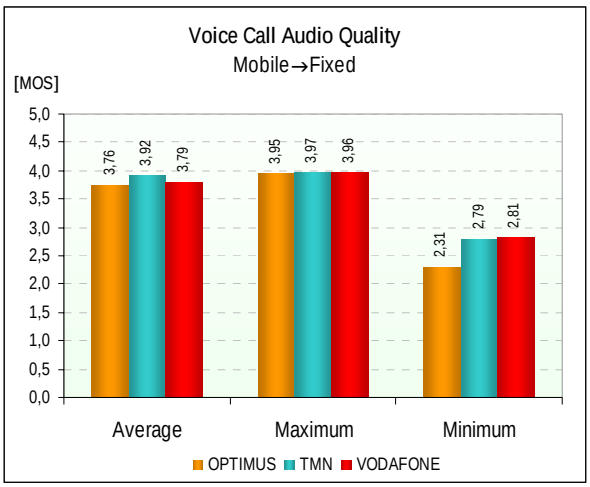


Figure 14 – *Call Audio Quality* indicator, on the Urban Agglomerations of the A. R. of Madeira.



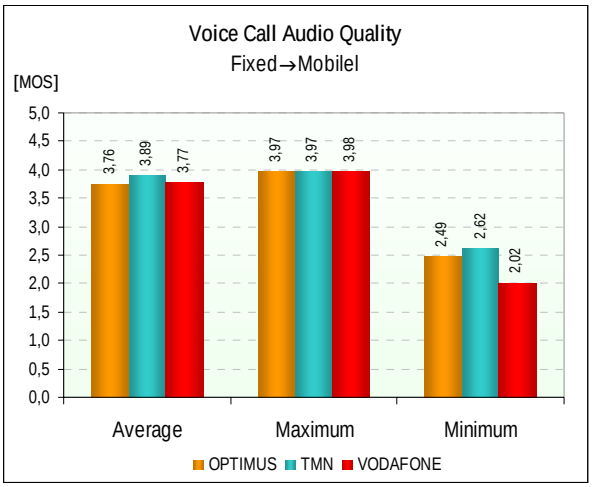
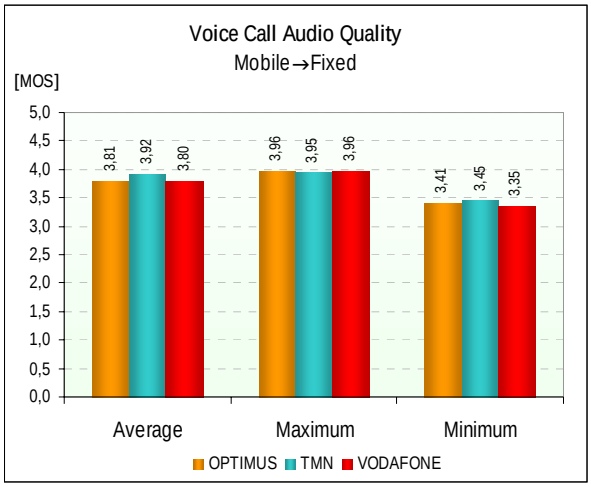


Figure 15 – *Call Audio Quality* indicator, on the Major Roads of the A. R. of the Azores.



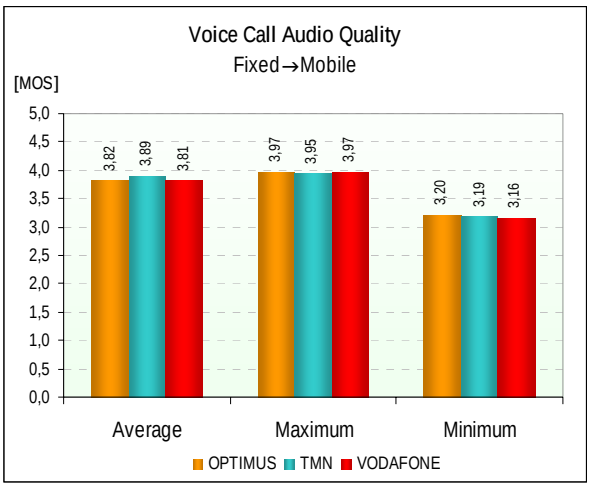


Figure 16 – *Call Audio Quality* indicator, on the Major Roads of the A. R. of Madeira.

Video-telephony Service (UMTS)

The video-telephony service's performance is below the one recorded for the voice service, namely regarding the *Service Accessibility* indicator on the major roads analysed.

As previously mentioned, operator OPTIMUS does not have a radio network supporting third generation services (WCDMA) in the Azores archipelago, thus preventing the access to the video-telephony service. The indicators concerning this operator present null values.

As with the voice service, the video-telephony service presents better performances on urban agglomerations than in major roads.

On urban agglomerations, the performance of operators TMN and VODAFONE can still be considered acceptable. In the Azores (Figure 17), operator VODAFONE presents the best performance with a 92.5% *Service Accessibility* and a 95% *Call Termination Rate*. In Madeira (Figure 18), the best performances were recorded by operators TMN and VODAFONE, with a *Service Accessibility* around 87% and a *Call Termination Rate* around 99%. The *Call Set Up Time* indicator shows good results, with operator VODAFONE recording the best performances (Figure 17 and Figure 18).

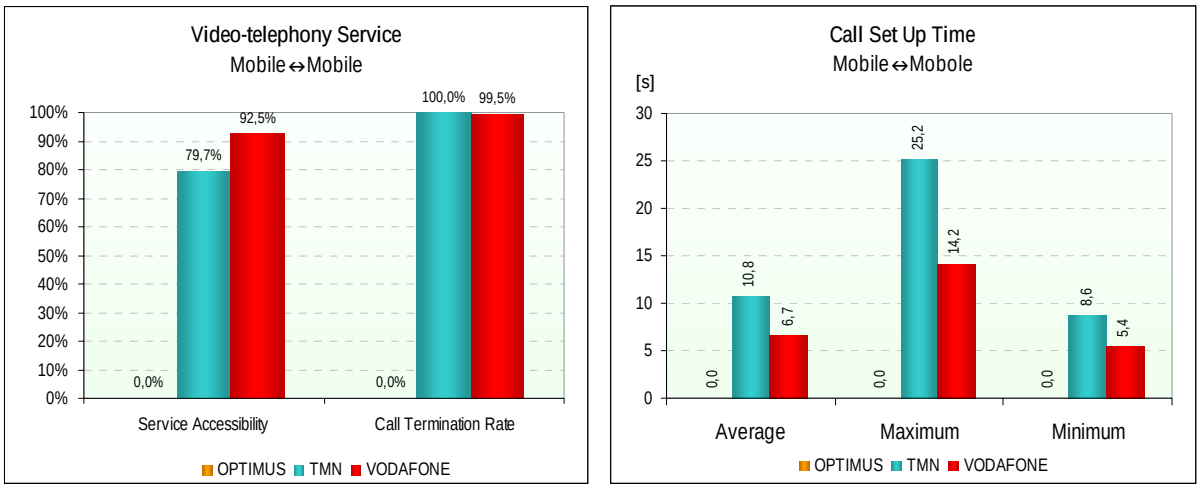


Figure 17 – *Service Accessibility*, *Call Termination Rate* and *Call Set Up Time* indicators, on the Urban Agglomerations of the A. R. of the Azores.

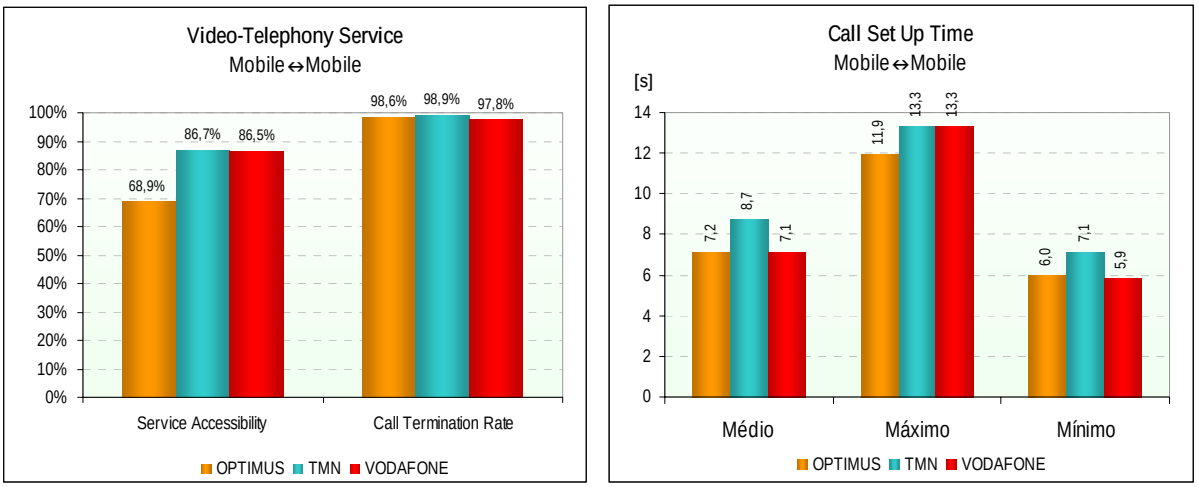


Figure 18 – *Service Accessibility*, *Call Termination Rate* and *Call Set Up Time* indicators, on the Urban Agglomerations of the A. R. of Madeira.

On major roads, *Service Accessibility* presents very low values; in the Azores they are even below 50% for all the studied operators (Figure 19). In the Madeira archipelago, TMN recorded the best performance, with 83.2%, while OPTIMUS and VODAFONE stood at 65.1% and 54.7%, respectively (Figure 20).

The *Call Termination Rate* indicator presents considerably higher levels than the *Service Accessibility* indicator (Figure 19 and Figure 20). The lowest level, 89.3%, was recorded by operator VODAFONE in the Autonomous Region of Madeira.

As with the urban agglomerations, the *Call Set Up Time* indicator presents good results (Figure 19 and Figure 20).

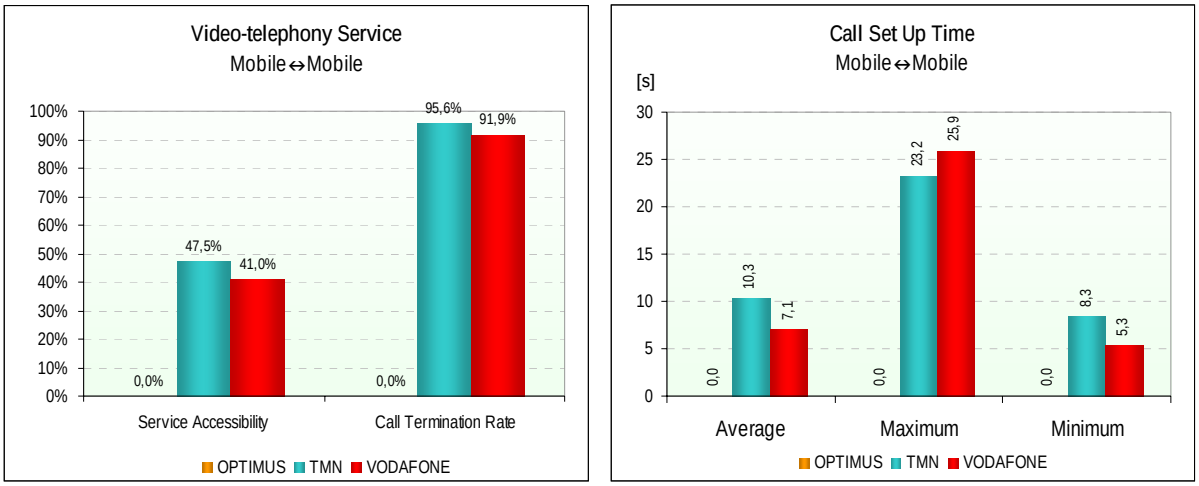


Figure 19 – *Service Accessibility*, *Call Termination Rate* and *Call Set Up Time* indicators, on the Major Roads of the A. R. of the Azores

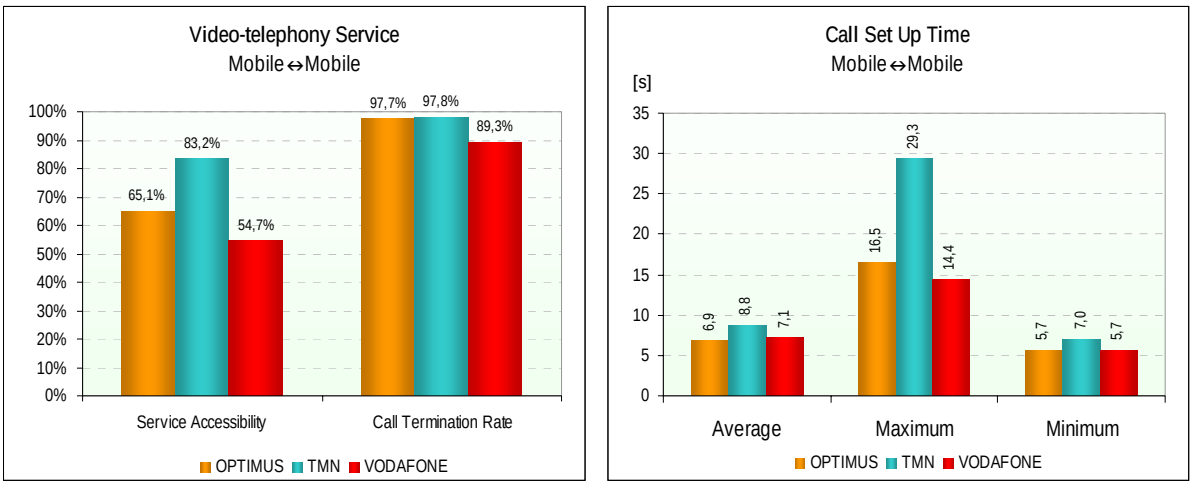


Figure 20 – *Service Accessibility*, *Call Termination Rate* and *Call Set Up Time* indicators, on the Major Roads of the A. R. of Madeira.

Normally ended video-telephony calls (120 seconds duration) present a good *Audio Quality* and acceptable *Video Quality*, on average. No major differences are recorded among operators or between urban agglomerations and major roads (Figure 21, Figure 22, Figure 23 and Figure 24).

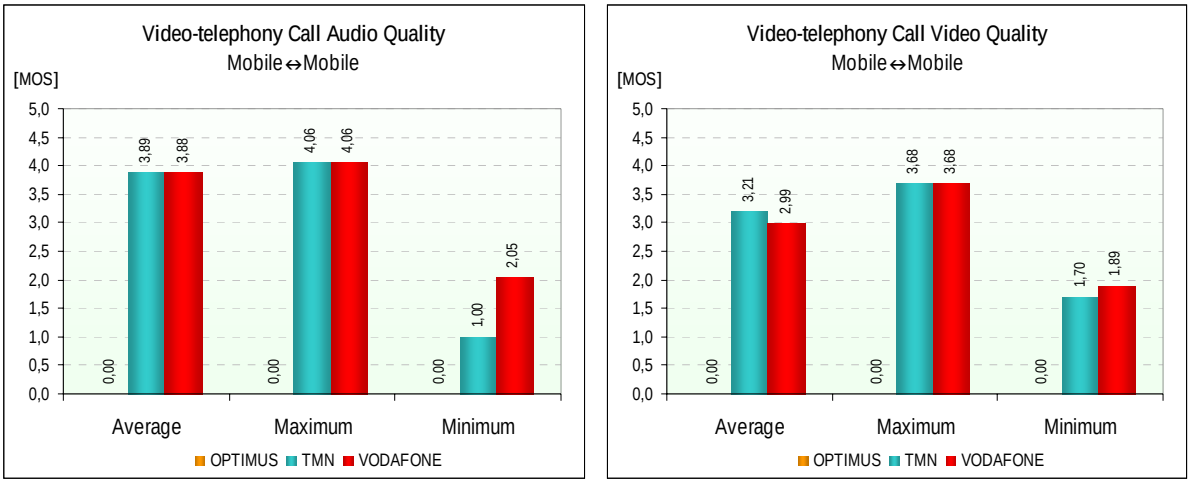


Figure 21 – *Call Audio Quality* and *Call Video Quality* indicators, on the Urban Agglomerations of the A.R. of the Azores.

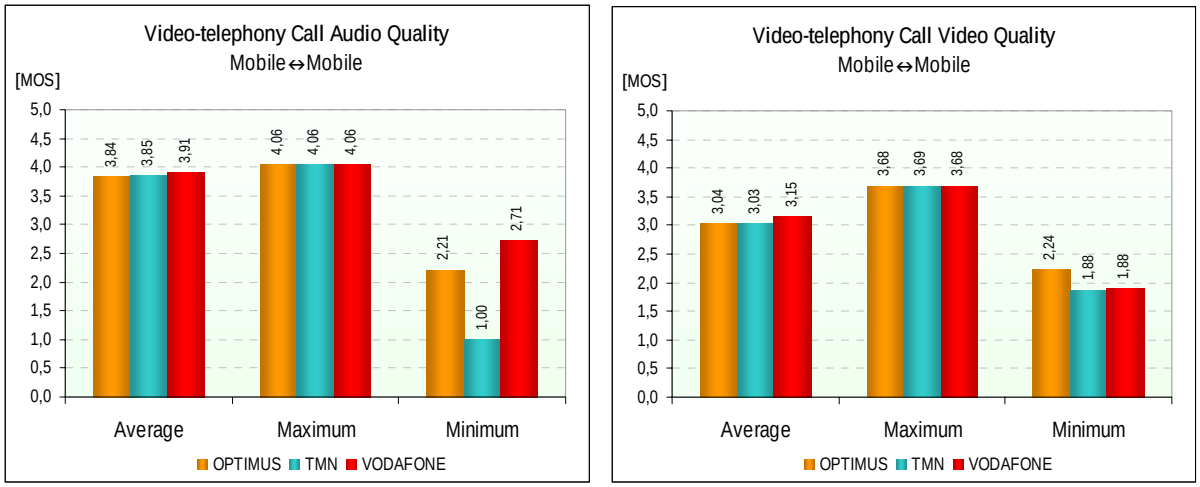


Figure 22 – *Call Audio Quality* and *Call Video Quality* indicators, on the Urban Agglomerations of the A.R. of Madeira.

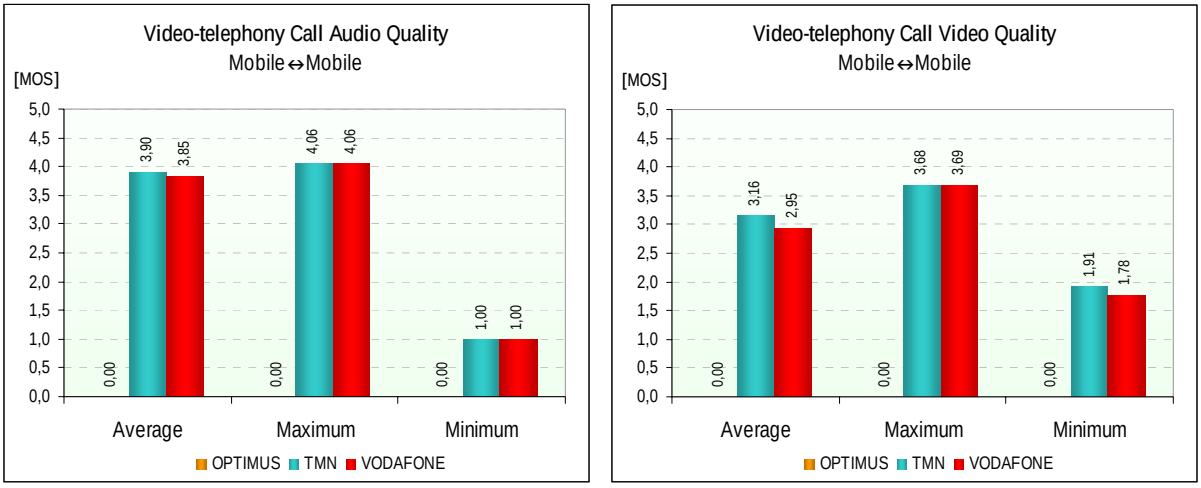


Figure 23 – *Call Audio Quality* and *Call Video Quality* indicators, on the Major Roads of the A.R. of the Azores.

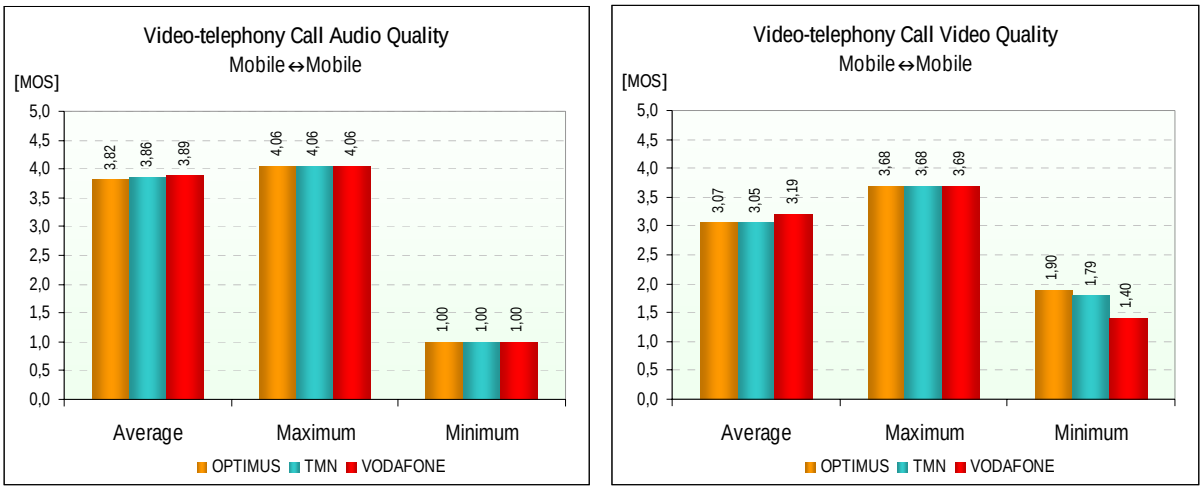


Figure 24 – *Call Audio Quality* and *Call Video Quality* indicators, on the Major Roads of the A.R. of Madeira.

1 QUALITY OF SERVICE ASSESSMENT

1.1 GOAL

To analyse the quality of the telecommunications services supported on the Portuguese GSM/UMTS mobile networks, from the user's standpoint, by conducting automatic end-to-end tests.

1.2 ANALYSED SERVICES

On an assessment of the QoS, from the user's standpoint, one must consider the services that, for each technology, show a greater relevance for end users, under a national and international market logic, and which are normally provided by all operators in the market.

With this guiding principle, and considering the current reality, the following services were included in this study:

1.2.1 TELEPHONY SERVICES:

a. Voice Service (GSM);

b. Video-telephony Service (UMTS);

1.2.2 REGARDLESS OF SERVICES:

c. Network Radio Coverage (GSM / WCDMA).

2 METHODOLOGY

The methodology is based on the performance of end-to-end automatic tests, thus making it possible to identify the quality of service on the field, giving as much a realistic perspective of the networks' performance as possible, from the user's standpoint.

Measurement collection is made using *drive-tests*. Besides providing an assessment from the user's standpoint, this approach makes it possible to carry out the tests independently from the correct functioning of the networks themselves, i.e., for example, also analysing the areas with poor or no coverage at all.

On the other hand, the use of a sole testing system to assess the services provided by the three mobile networks makes the results highly comparable, regarding time and space.

2.1 FUNDAMENTALS

This study's methodology is based on three basic characteristics:

a) End-to-end measurements - measurements reflect all aspects that impact the quality of a service;

b) Impartiality: Measurements are carried out under equal terms for the three operators (OPTIMUS, VODAFONE and TMN);

c) Objectivity: Tests are carried out in a totally automatic way, eliminating the subjectivity inherent to human intervention or decision.

2.2 MAIN QOS INDICATORS

From the user's standpoint, the use of mobile services presents the following stages (different features of the Quality of Service):

a. Network Availability – Shows that the mobile network is present;

b. Network Access – Shows that it is possible to use the services (usually it corresponds to the indication of the network's name on the screen of the terminal equipment and the indication of the availability of GPRS and/or 3G);

c. Service Access – When the user intends to use a service, the mobile operator provides the access to that service (*e.g.* to set up a voice call);

d. Service Integrity – Corresponds to the Quality of Service (QoS) during its use (*e.g.* Audio Quality during a voice call; Video Quality during a video-telephony call);

e. Service Consistency – Corresponds to the way the use of the service is ended (according or not to the user's will).

The main Quality of Service Indicators were analysed for each of the QoS features.

2.2.1 REGARDLESS OF THE SERVICE

2.2.1.1 RADIO NETWORK AVAILABILITY (COVERAGE)

Network availability is the probability of the mobile services being available to a user (radio network coverage).

$$\text{Radio Network Availability}\left[\%\right] = \frac{\text{No. of Measurements with Availability Mobile Services}}{\text{Total No. of Measurements}} \times 100\%$$

Mobile services are considered to be available when the radio signal shows values above the minimum levels that make its use possible. These levels may be adjusted by mobile operators and normally present different values for GSM and WCDMA[1].

The used testing and measurement system, through an RF Scanner, makes it possible to continuously measure each network's signal levels. These measurements are geographically referenced, thus rendering possible their representation on maps and making it easy to visualize the coverage levels of mobile networks on the routes under study.

[1] Wideband Code Division Multiple Access – Technology used on the radio networks of UMTS communications systems.

Table 1 – Coverage Levels

Coverage	GSM	WCDMA
Good	RxLev ≥ –85 dBm	CPICH RSCP ≥ –95 dBm
Acceptable	–95 dBm ≤ RxLev < –85 dBm	–105 dBm ≤ CPICH RSCP < –95 dBm
Bad	–110 dBm ≤ RxLev < –95 dBm	–115 dBm ≤ CPICH RSCP < –105 dBm
Non-existent	RxLev < –110 dBm	CPICH RSCP < –115 dBm

2.2.2 TELEPHONY SERVICES

2.2.2.1 SERVICE ACCESSIBILITY (VOICE OR VIDEO-TELEPHONY)

Service accessibility is the probability that the user has of having access to the service (voice or video-telephony), i.e., success probability when establishing a (voice or video-telephony) call.

It is considered that a call was "Set Up with Success" if it reaches the called terminal (one hears the "calling signal" on the calling terminal).

$$\text{Service Accessibility}\left[\%\right] = \frac{\text{No. of Calls Set Up with Success}}{\text{Total No. of Attemps to Set Up Calls}} \times 100\%$$

2.2.2.2 CALL SET UP TIME (VOICE OR VIDEO-TELEPHONY)

Call set up time is the period of time elapsing from the sending of a complete destination address (target telephone number) to the setting up of a call.

$$\text{Call Set Up Time}\left[s\right] = t_{address\_sending} - t_{calling\_signal}$$

$t_{address\_sending}$ – moment when the user presses the send button

$t_{calling\_signal}$ – moment when the call is successfully set up

(One hears the "calling signal" on the caller terminal).

2.2.2.3 CALL TERMINATION RATE (VOICE OR VIDEO-TELEPHONY)

Call termination rate is the probability of a call being maintained, after its set-up, during a given period of time, ending normally, i.e., according to the user's will.

$$\text{Call Termination Rate}\left[\%\right] = \frac{\text{No. of Normally Ended Calls}}{\text{No of Succefully Set Up Calls}} \times 100\%$$

2.2.2.4 CALL AUDIO QUALITY (VOICE OR VIDEO-TELEPHONY)

This indicator quantifies how well the conversation is perceived during a (voice or video-telephony) call. Both-ways communication is assessed and only calls with normal termination are considered.

The assessment of this QoS indicator is made by comparing the sent original audio sample, *X(t)* with the corresponding received degraded sample, *Y(t)*, on the other end of the call, by applying the *PESQ*[2] algorithm.

The objective audio quality index obtained by applying this algorithm is close to what would be obtained if sample *Y(t)* were submitted to the subjective appreciation of a panel of service users.

$$\text{Call Audio Quality}_{\text{side A}}\left[\text{MOS\_LQO}\right] = f\left\{X_B(t); Y_A(t)\right\}$$
$$\text{Call Audio Quality}_{\text{side B}}\left[\text{MOS\_LQO}\right] = f\left\{X_A(t); Y_B(t)\right\}$$

side A; side B – name of both ends of a voice call.

MOS_LQO – perceived audio quality quantification scale (Mean Opinion Score - Listening Quality Objective).

f – function corresponding to the application of the reckoning algorithm and conversion function of the results in MOS_LQO values.

$X_A(t)$; $X_B(t)$ – original audio sample sent from side A (B).

$Y_A(t)$; $Y_B(t)$ – degraded audio sample sent from side A (B), resulting from the transmission of the original sample $X_B(t)$ ($X_A(t)$).

The results of the algorithm application are shown on a MOS (Mean Opinion Score) type scale from 1 to 5 named MOS_LQO (Mean Opinion Score – Listening-only Quality Objective), such as shown on Table 2. The MOS scale quantifies the effort that it takes to understand a conversation. Its limits are 0 (zero) when there is no communication and 5 (five) when the communication is perfect. Value "zero" never shows on the results since they only consider situations where the connection was set up and kept during a given period. "Five" also never shows on the results because the *CoDec*[3] used by mobile networks does not render possible such high voice or video quality values (the voice or video quality reached with the usually used *CoDec* presents MOS values lower than 4.5).

[2] PESQ – Perceptual Evaluation of Speech Quality. Recommended by the ITU-International Telecommunications Union (ITU-T Recommendation P.862 (02/2001); ITU-T Recommendation P.862.1 (11/2003)).

[3] CoDec – Codifier/De-codifier.

Table 2 - MOS_LQO / MOS_VQO Scale

MOS	Quality
5	Excellent
4	Good
3	Acceptable
2	Poor
1	Bad

In situations where each direction of the same call sends and receives several audio samples {$X_1(t)$, …, $X_n(t)$; $Y_1(t)$, …, $Y_n(t)$}, the *Call Audio Quality* indicator is reckoned through the arithmetic average of the values obtained by applying the formula presented above to each pair of audio samples, i.e.:

$$\text{Call Video Quality}_{\text{side A}}\left[\text{MOS\_LQO}\right] = \frac{f\left\{X_{1B}(t); Y_{1A}(t)\right\} + \ldots + f\left\{X_{nB}(t); Y_{nA}(t)\right\}}{n}$$

$$\text{Call Video Quality}_{\text{side B}}\left[\text{MOS\_LQO}\right] = \frac{f\left\{X_{1A}(t); Y_{1B}(t)\right\} + \ldots + f\left\{X_{nA}(t); Y_{nB}(t)\right\}}{n}$$

2.2.2.5 VIDEO-TELEPHONY CALL VIDEO QUALITY

This indicator quantifies the communication's visual quality during a video-telephony call. Both directions of the communications are evaluated and only calls that ended normally are considered.

The evaluation process of this indicator is similar to the one used for *Call Audio Quality*.

$$\text{Call Video Quality}_{\text{side A}}\left[\text{MOS\_VQO}\right] = f\left\{W_B(t); Z_A(t)\right\}$$

$$\text{Call Video Quality}_{\text{side B}}\left[\text{MOS\_VQO}\right] = f\left\{W_A(t); Z_B(t)\right\}$$

side A; side B – name of both ends of a voice call.

MOS_VQO – perceived audio quality quantification scale (Mean Opinion Score – Visual Quality Objective).

f – function corresponding to the application of the reckoning algorithm and conversion function of the results in MOS_VQO values.

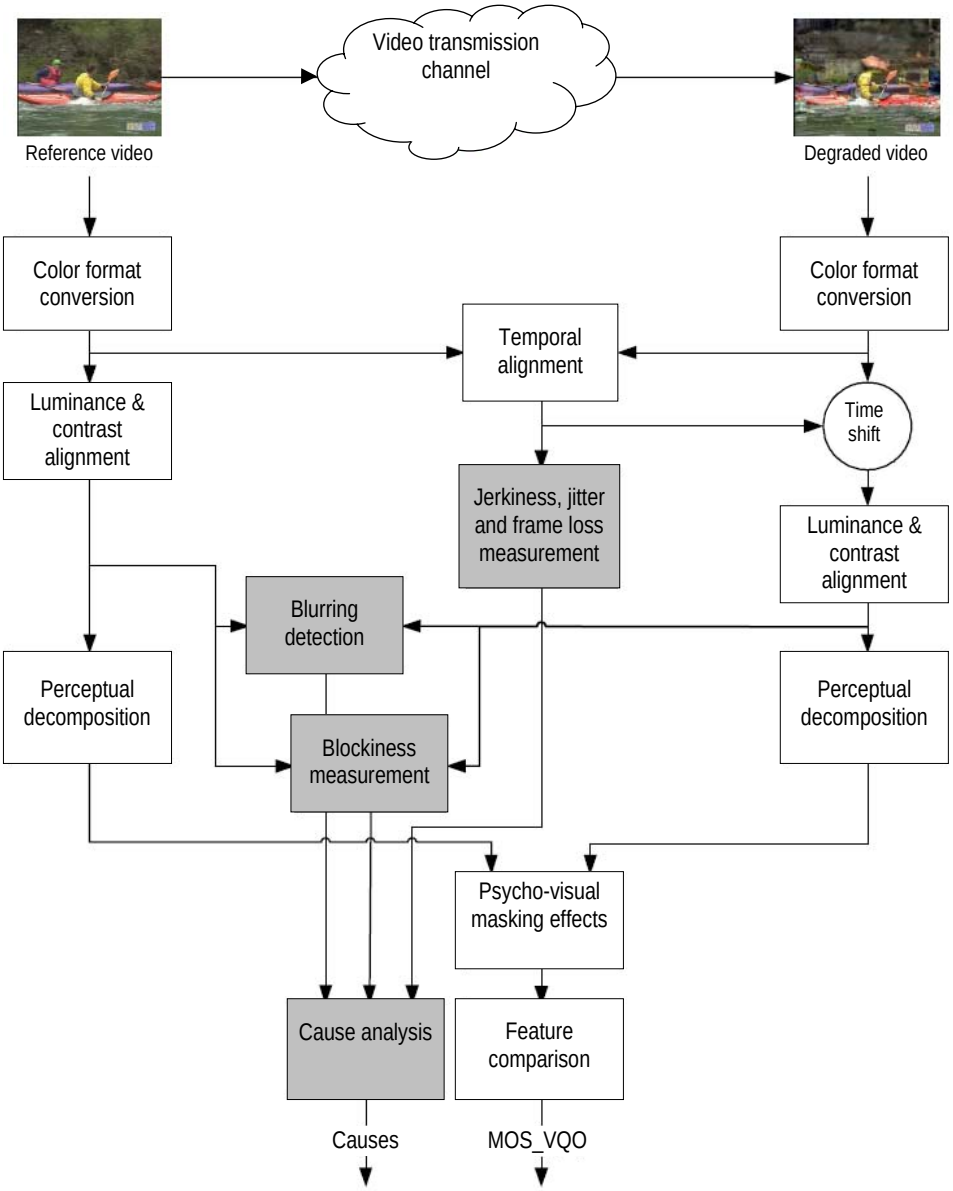
$W_A(t)$; $W_B(t)$ – original video sample sent from side A (B).

$Z_A(t)$; $Z_B(t)$ –degraded video sample sent from side A (B), resulting from the transmission of the original sample $W_B(t)$ ($W_A(t)$).

There is currently no algorithm being recommended by international standard organizations to evaluate video quality. However, some measurement system manufacturers have developed their own algorithms taking into account the guidelines established by ETSI (ETSI TR 102 493 V1.1.1 (2005-08)) and by *VQEG* – Video Quality Experts Group ("Multimedia Group Test Plan", Draft Version 1.16, February 7, 2007). That is the case with SwissQual, AG, supplier of the testing and measurement system used in

this study, which uses in its products its own algorithm, named VQuad - Objective Model for Video Quality Assessment.

Figure 25 shows the functional diagram of the VQuad algorithm. This algorithm is based on a full-reference type model, i.e., on a perceptual comparison of the degraded video sample with its reference. A reference video sequence (sample) is carried through the mobile network being tested. At the destination, the video sequence is captured and objectively validated through the perceptual comparison with the reference video sequence. It results in a global visual quality index (MOS_VQO) and other specific quality parameters (block distortion, blurring, jerkiness, level, PSNR, frame jitter, frame loss, lip-sync, etc.).



The global visual quality index, resulting from the application of the VQuad algorithm, is presented in a MOS (Mean Opinion Score) type scale from 1 to 5 named MOS_VQO (Mean Opinion Score – Visual Quality Objective), such as shown on Table 2.

In situations where each direction of the same call sends and receives several video samples $\{W_1(t), \ldots, W_n(t); Z_1(t), \ldots, Z_n(t)\}$, the *Call Video Quality* indicator is reckoned through the arithmetic average of the values obtained by applying the formula presented above to each pair of video samples, i.e.:

$$\text{Call Video Quality}_{\text{side A}}\left[\text{MOS\_VQO}\right]=\frac{f\left\{W_{1B}(t);Z_{1A}(t)\right\}+\ldots+f\left\{W_{nB}(t);Z_{nA}(t)\right\}}{n}$$

$$\text{Call Video Quality}_{\text{side B}}\left[\text{MOS\_VQO}\right]=\frac{f\left\{W_{1A}(t);Z_{1B}(t)\right\}+\ldots+f\left\{W_{nA}(t);Z_{nB}(t)\right\}}{n}$$

2.3 MEASUREMENT PROFILES[4]

Measurement profiles define a set of conditions that must the verified in order to correctly assess the services' quality and to guarantee the reliability of the tests. They also include process standardization and the definition of testing and measurement parameters, thus making it possible to perform analyses and compare results.

2.3.1 GENERAL FEATURES

Tests are performed automatically and using the Seven Five system (there is no human intervention or decision during the caring out of a test).

Voice tests are made by manually selecting the 2G (GSM) infrastructure, while video-telephony tests are performed with automatic selection of the 2G or 3G (GSM/UMTS) infrastructures.

Measurements are carried out in moving vehicles and with outdoor antennas (without gain). All collected parameters are geographically referenced and can be later shown by digital cartography.

2.3.2 COVERAGE

Network coverage assessment is made by measuring the downlink signal levels, RxLev (Received

[4] The measurement profiles presented here are supported on the technical specifications ETSI TS 102 250, namely part 5 (ETSI TS 102 250-5 V1.3.1 (2005-11)), and ETSI EG 202 057, namely parts 3 and 4 (ETSI EG 202 057-3 V1.1.1 (2005-04) and ETSI EG 202 057-4 V1.1.1 (2005-10)).

signal Level) for GSM and CPICH RSCP (Common Pilot Channel Received Signal Code Power) for WCDMA, along each analysed route.

Measurements are made through a RF Scanner device adapted and exclusively dedicated to this task, so that the measured signal levels correspond to the effective levels. The measurement equipment has the ability, at each point, to collect signal samples from all GSM and WCDMA radio channels used by the operators under analysis, at 1 and 2.5 second intervals, respectively. These samples are later analysed and only the best signal level results obtained for each point, technology and operator are considered.

Each measurement point is geographically referenced so that signal levels can be later represented on digital cartography, thus making it easier to visualise coverage levels of the mobile networks along the routes under study and to identify the locations with a poor or non-existent coverage.

2.3.3 TELEPHONY SERVICES

These services are evaluated end-to-end, using a “call” as the basic test unit.

Test calls are made between two mobile terminal devices, where at least one of them is of a mobile type (MS – Mobile Station or UE – User Equipment). This MS or UE moves along the studied route/location, and the calls originated from this terminal equipment are named MOC (Mobile Originated Call).

In order to minimize the uncertainty that is always accompanies measurement procedures, the second end of the test calls must present good performance levels and great stability. This end’s impact on the services’ performance indicators is intended to be the minimum. The solutions includes using fixed network terminals (ISDN) to assess the performance of voice services, and to use mobile terminals (UE) to assess the performance of the video-telephony service. UE are kept motionless in locations with proper (good) radio coverage, minimum interference and with a (virtually) 100% probability of accessing the video-telephony service. Calls originated on this end, at the ISDN or UE terminal, and ended at the mobile terminal that is under test, are named MTC (Mobile Terminated Call).

After a test call is established, the communication’s integrity is analysed (audio quality, for the voice service, and audio/video quality for the video-telephony service), alternately in both directions, regardless of the end that started the call.

With the purpose of comparing the performance of the several operators (benchmark), a fixed time frame is used for making each call during the test sessions. When a call malfunction occurs, either when establishing a call or in the conversation phase, the next call is only started when the next time frame arrives.

2.3.3.1 VOICE SERVICE

The analysis of the voice service, at a given location, includes the abilities to establish and to end calls.

Since the aim is to study the normal use of the voice service, the duration of test calls is close to the average duration of calls routed on the networks. Besides the call's own duration, the time frame considers time periods that make possible the setting up and ending of a call, and also a 20 second pause between consecutive calls, to prevent possible network constraints regarding signalling or mobility management.

The test parameters used for the analysis of the voice service present the following values:

- Relationship between MOC/MTC: 1/1;
- Duration of the test calls: 120 seconds;
- Time frame for making a test call: 180 seconds;
- Maximum call set up time: 20 seconds.

2.3.3.2 VIDEO-TELEPHONY SERVICE

The test parameters for the analysis of the video-telephony service are similar to those used for the voice service. The difference relies on the time frame, which is larger, since the time needed for establishing calls and negotiating audio/video communications between terminals is longer.

The test parameters used for the analysis of the video-telephony service present the following values:

- Relationship between MOC/MTC: 1/1;
- Duration of the test calls: 120 seconds;
- Time frame for making a test call: 210 seconds;
- Maximum call set up time: 20 seconds;
- Maximum audio and video communication set up time: 30 seconds

2.4 TEST/MEASUREMENT AND POST-PROCESSING SYSTEM

The Seven.Five/NetQual system, conceived and developed by SwissQual, A.G. (Switzerland), was used for measurements on the field and for their post-processing. This is a tool specifically designed for the analysis and benchmarking of mobile communications systems.

The system is made up of the following modules:

a. *7.5 Multi* – Mobile Unit, with an RF scanner and commercial mobile terminal devices (NOKIA 6680 terminals were used in the study carried out);

b. *Land Unit* – Fixed Unit, with ISDN interface cards, used for voice tests;

c. *Video Call Server* – Fixed Unit, with commercial mobile terminal devices (also NOKIA 6680), used for video-telephony tests;

d. *Media Server* – Fixed Unit, server used for data and video streaming tests;

e. *NQDI* – Post-processing System, for analysis and reporting of the completed measurements.

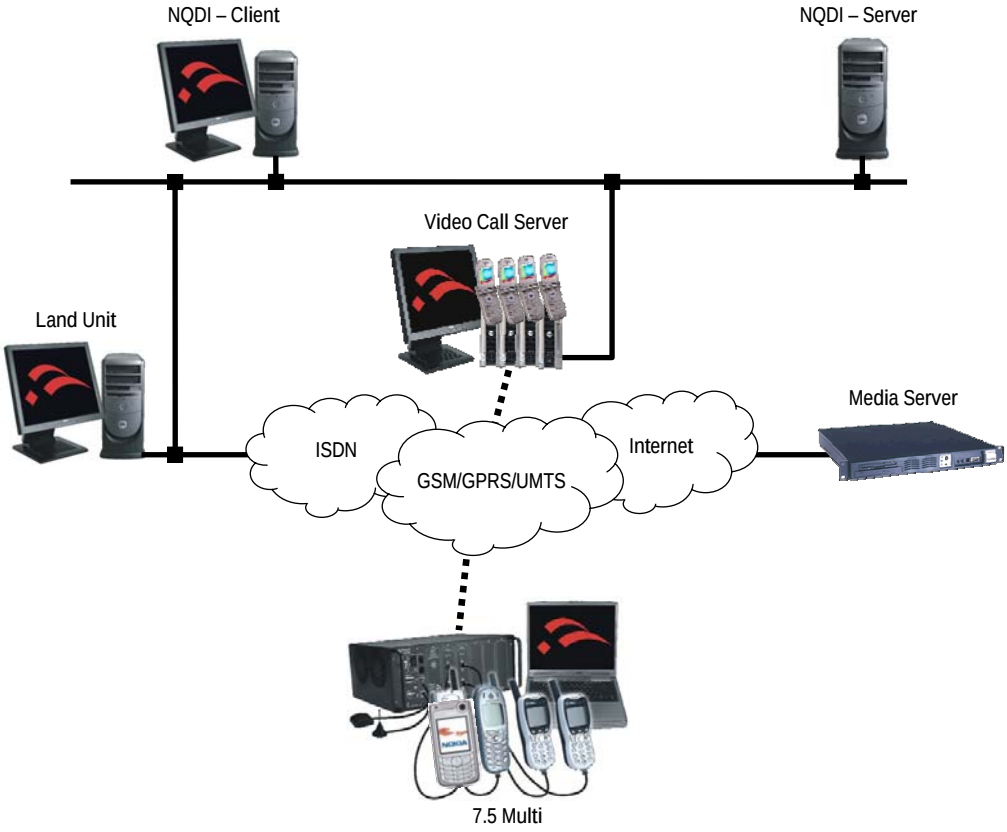


Figure 26 – Seven.Five/NetQual system architecture

3 STUDY SAMPLE

A sample representing the use of these services in the autonomous regions of the Azores and Madeira was chosen for a proper assessment of the quality of Voice (GSM), Video-telephony (UMTS) and Network Coverage (GSM and WCDMA).

3.1 TESTED AREAS

Tests were carried out in the main urban agglomerations of these archipelagos – Ponta Delgada, Angra do Heroísmo and Funchal – as well as in all islands' major roads.

3.2 SAMPLE SIZE

Table 3 – Sample, for the three analysed operators

		Hours of Measurements	Voice Calls	Video-telephony Calls	Coverage Measurements		Measurements in Kilometres
					GSM	WCDMA	
Azores	Angra do Heroísmo	6 h 11	361	317	66.975	26.754	132
	Ponta Delgada	6 h 24	374	323	69.089	27.441	178
	Corvo Island	1 h 01	60	54	11.040	4.426	19
	Faial Island	6 h 02	355	308	66.728	26.759	230
	Flores Island	3 h 13	189	162	34.957	13.998	142
	Graciosa Island	3 h 08	189	166	34.823	13.960	188
	Pico Island	6 h 11	367	310	67.220	26.956	247
	S. Jorge Island	6 h 19	365	323	68.614	27.446	209
	S. Miguel Island	12 h 10	717	611	131.578	52.683	606
	Sta. Maria Island	3 h 40	214	183	39.625	15.827	129
	Terceira Island	6 h 16	371	319	67.849	25.877	305
	Total A. R. Azores	60 h 35	3.562	3.076	658.498	262.127	2.385
Madeira	Funchal	6 h 15	366	312	66.819	26.738	161
	Madeira Island	12 h 50	739	646	138.194	55.487	566
	Porto Santo Island	3 h 25	201	174	36.614	14.528	157
	Total A. R. Madeira	22 h 30	1.306	1.132	241.627	96.753	884
	Overall Total	83 h 05	4.868	4.208	900.125	358.880	3.269

3.3 DATA COLLECTION CONDITIONS

Measurement sessions were carried out during normal working day periods.

4 AGGREGATED RESULTS

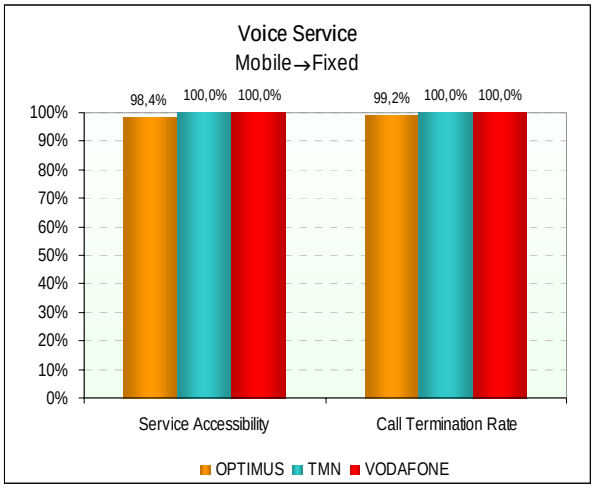
4.1 AUTONOMOUS REGION OF THE AZORES

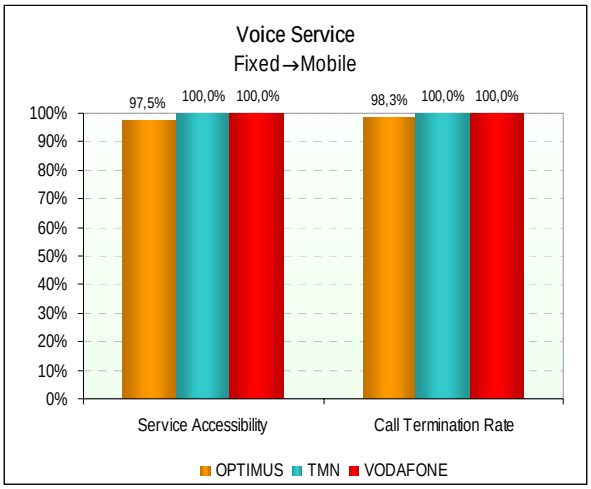
4.1.1 URBAN AGGLOMERATIONS

4.1.1.1 VOICE SERVICE (GSM)

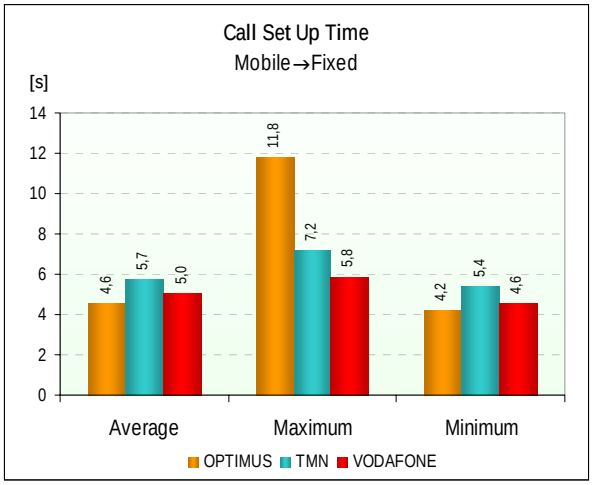
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	122	120	124	122	125	122
	Dropped on Set Up	2	3	0	0	0	0
	Dropped during Call	1	2	0	0	0	0
	With Normal Termination	119	115	124	122	125	122
	Service Accessibility	98,4%	97,5%	100,0%	100,0%	100,0%	100,0%
	Call Termination Rate	99,2%	98,3%	100,0%	100,0%	100,0%	100,0%
Call Set Up	Number of Samples (Calls)	120	117	124	122	125	122
	Average Time [s]	4,6	5,9	5,7	7,9	5,0	7,7
	Maximum Time [s]	11,8	7,2	7,2	10,9	5,8	13,0
	Minimum Time [s]	4,2	5,1	5,4	6,8	4,6	6,7
	Standard Deviation [s]	0,7	0,4	0,3	0,6	0,2	0,9
Audio Quality	Number of Samples (Calls)	234	234	246	246	247	247
	Average [MOS]	3,81	3,83	3,91	3,81	3,79	3,79
	Maximum [MOS]	3,96	3,97	3,96	3,96	3,96	3,96
	Minimum [MOS]	3,56	3,15	3,69	3,19	3,54	3,39
	Standard Deviation [MOS]	0,03	0,05	0,05	0,12	0,07	0,08

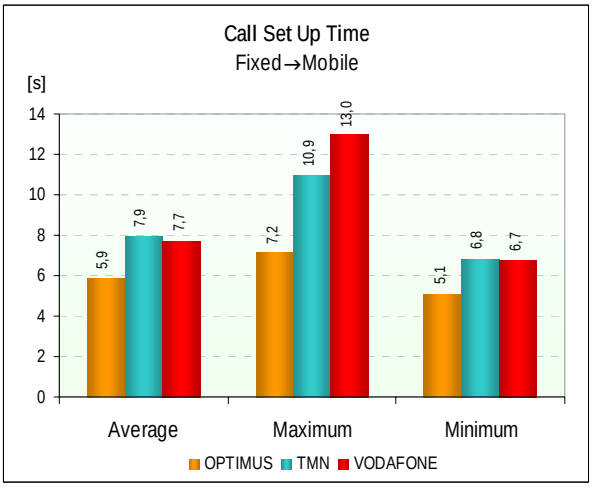
4.1.1.1.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION* RATE INDICATORS



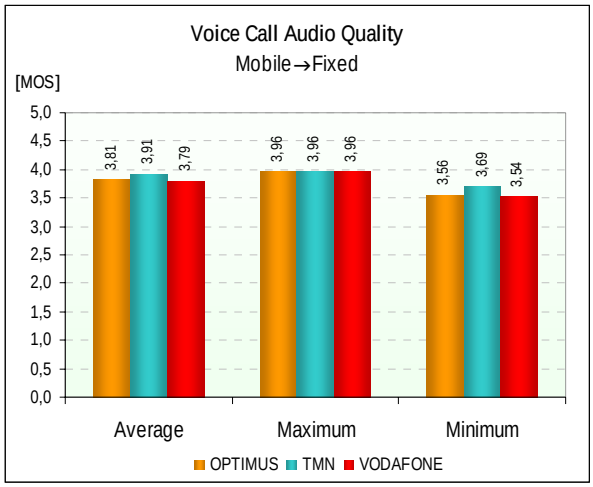


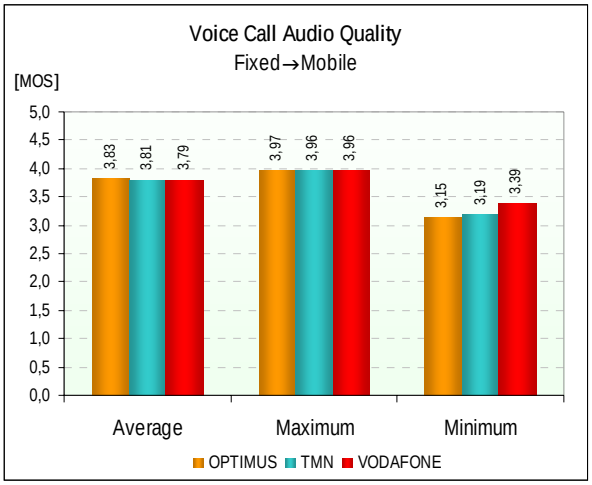
4.1.1.1.2 *CALL SET UP TIME* INDICATOR



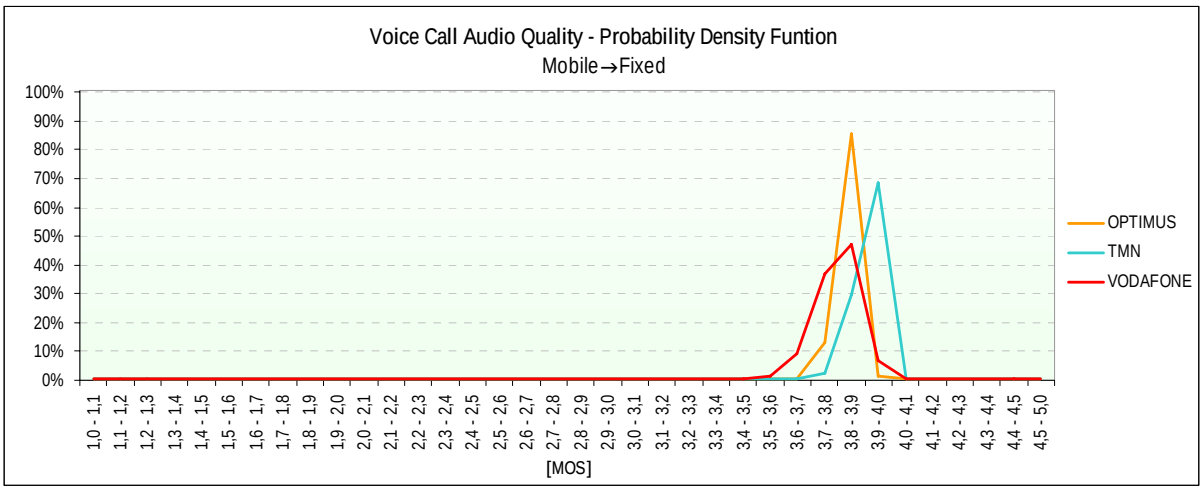


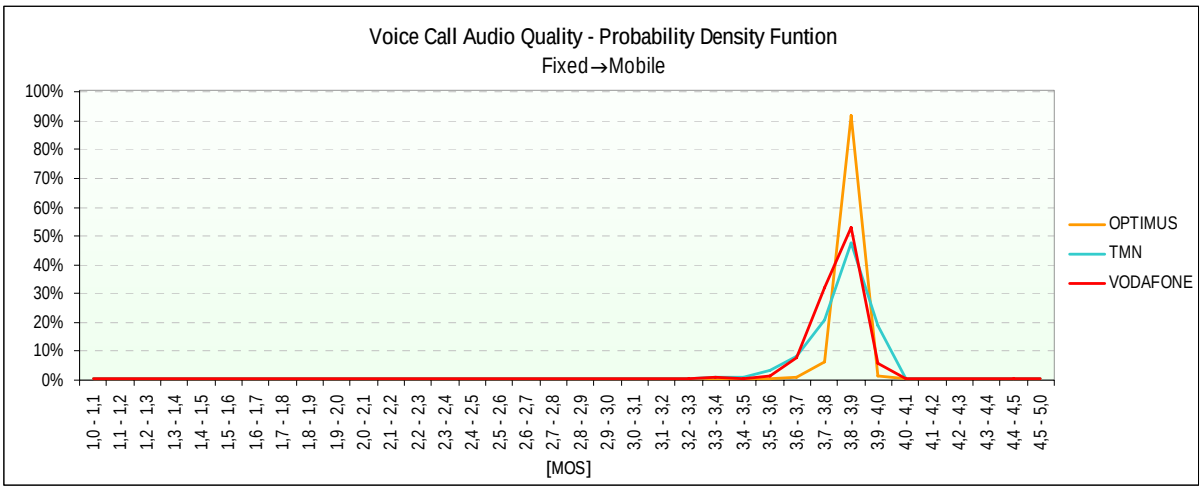
4.1.1.1.3 *VOICE CALL AUDIO QUALITY* INDICATOR





4.1.1.1.4 PROBABILITY DENSITY FUNCTION OF THE VOICE CALL *AUDIO QUALITY* INDICATOR

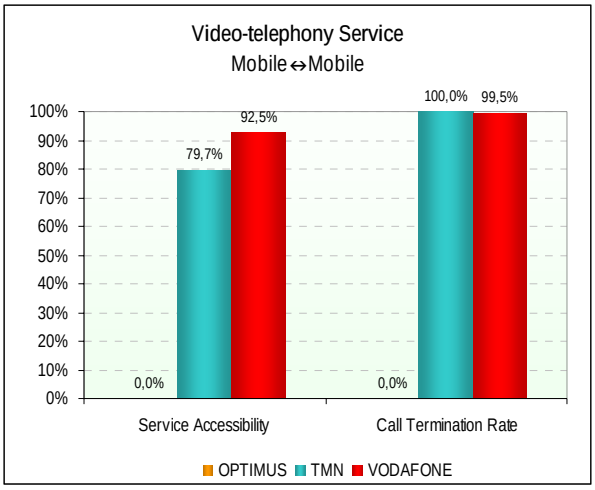




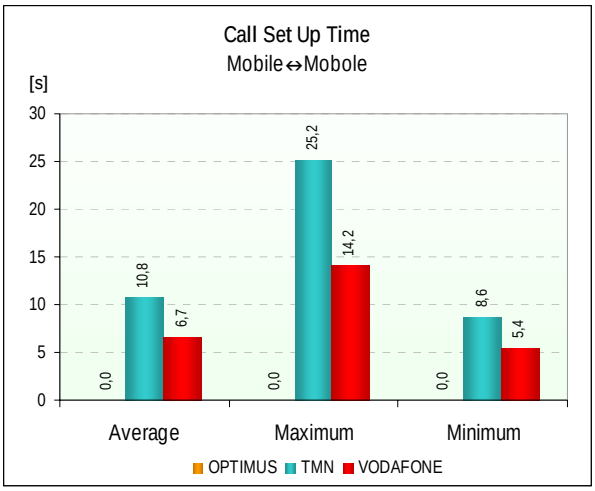
4.1.1.2 VIDEO-TELEPHONY SERVICE (UMTS)

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	215	212	213
	Dropped on Set Up	215	43	16
	Dropped during Call	0	0	1
	With Normal Termination	0	169	196
	Service Accessibility	0,0%	79,7%	92,5%
	Call Termination Rate	0,0%	100,0%	99,5%
Call Set Up	Number of Samples (Calls)	0	169	197
	Average Time [s]	0,0	10,8	6,7
	Maximum Time [s]	0,0	25,2	14,2
	Minimum Time [s]	0,0	8,6	5,4
	Standard Deviation [s]	0,0	2,1	1,3
Audio Quality	Number of Samples (Calls)	0	335	392
	Average [MOS]	0,00	3,89	3,88
	Maximum [MOS]	0,00	4,06	4,06
	Minimum [MOS]	0,00	1,00	2,05
	Standard Deviation [MOS]	0,00	0,45	0,22
Video Quality	Number of Samples (Calls)	0	332	392
	Average [MOS]	0,00	3,21	2,99
	Maximum [MOS]	0,00	3,68	3,68
	Minimum [MOS]	0,00	1,70	1,89
	Standard Deviation [MOS]	0,00	0,54	0,54

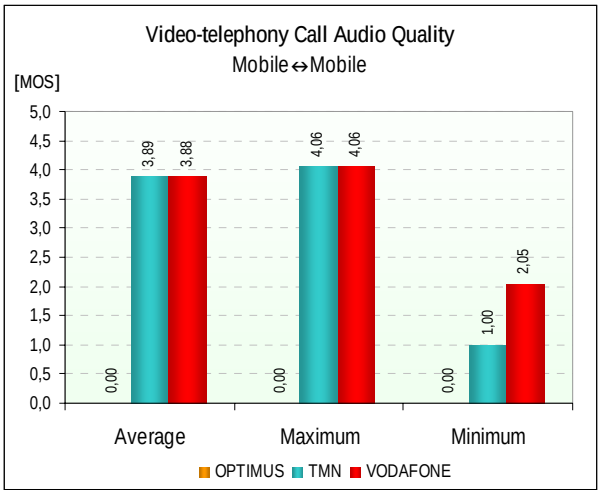
4.1.1.2.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



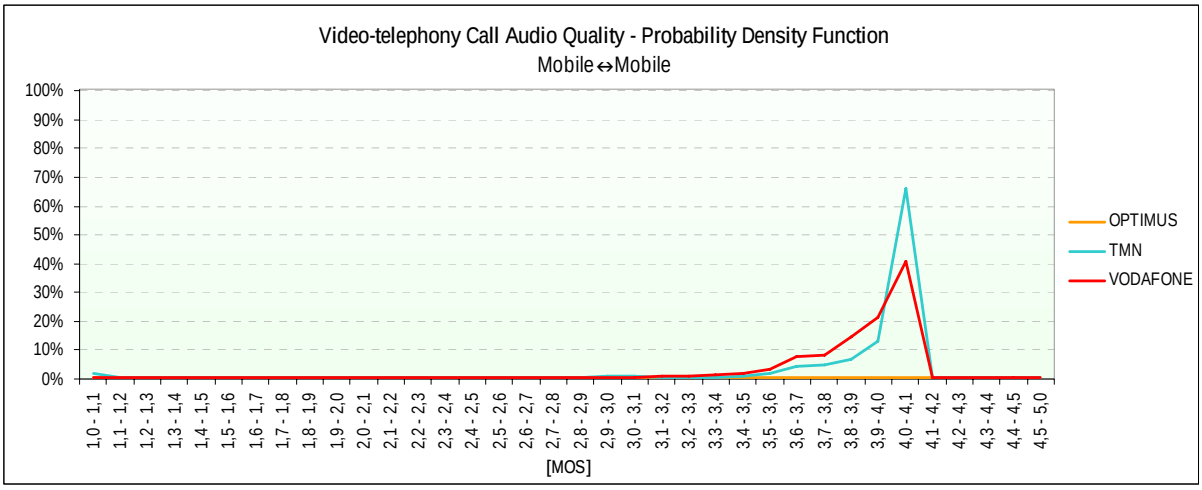
4.1.1.2.2 *CALL SET UP TIME* INDICATOR



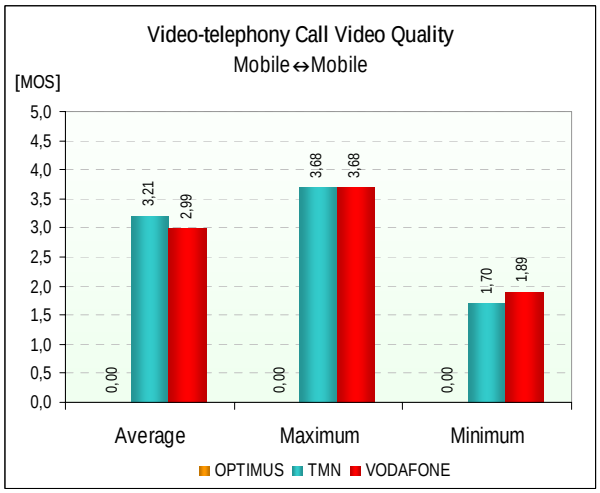
4.1.1.2.3 VIDEO-TELEPHONY *CALL AUDIO QUALITY*



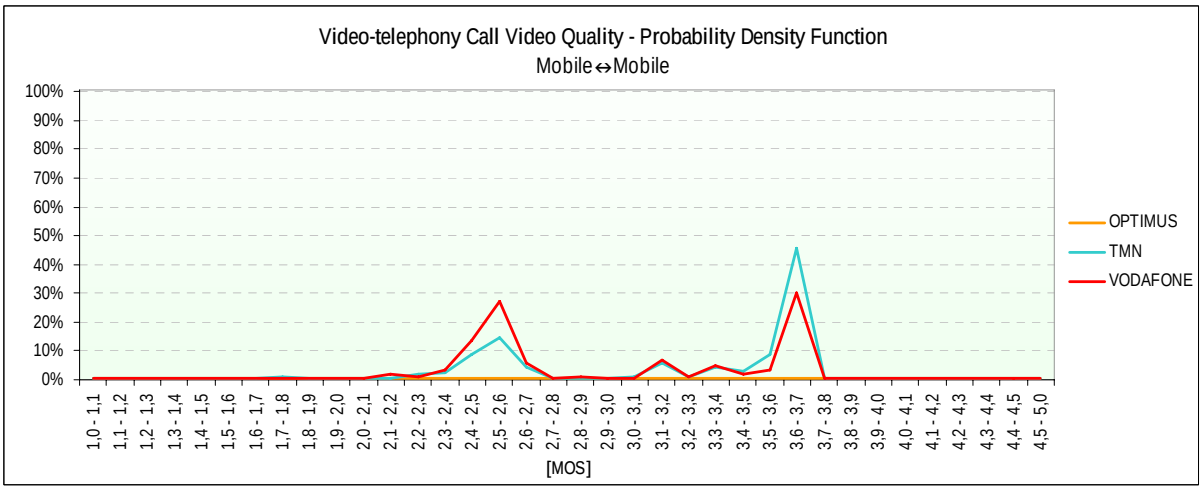
4.1.1.2.4 PROBABILITY DENSITY FUNCTION OF *THE VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



4.1.1.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



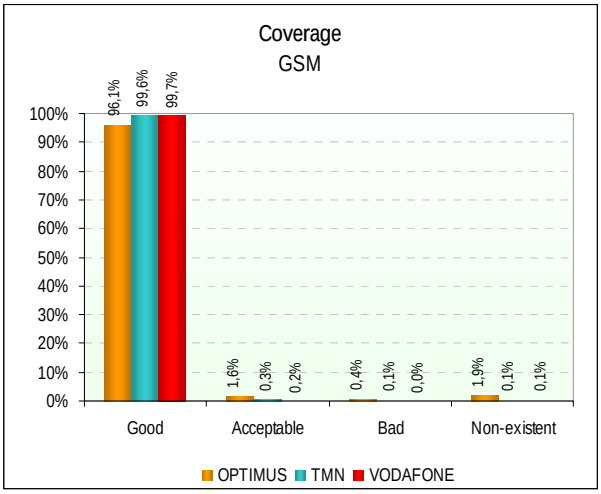
4.1.1.2.6 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



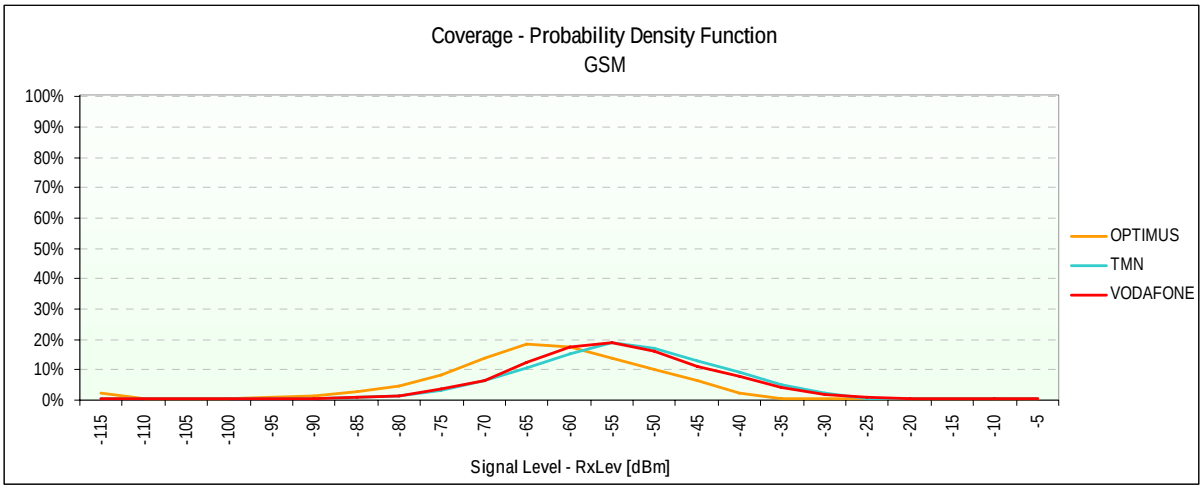
4.1.1.3 NETWORK COVERAGE

		GSM			WCDMA		
		OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Coverage	Number of Samples (Measurements)	45.444	45.176	45.444	18.094	18.011	18.090
	Signal Average Level [dBm]	-61	-51	-53	-122	-69	-69
	Signal Maximum Level [dBm]	-22	-14	-11	-115	-34	-32
	Signal Minimum Level [dBm]	-115	-115	-115	-127	-120	-117
	Standard Deviation [dBm]	13	11	11	1	13	13
	Good	96,1%	99,6%	99,7%	0,0%	97,7%	97,4%
	Acceptable	1,6%	0,3%	0,2%	0,0%	1,9%	2,3%
	Bad	0,4%	0,1%	0,0%	0,0%	0,4%	0,3%
	Non-existent	1,9%	0,1%	0,1%	100,0%	0,0%	0,0%

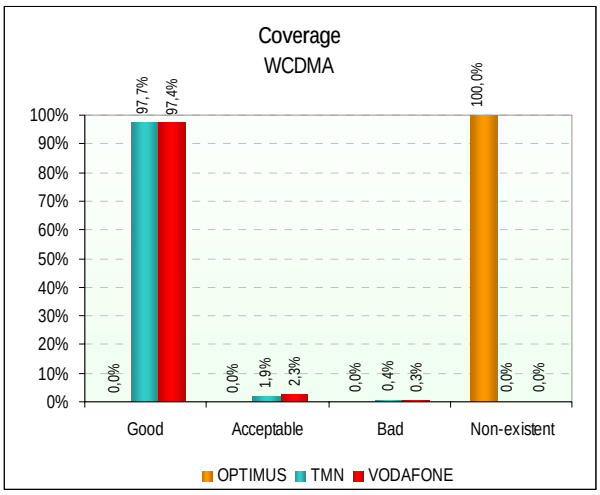
4.1.1.3.1 GSM



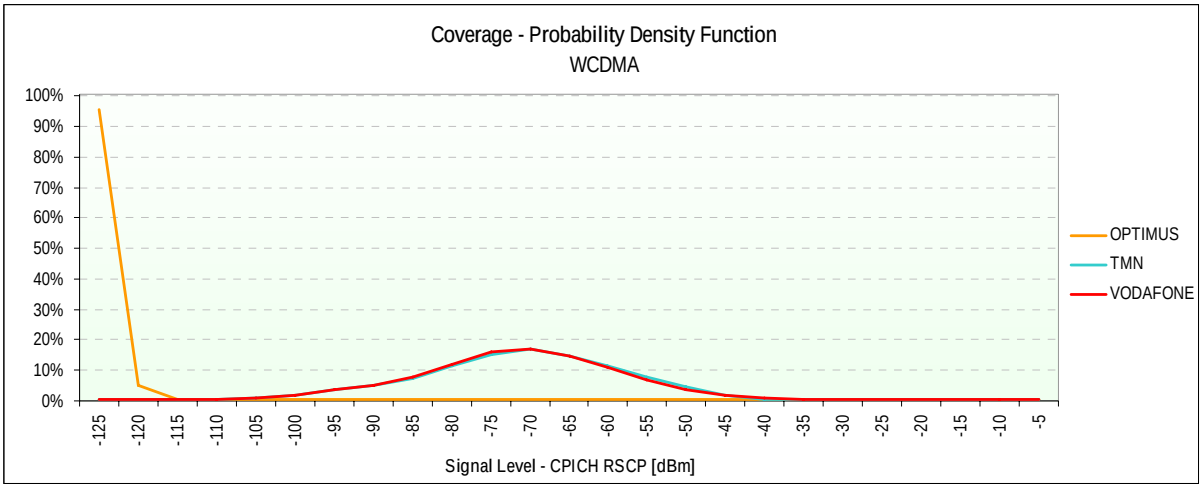
4.1.1.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.1.1.3.3 WCDMA



4.1.1.3.4 WCDMA – PROBABILITY DENSITY FUNCTION

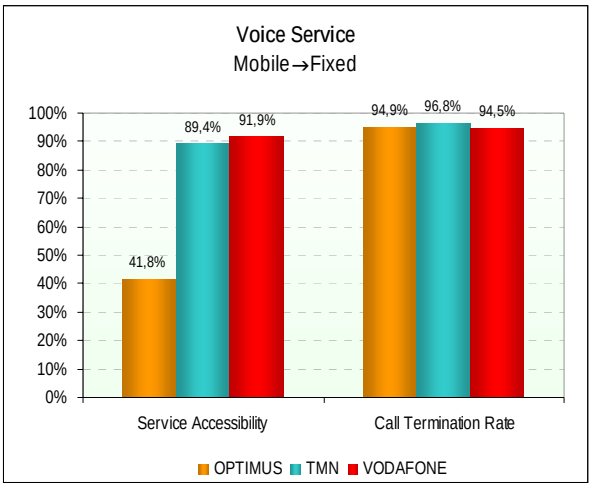


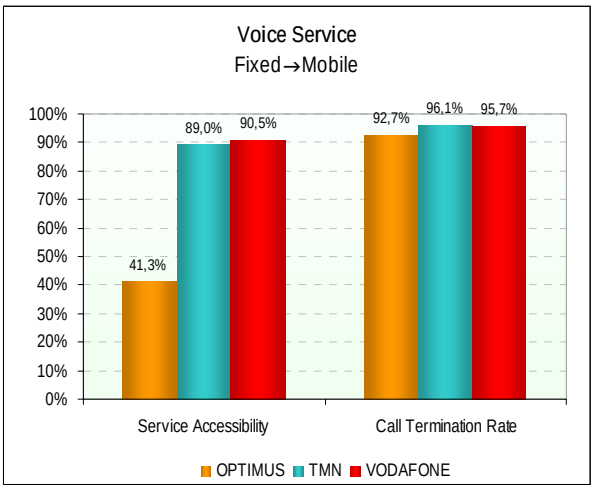
4.1.2 MAJOR ROADS

4.1.2.1 VOICE SERVICE (GSM)

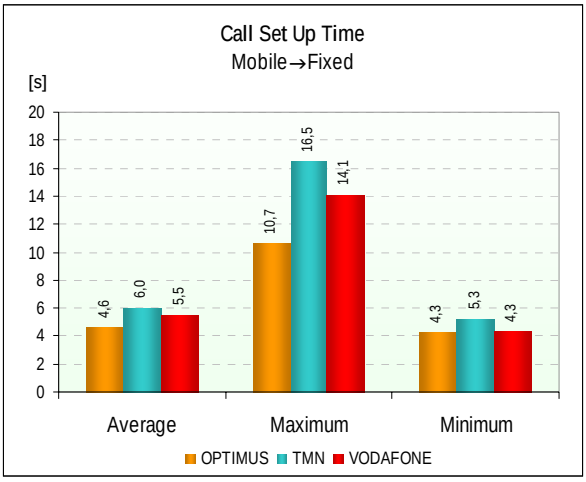
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	474	462	483	465	479	464
	Dropped on Set Up	276	271	51	51	39	44
	Dropped during Call	10	14	14	16	24	18
	With Normal Termination	188	177	418	398	416	402
	Service Accessibility	41,8%	41,3%	89,4%	89,0%	91,9%	90,5%
	Call Termination Rate	94,9%	92,7%	96,8%	96,1%	94,5%	95,7%
Call Set Up	Number of Samples (Calls)	198	191	432	414	440	420
	Average Time [s]	4,6	6,3	6,0	8,3	5,5	8,1
	Maximum Time [s]	10,7	15,1	16,5	14,5	14,1	17,4
	Minimum Time [s]	4,3	5,2	5,3	6,8	4,3	6,3
	Standard Deviation [s]	0,7	1,3	1,3	1,1	1,6	1,6
Audio Quality	Number of Samples (Calls)	365	365	816	816	818	818
	Average [MOS]	3,76	3,76	3,92	3,89	3,79	3,77
	Maximum [MOS]	3,95	3,97	3,97	3,97	3,96	3,98
	Minimum [MOS]	2,31	2,49	2,79	2,62	2,81	2,02
	Standard Deviation [MOS]	0,18	0,19	0,09	0,13	0,11	0,20

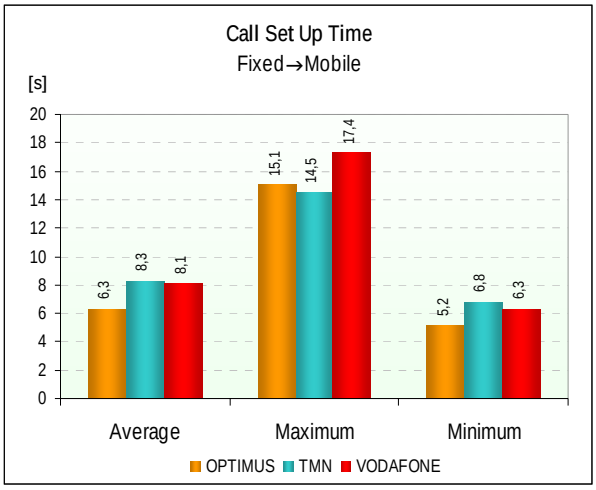
4.1.2.1.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



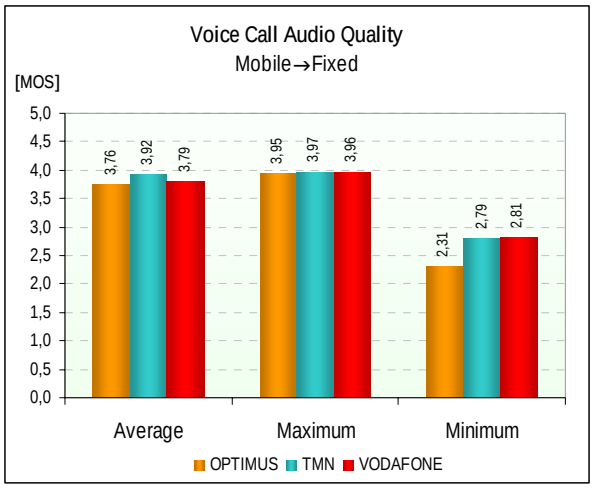


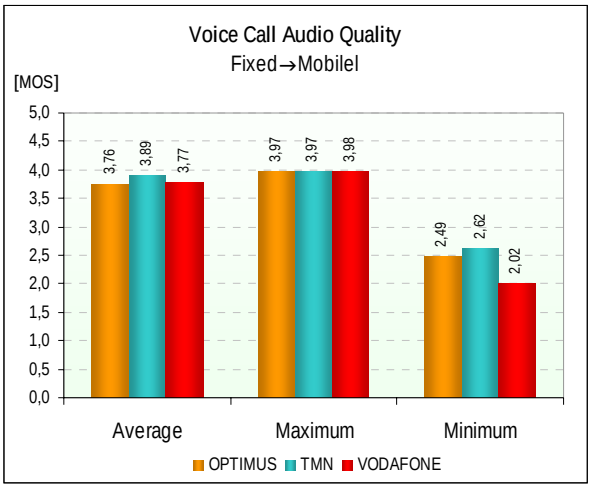
4.1.2.1.2 *CALL SET UP TIME* INDICATOR



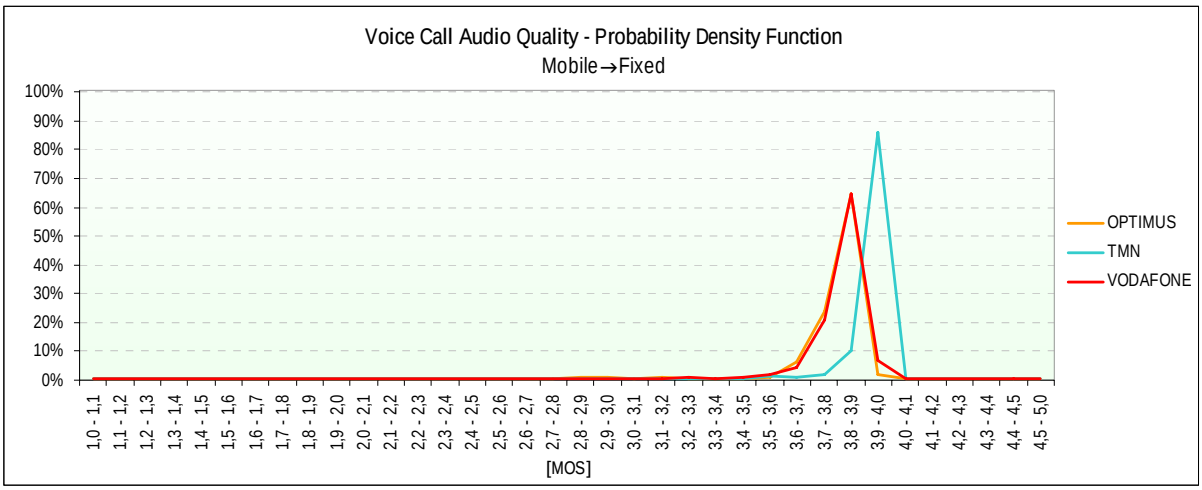


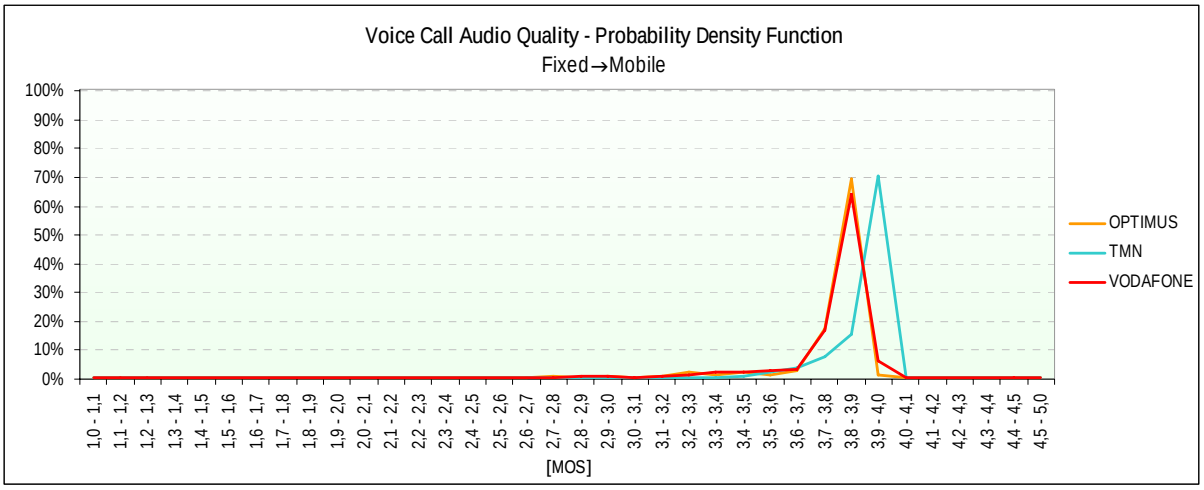
4.1.2.1.3 *VOICE CALL AUDIO QUALITY* INDICATOR





4.1.2.1.4 PROBABILITY DENSITY FUNCTION OF *THE VOICE CALL AUDIO QUALITY INDICATOR*

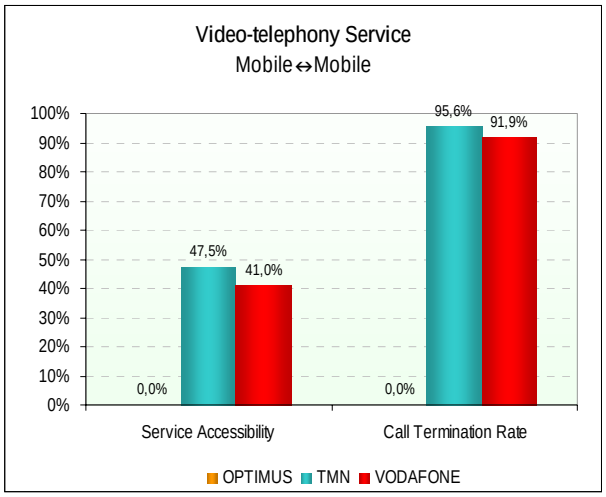




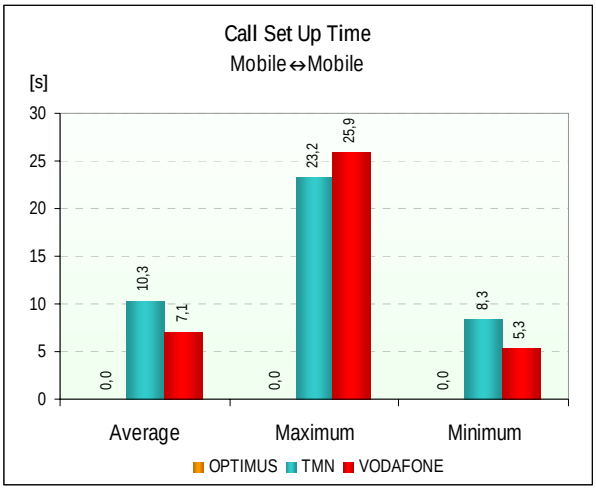
4.1.2.2 VIDEO-TELEPHONY SERVICE (UMTS)

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	808	813	815
	Dropped on Set Up	808	427	481
	Dropped during Call	0	17	27
	With Normal Termination	0	369	307
	Service Accessibility	0,0%	47,5%	41,0%
	Call Termination Rate	0,0%	95,6%	91,9%
Call Set Up	Number of Samples (Calls)	0	386	334
	Average Time [s]	0,0	10,3	7,1
	Maximum Time [s]	0,0	23,2	25,9
	Minimum Time [s]	0,0	8,3	5,3
	Standard Deviation [s]	0,0	1,9	2,4
Audio Quality	Number of Samples (Calls)	0	731	610
	Average [MOS]	0,00	3,90	3,85
	Maximum [MOS]	0,00	4,06	4,06
	Minimum [MOS]	0,00	1,00	1,00
	Standard Deviation [MOS]	0,00	0,37	0,39
Video Quality	Number of Samples (Calls)	0	729	607
	Average [MOS]	0,00	3,16	2,95
	Maximum [MOS]	0,00	3,68	3,69
	Minimum [MOS]	0,00	1,91	1,78
	Standard Deviation [MOS]	0,00	0,54	0,53

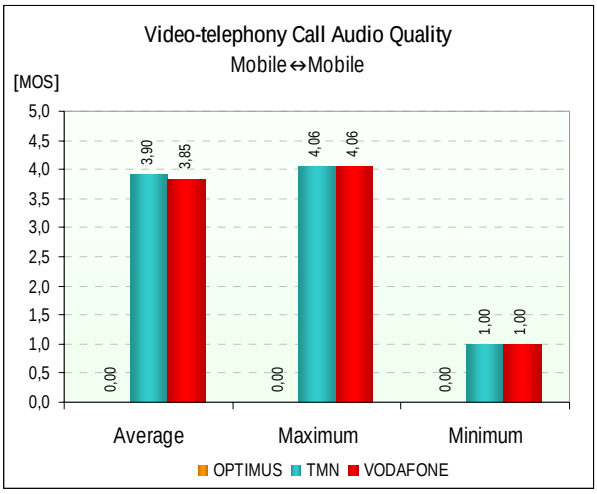
4.1.2.2.1 *SERVICE ACCESSIBILITY AND CALL TERMINATION RATE* INDICATORS



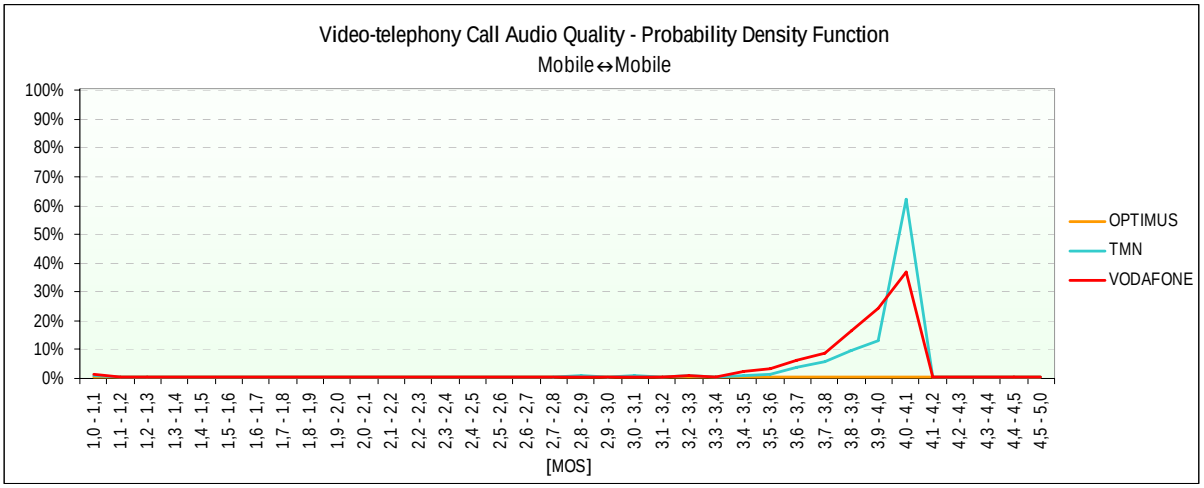
4.1.2.2.2 *CALL SET UP TIME* INDICATOR



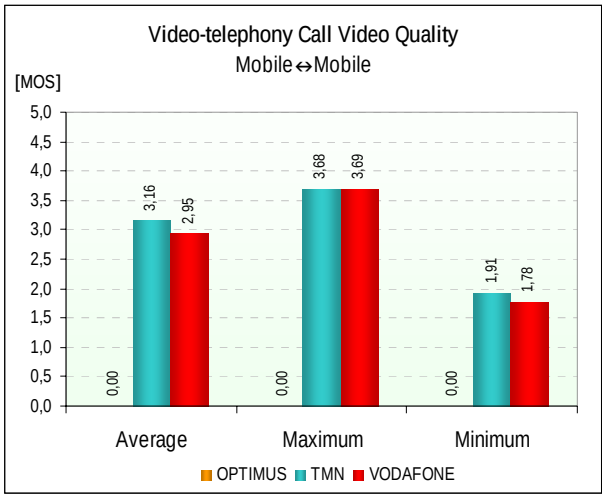
4.1.2.2.3 *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



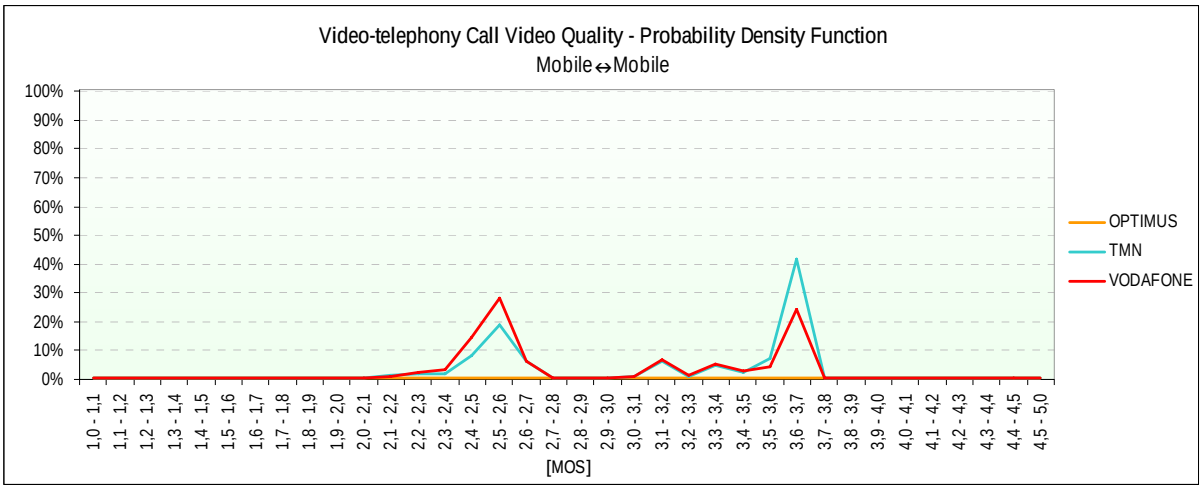
4.1.2.2.4 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY AUDIO QUALITY* INDICATOR



4.1.2.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY INDICATOR*



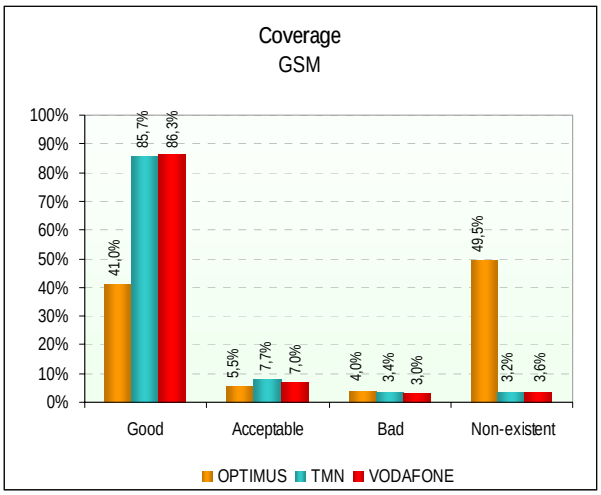
4.1.2.2.6 PROBABILITY DENSITY FUNCTION OF THE VIDEO-TELEPHONY CALL VIDEO QUALITY INDICATOR



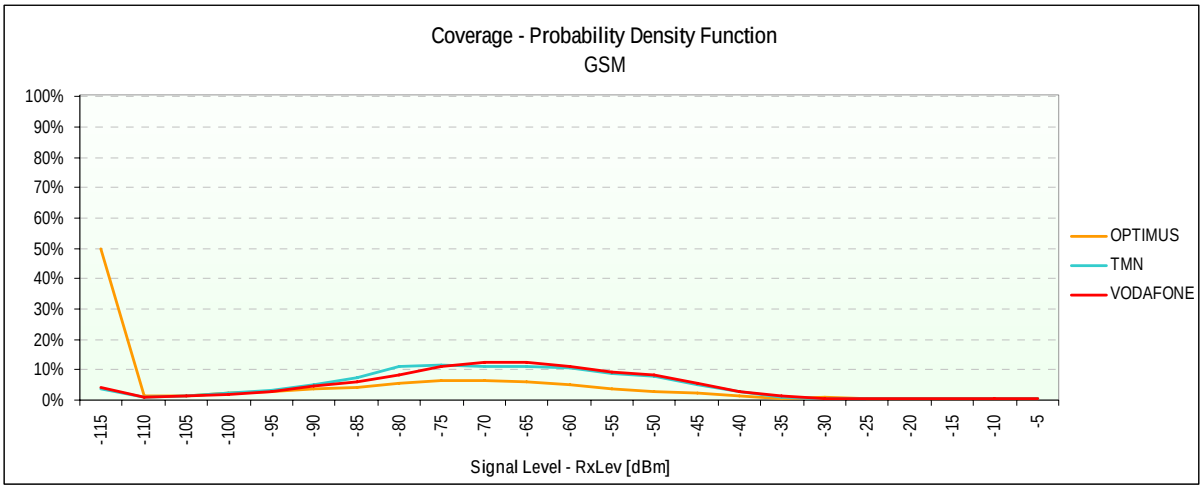
4.1.2.3 NETWORK COVERAGE

		GSM			WCDMA		
		OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Coverage	Number of Samples (Measurements)	174.169	174.096	174.169	69.331	69.304	69.297
	Signal Average Level [dBm]	-92	-68	-67	-122	-91	-98
	Signal Maximum Level [dBm]	-13	-22	-12	-114	-42	-32
	Signal Minimum Level [dBm]	-115	-115	-115	-127	-125	-126
	Standard Deviation [dBm]	25	17	18	2	19	21
	Good	41,0%	85,7%	86,3%	0,0%	60,0%	41,7%
	Acceptable	5,5%	7,7%	7,0%	0,0%	13,9%	11,9%
	Bad	4,0%	3,4%	3,0%	0,0%	8,3%	8,6%
	Non-existent	49,5%	3,2%	3,6%	100,0%	17,8%	37,8%

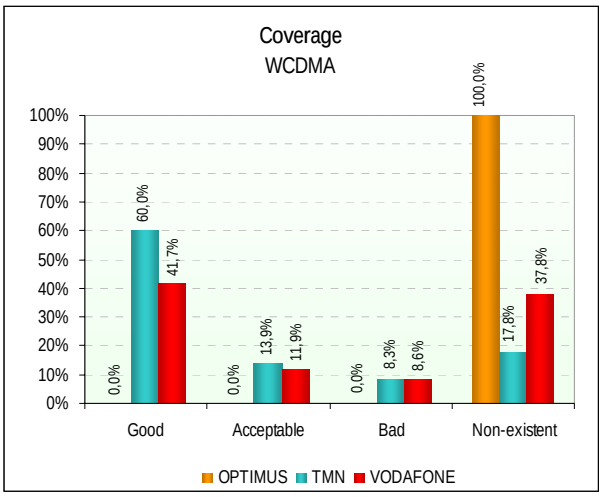
4.1.2.3.1 GSM



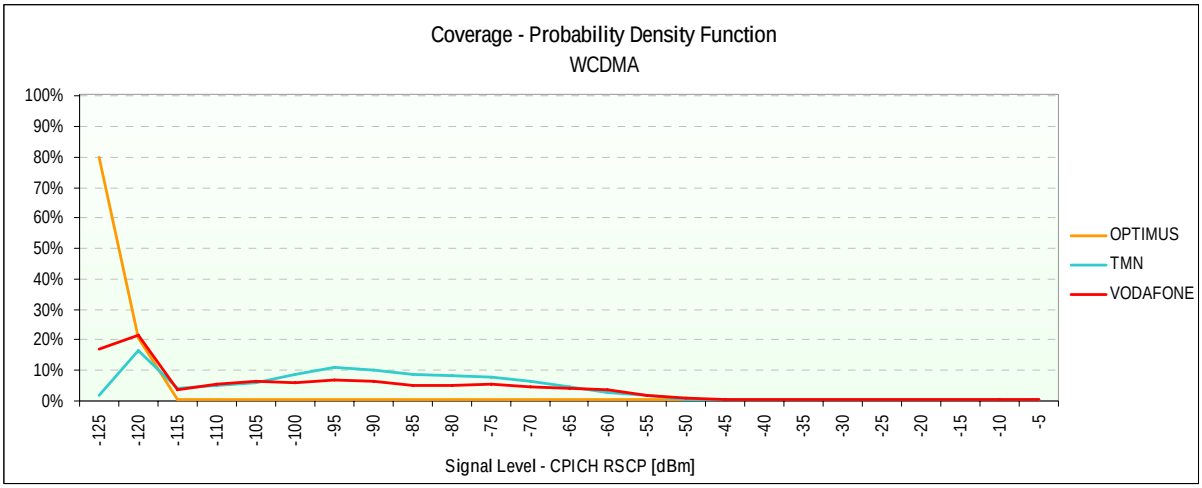
4.1.2.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.1.2.3.3 WCDMA



4.1.2.3.4 WCDMA – PROBABILITY DENSITY FUNCTION



4.1.3 GLOBAL

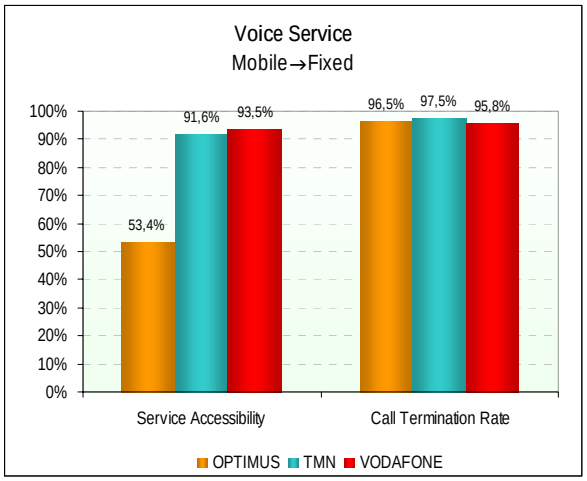
4.1.3.1 VOICE SERVICE (GSM)

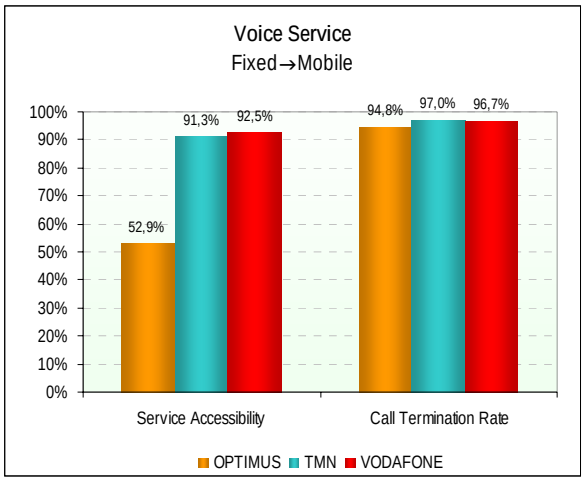
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	596	582	607	587	604	586
	Dropped on Set Up	278	274	51	51	39	44
	Dropped during Call	11	16	14	16	24	18
	With Normal Termination	307	292	542	520	541	524
	Service Accessibility	53,4%	52,9%	91,6%	91,3%	93,5%	92,5%
	Call Termination Rate	96,5%	94,8%	97,5%	97,0%	95,8%	96,7%
Call Set Up	Number of Samples (Calls)	318	308	556	536	565	542
	Average Time [s]	4,6	6,1	6,0	8,2	5,4	8,0
	Maximum Time [s]	11,8	15,1	16,5	14,5	14,1	17,4
	Minimum Time [s]	4,2	5,1	5,3	6,8	4,3	6,3
	Standard Deviation [s]	0,7	1,1	1,2	1,0	1,4	1,5
Audio Quality	Number of Samples (Calls)	599	599	1.062	1.062	1.065	1.065
	Average [MOS]	3,78	3,79	3,92	3,87	3,79	3,77
	Maximum [MOS]	3,96	3,97	3,97	3,97	3,96	3,98
	Minimum [MOS]	2,31	2,49	2,79	2,62	2,81	2,02
	Standard Deviation [MOS]	0,14	0,16	0,08	0,13	0,10	0,18

		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Error	Service Accessibility	4,1%	4,1%	2,5%	2,6%	2,3%	2,4%
	Call Termination Rate	2,6%	3,1%	1,7%	1,8%	2,0%	1,9%
	Call Set Up Time	0,077	0,124	0,096	0,088	0,115	0,127
	Audio Quality [MOS]	0,012	0,013	0,005	0,008	0,006	0,011

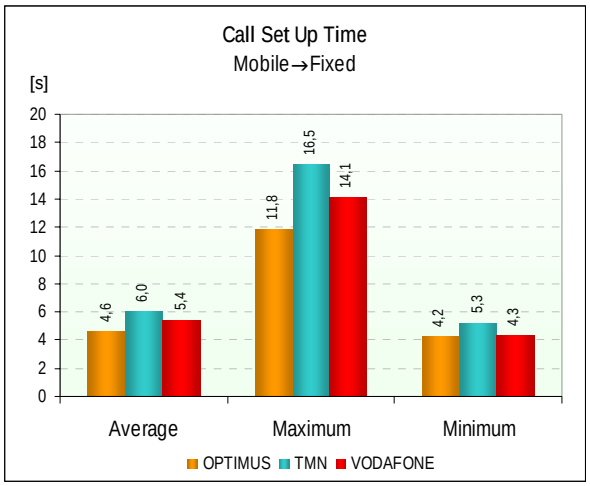
Confidence Level = 95 %

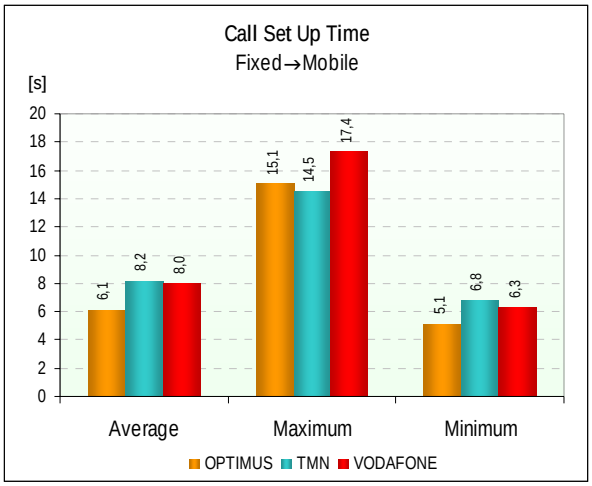
4.1.3.1.1 *SERVICE ACCESSIBILITY AND CALL TERMINATION RATE* INDICATORS



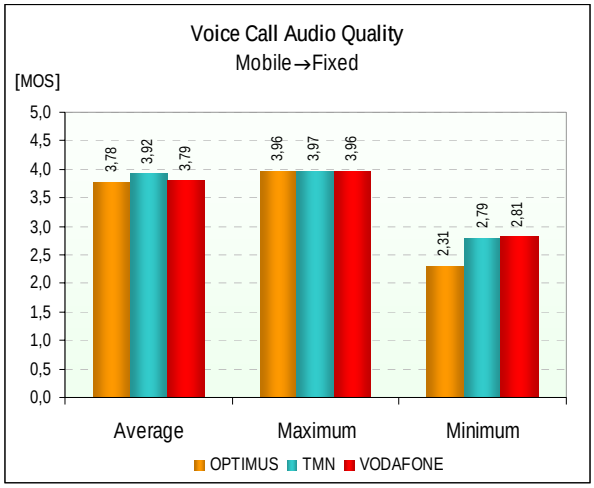


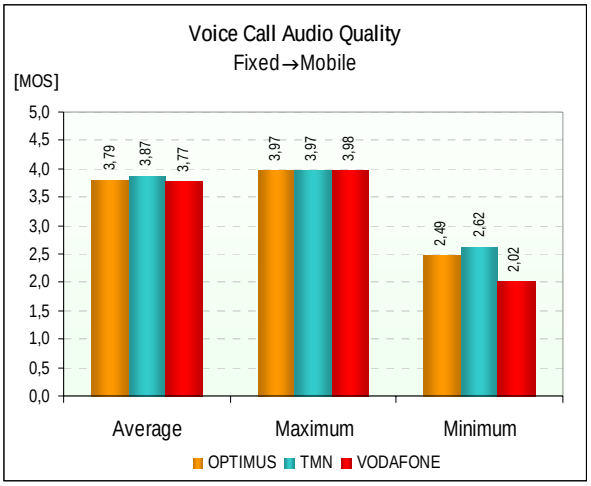
4.1.3.1.2 *CALL SET UP TIME* INDICATOR



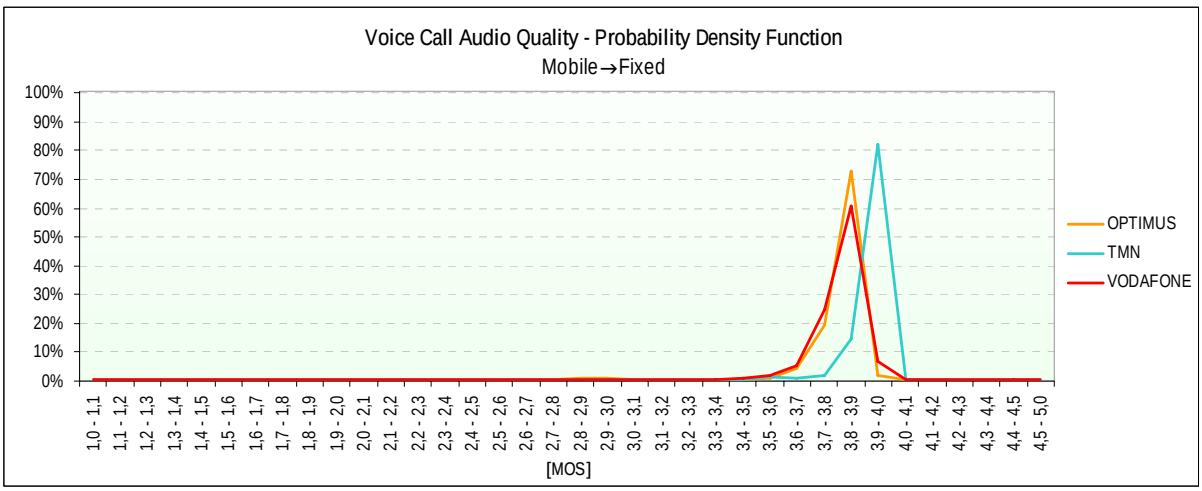


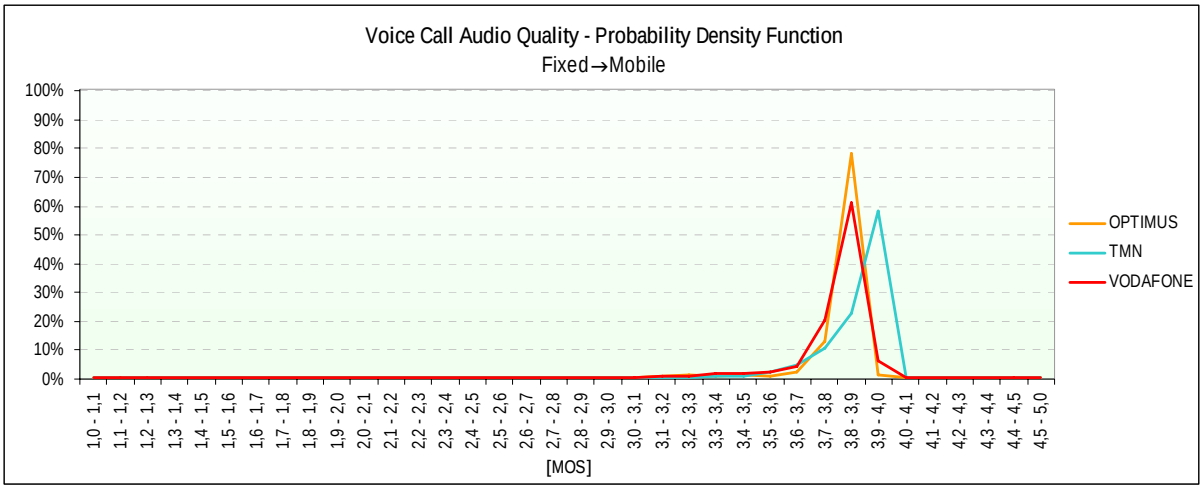
4.1.3.1.3 *VOICE CALL AUDIO QUALITY INDICATOR*





4.1.3.1.4 PROBABILITY DENSITY FUNCTION OF THE *VOICE CALL AUDIO QUALITY* INDICATOR





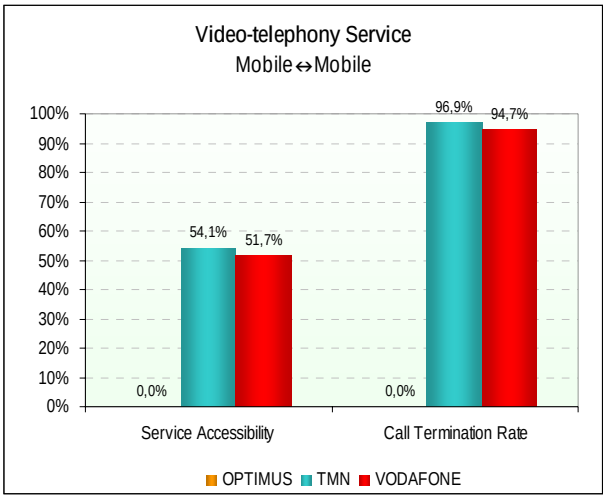
4.1.3.2 VIDEO-TELEPONHY SERVICE (UMTS)

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	1.023	1.025	1.028
	Dropped on Set Up	1.023	470	497
	Dropped during Call	0	17	28
	With Normal Termination	0	538	503
	Service Accessibility	0,0%	54,1%	51,7%
	Call Termination Rate	0,0%	96,9%	94,7%
Call Set Up	Number of Samples (Calls)	0	555	531
	Average Time [s]	0,0	10,5	6,9
	Maximum Time [s]	0,0	25,2	25,9
	Minimum Time [s]	0,0	8,3	5,3
	Standard Deviation [s]	0,0	1,9	2,1
Audio Quality	Number of Samples (Calls)	0	1.066	1.002
	Average [MOS]	0,00	3,90	3,86
	Maximum [MOS]	0,00	4,06	4,06
	Minimum [MOS]	0,00	1,00	1,00
	Standard Deviation [MOS]	0,00	0,40	0,34
Video Quality	Number of Samples (Calls)	0	1.061	999
	Average [MOS]	0,00	3,18	2,96
	Maximum [MOS]	0,00	3,68	3,69
	Minimum [MOS]	0,00	1,70	1,78
	Standard Deviation [MOS]	0,00	0,54	0,53

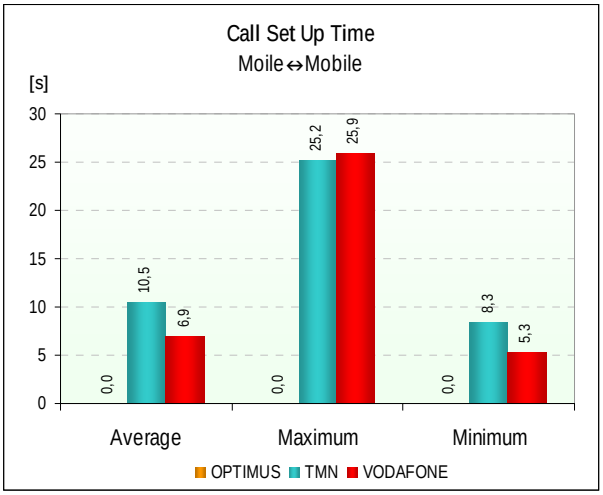
		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Error	Service Accessibility	0,0%	3,1%	3,1%
	Call Termination Rate	0,0%	1,8%	2,3%
	Call Set Up Time	0,000	0,160	0,179
	Audio Quality [MOS]	0,000	0,024	0,021
	Video Quality [MOS]	0,000	0,032	0,033

Confidence Level = 95 %

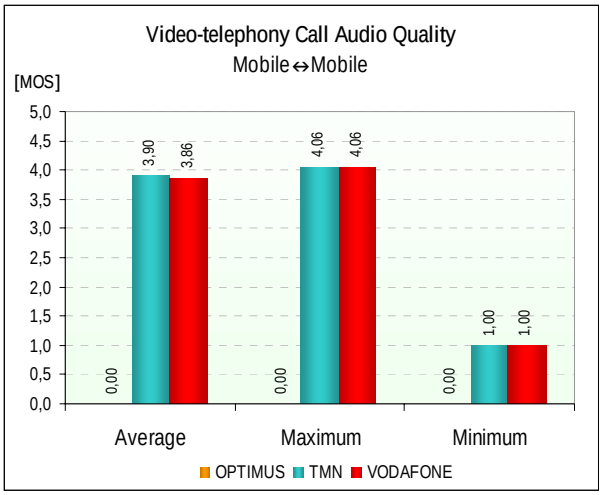
4.1.3.2.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



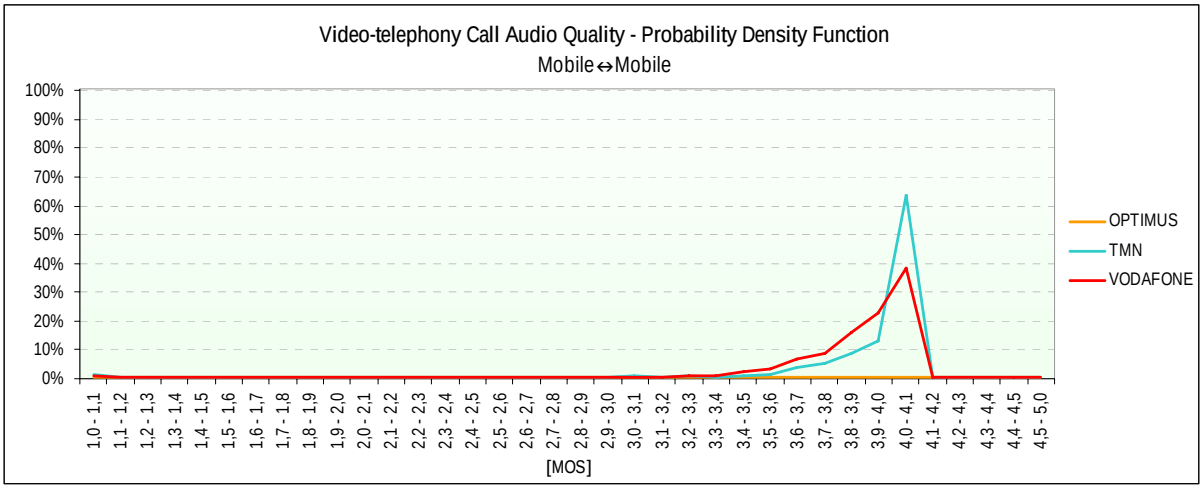
4.1.3.2.2 *CALL SET UP TIME* INDICATOR



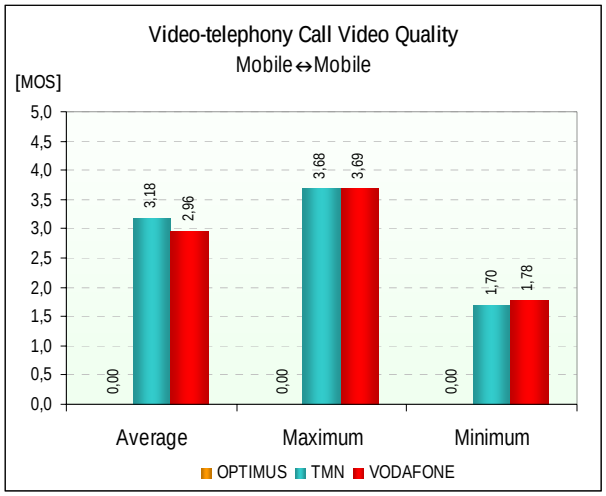
4.1.3.2.3 *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



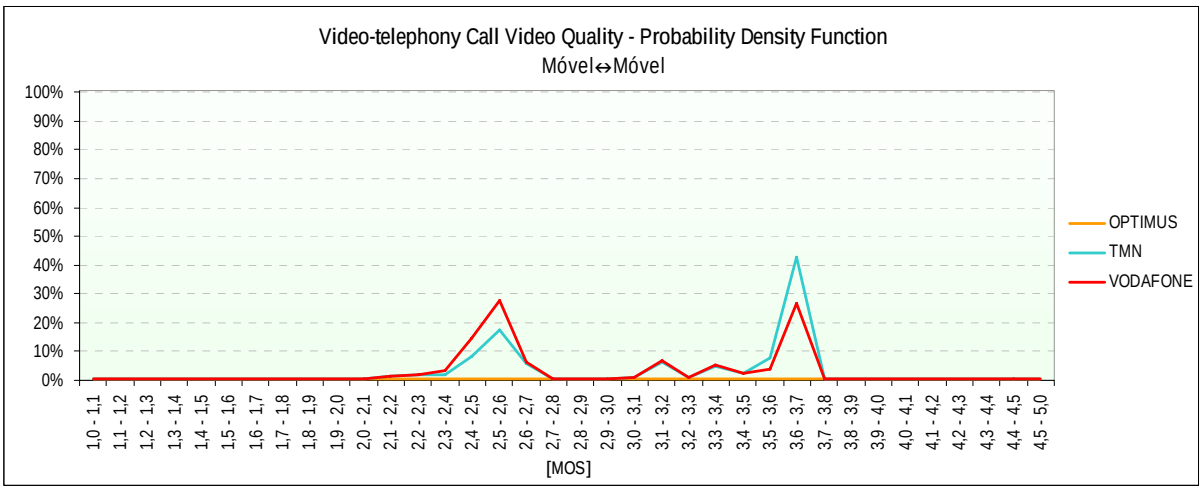
4.1.3.2.4 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPNHY CALL AUDIO QUALITY* INDICATOR



4.1.3.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



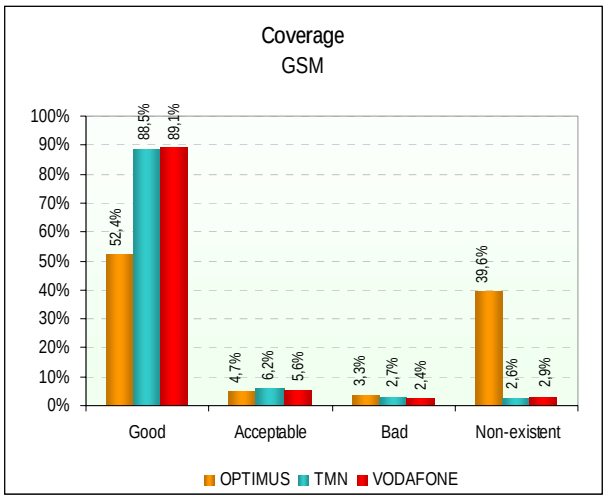
4.1.3.2.6 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



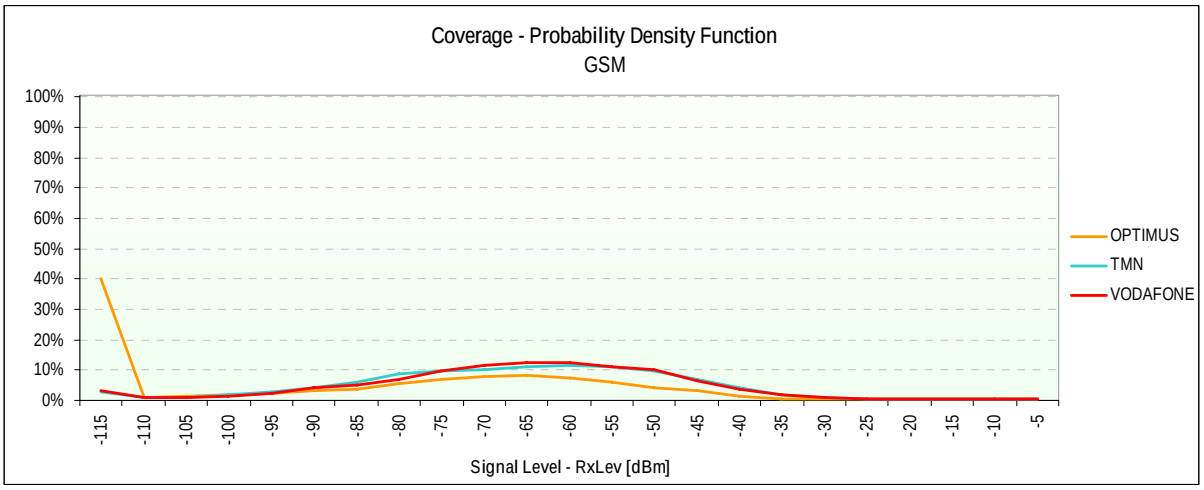
4.1.3.3 NETWORK COVERAGE

	GSM			WCDMA		
	OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Number of Samples (Measurements)	219.613	219.272	219.613	87.425	87.315	87.387
Signal Average Level [dBm]	-86	-65	-64	-122	-87	-92
Signal Maximum Level [dBm]	-13	-14	-11	-114	-34	-32
Signal Minimum Level [dBm]	-115	-115	-115	-127	-125	-126
Standard Deviation [dBm]	27	18	18	2	20	23
Good	52,4%	88,5%	89,1%	0,0%	67,8%	53,2%
Acceptable	4,7%	6,2%	5,6%	0,0%	11,4%	9,9%
Bad	3,3%	2,7%	2,4%	0,0%	6,6%	6,9%
Non-existent	39,6%	2,6%	2,9%	100,0%	14,2%	30,0%

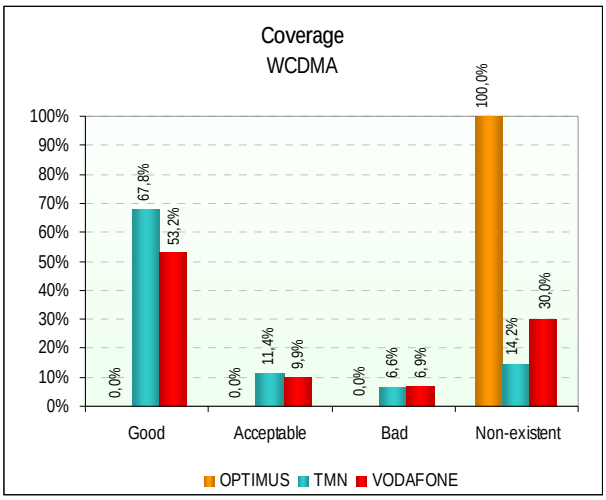
4.1.3.3.1 GSM



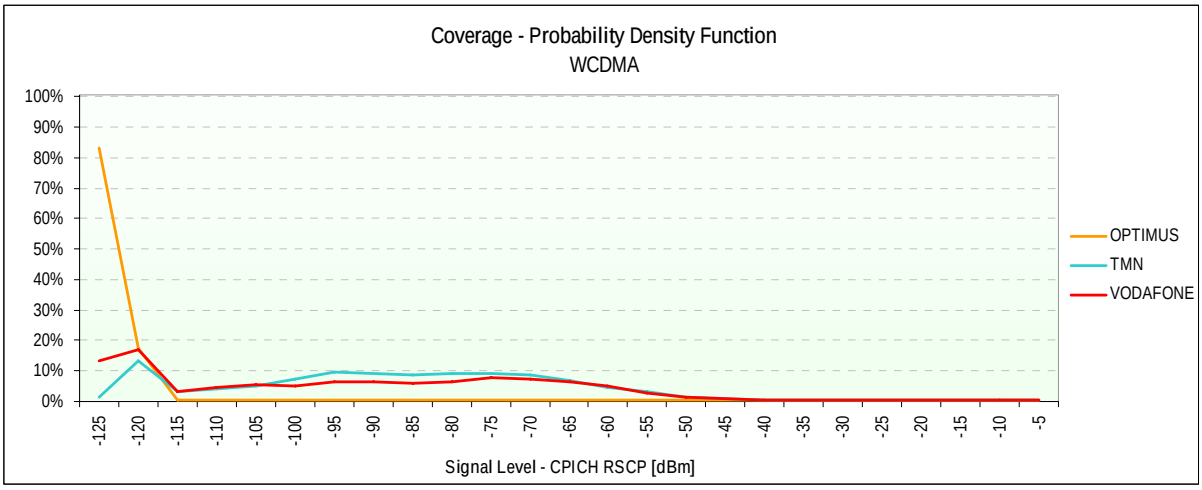
4.1.3.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.1.3.3.3 WCDMA



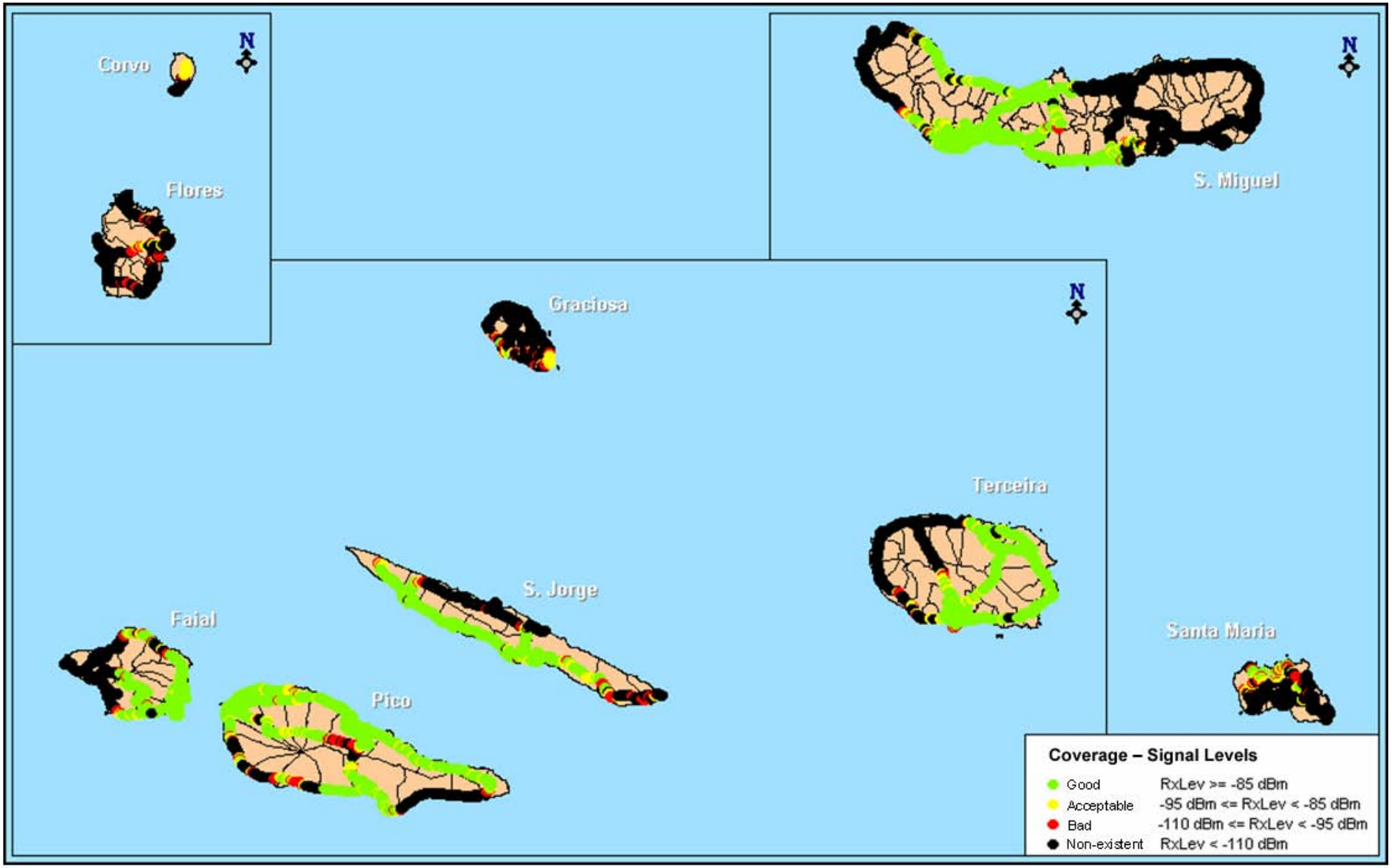
4.1.3.3.4 WCDMA – PROBABILITY DENSITY FUNCTION



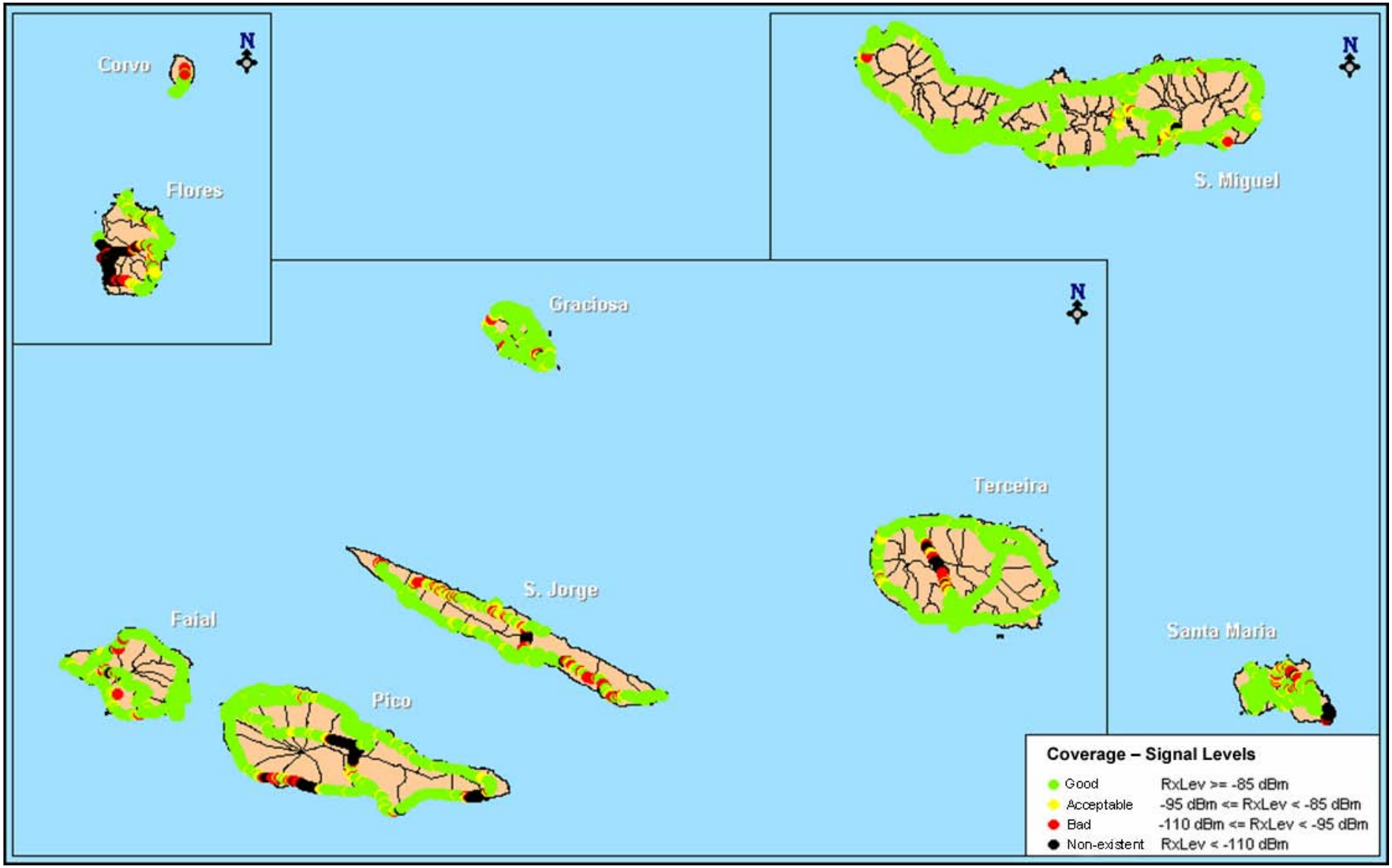
4.1.3.3.5 COVERAGE MAPS

(Following pages)

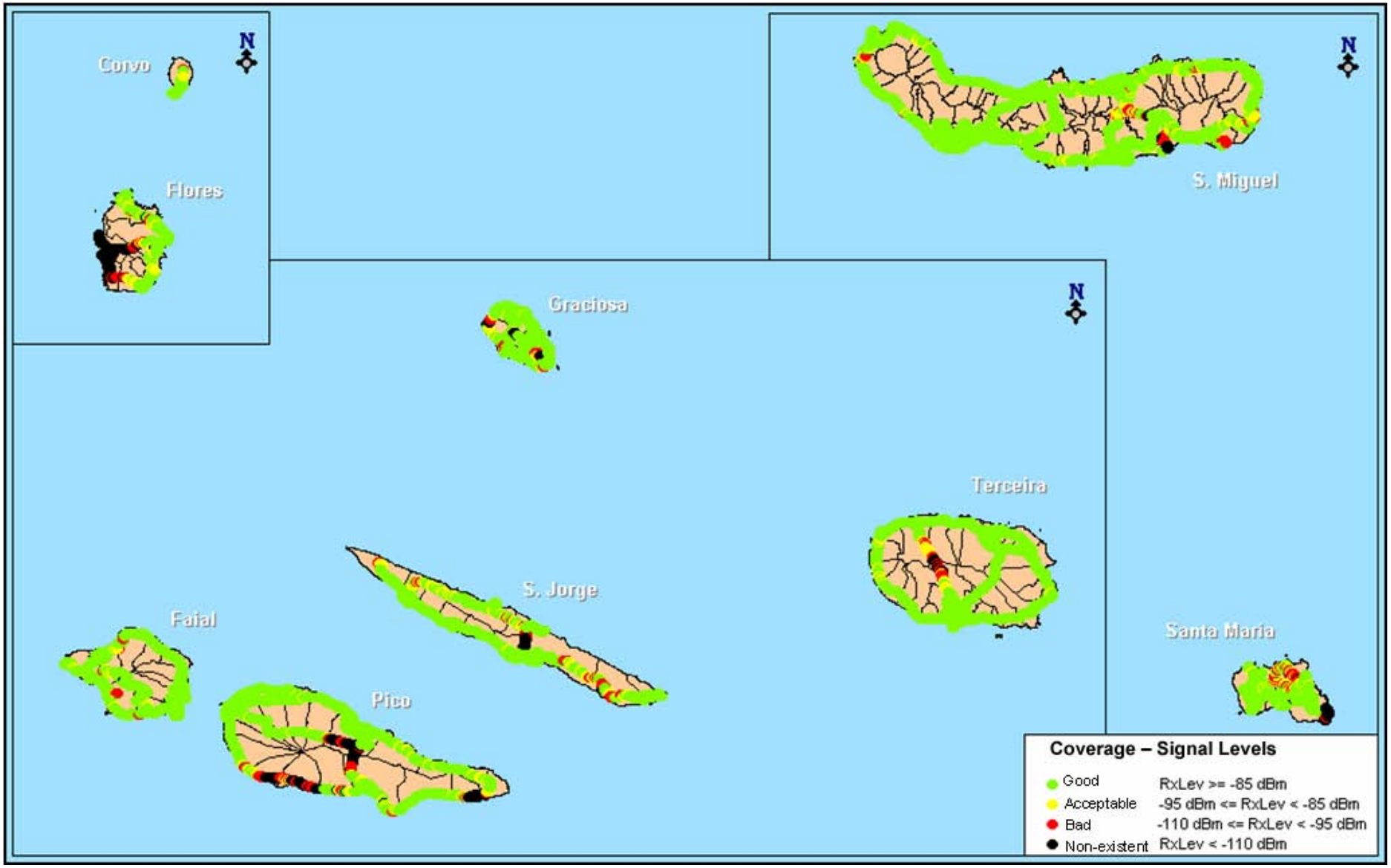
OPTIMUS – GSM Coverage



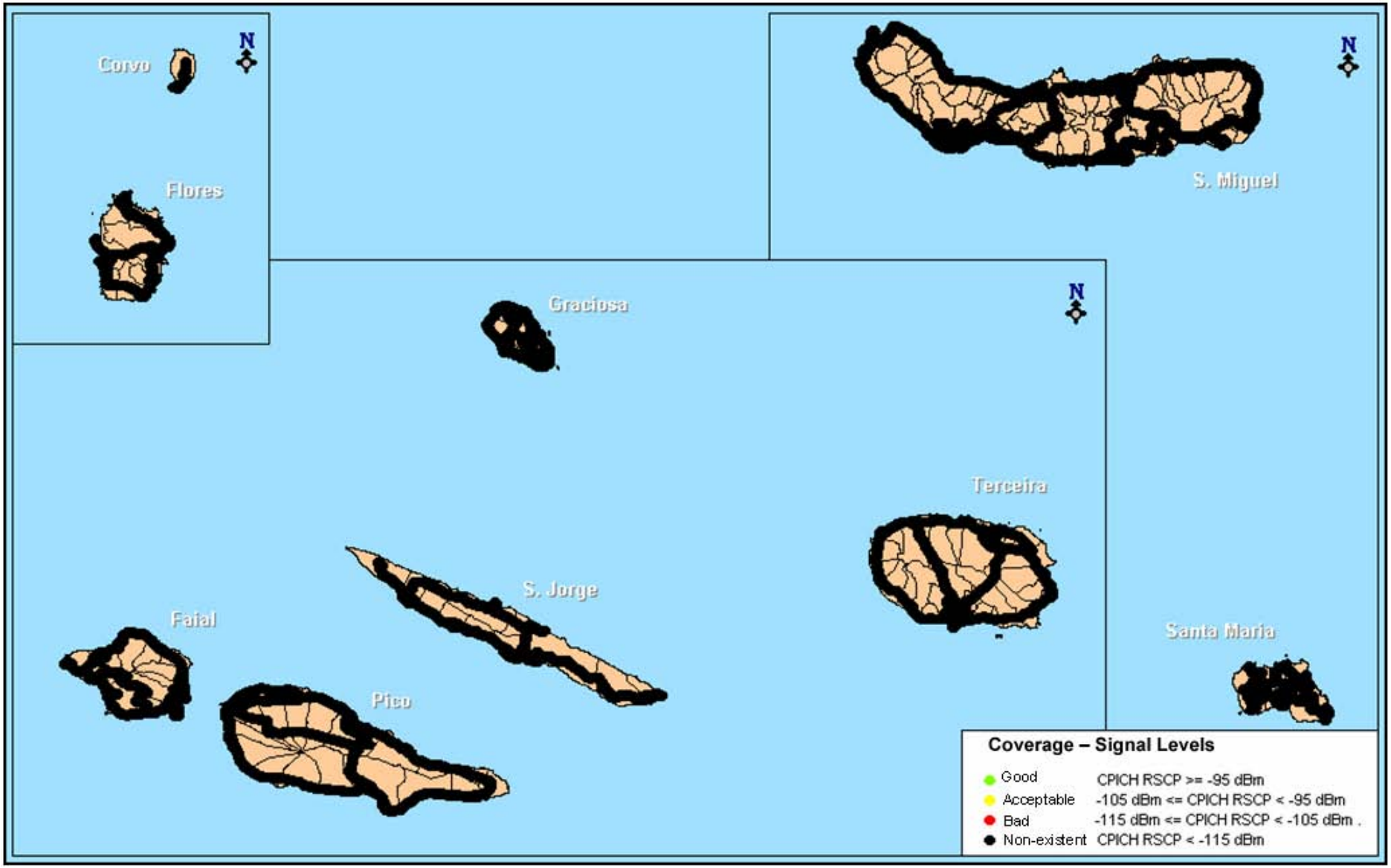
TMN – GSM Coverage



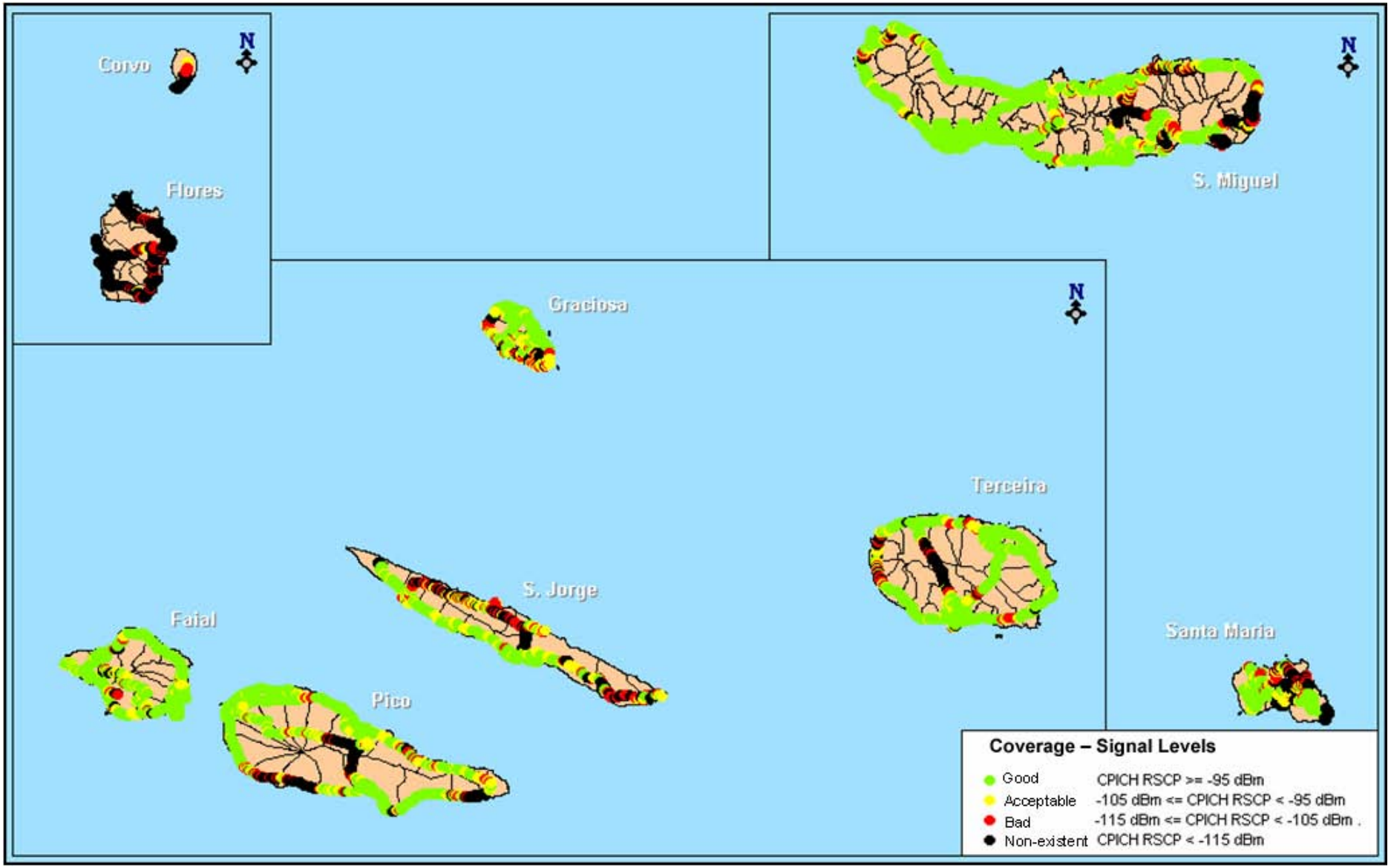
VODAFONE – GSM Coverage



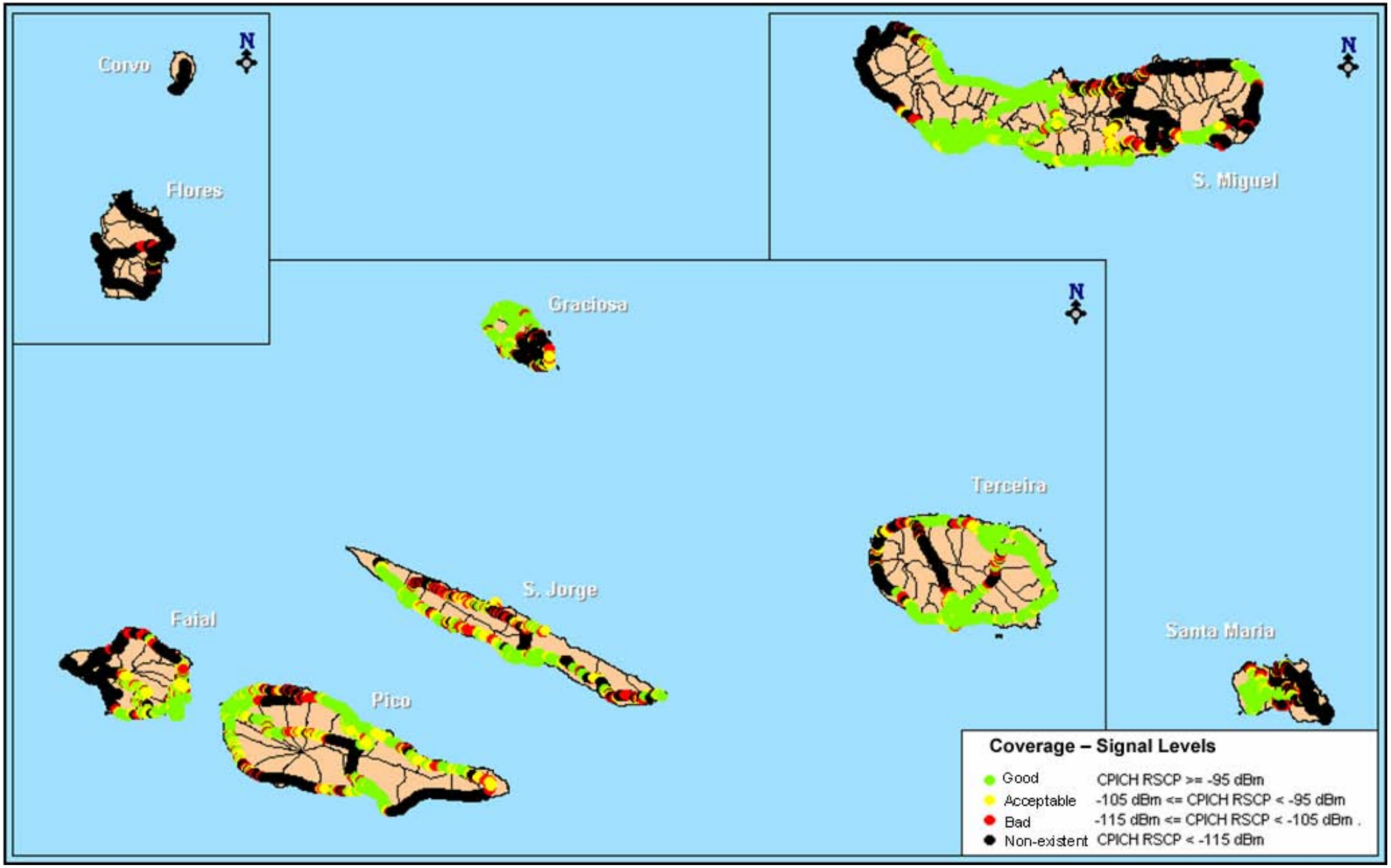
OPTIMUS – WCDMA Coverage



TMN – WCDMA Coverage



VODAFONE – WCDMA Coverage



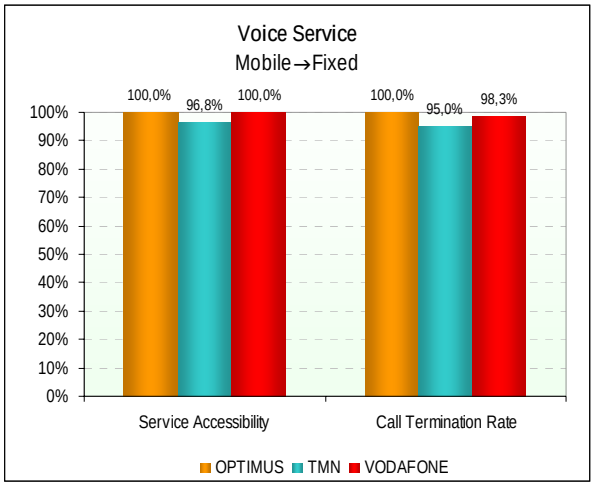
4.2 AUTONOMOUS REGION OF MADEIRA

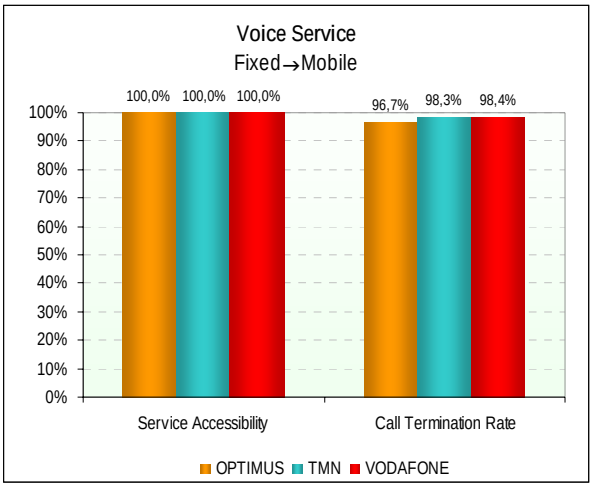
4.2.1 URBAN AGGLOMERATIONS

4.2.1.1 VOICE SERVICE (GSM)

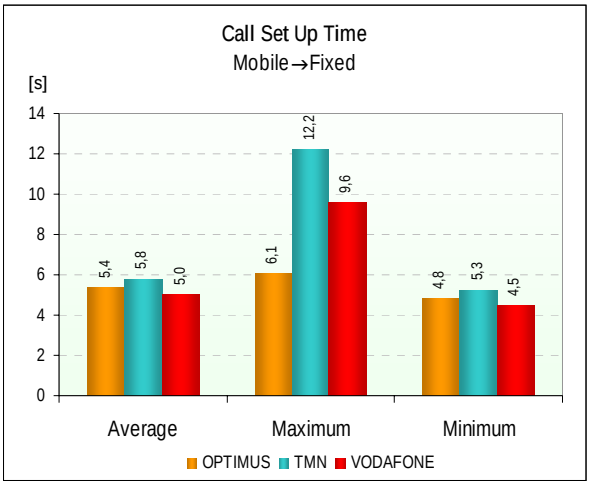
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	62	61	62	60	60	61
	Dropped on Set Up	0	0	2	0	0	0
	Dropped during Call	0	2	3	1	1	1
	With Normal Termination	62	59	57	59	59	60
	Service Accessibility	100,0%	100,0%	96,8%	100,0%	100,0%	100,0%
	Call Termination Rate	100,0%	96,7%	95,0%	98,3%	98,3%	98,4%
Call Set Up	Number of Samples (Calls)	62	61	60	60	60	61
	Average Time [s]	5,4	6,1	5,8	7,9	5,0	7,1
	Maximum Time [s]	6,1	7,4	12,2	12,8	9,6	11,3
	Minimum Time [s]	4,8	5,3	5,3	6,5	4,5	6,0
	Standard Deviation [s]	0,3	0,5	0,9	1,3	0,7	0,8
Audio Quality	Number of Samples (Calls)	121	121	116	116	119	119
	Average [MOS]	3,79	3,77	3,90	3,84	3,77	3,73
	Maximum [MOS]	3,96	3,97	3,94	3,95	3,96	3,97
	Minimum [MOS]	3,39	3,26	3,65	3,19	3,30	2,81
	Standard Deviation [MOS]	0,11	0,13	0,05	0,11	0,11	0,18

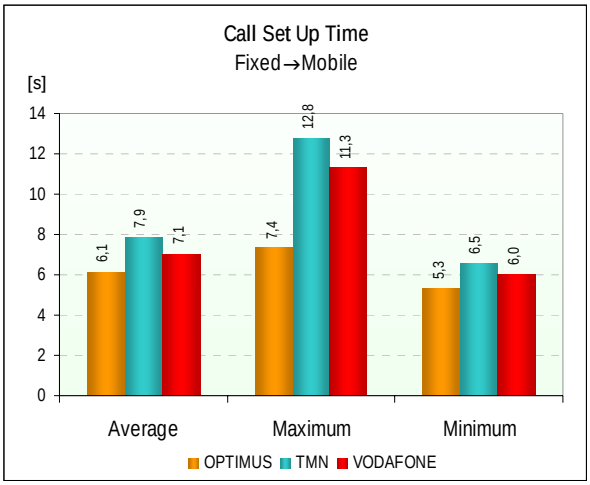
4.2.1.1.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



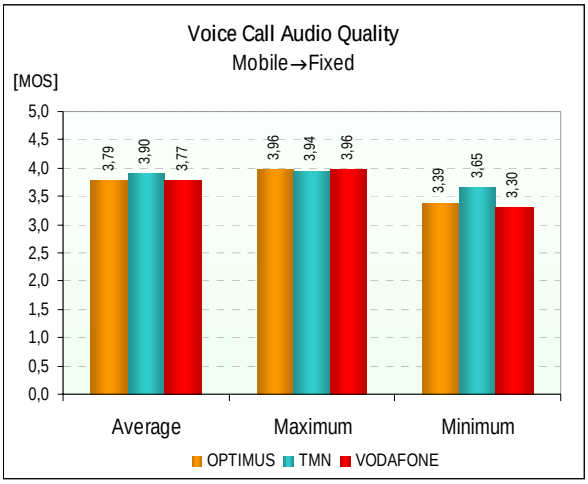


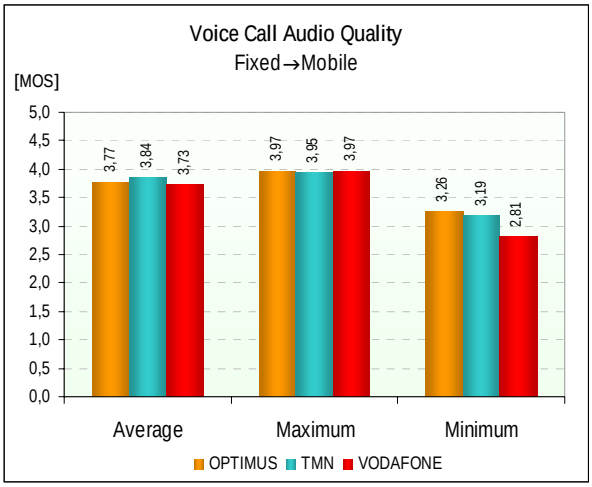
4.2.1.1.2 *CALL SET UP TIME INDICATOR*



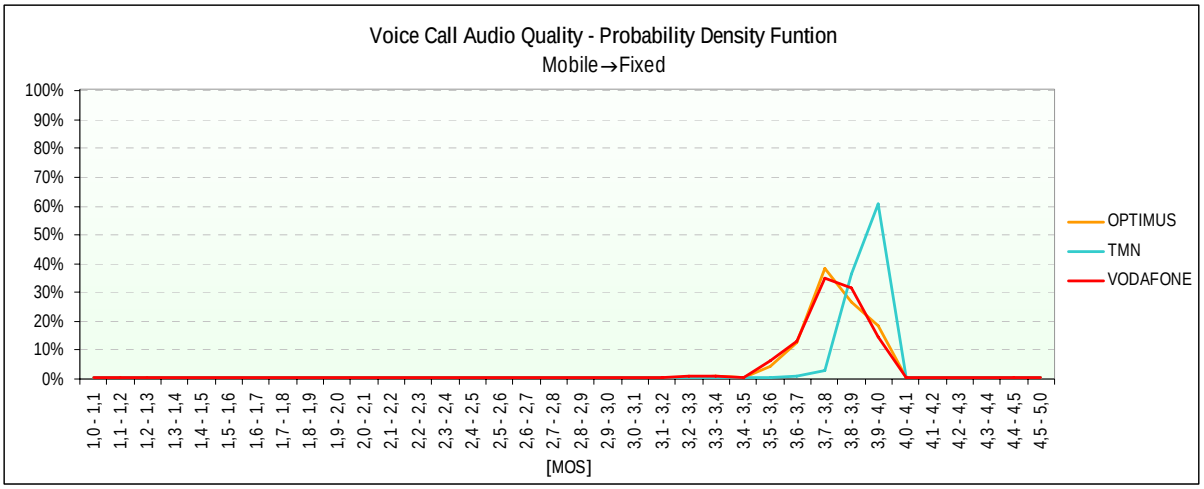


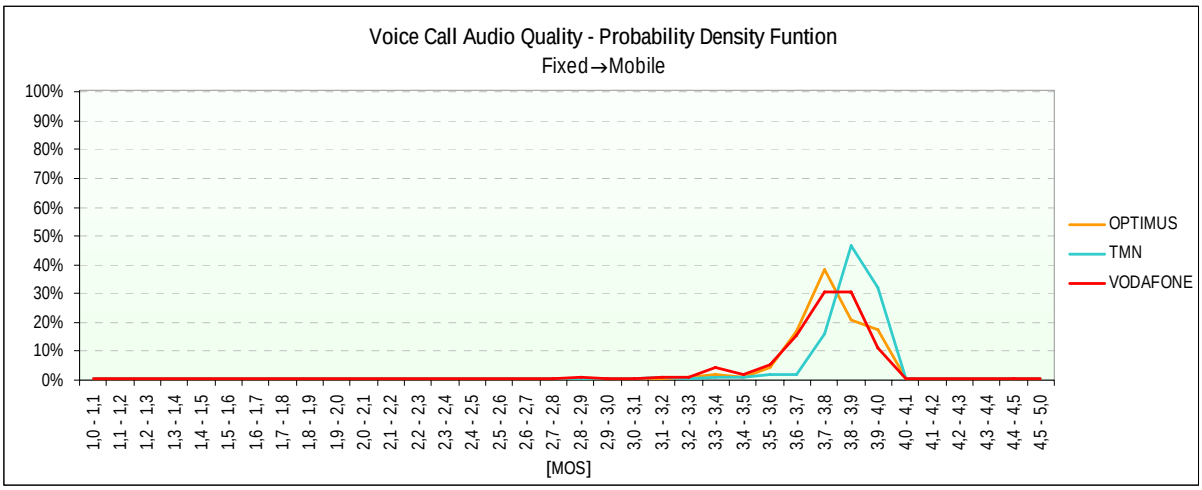
4.2.1.1.3 *VOICE CALL AUDIO QUALITY* INDICATOR





4.2.1.1.4 PROBABILITY DENSITY FUNCTION OF *THE VOICE CALL AUDIO QUALITY* INDICATOR

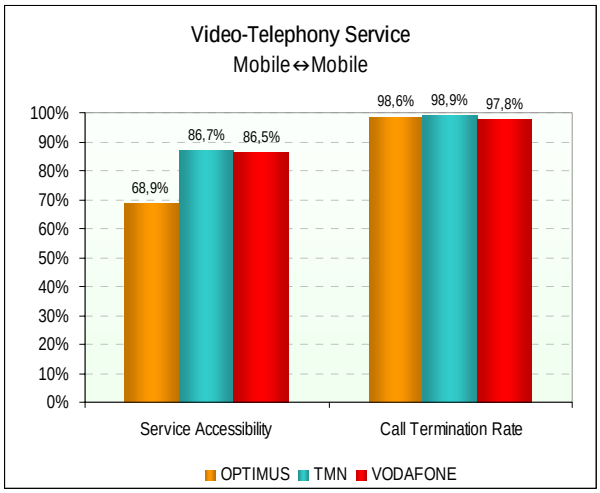




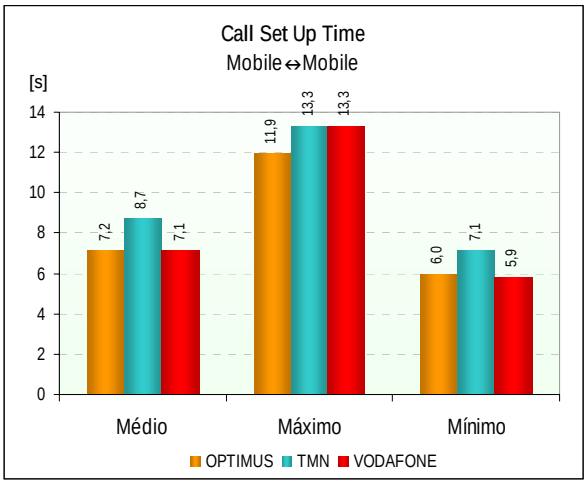
4.2.1.2 VIDEO-TELEPHONY SERVICE (UMTS)

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	103	105	104
	Dropped on Set Up	32	14	14
	Dropped during Call	1	1	2
	With Normal Termination	70	90	88
	Service Accessibility	68,9%	86,7%	86,5%
	Call Termination Rate	98,6%	98,9%	97,8%
Call Set Up	Number of Samples (Calls)	71	91	90
	Average Time [s]	7,2	8,7	7,1
	Maximum Time [s]	11,9	13,3	13,3
	Minimum Time [s]	6,0	7,1	5,9
	Standard Deviation [s]	1,5	1,2	1,4
Audio Quality	Number of Samples (Calls)	140	179	176
	Average [MOS]	3,84	3,85	3,91
	Maximum [MOS]	4,06	4,06	4,06
	Minimum [MOS]	2,21	1,00	2,71
	Standard Deviation [MOS]	0,29	0,43	0,22
Video Quality	Number of Samples (Calls)	140	179	176
	Average [MOS]	3,04	3,03	3,15
	Maximum [MOS]	3,68	3,69	3,68
	Minimum [MOS]	2,24	1,88	1,88
	Standard Deviation [MOS]	0,58	0,55	0,54

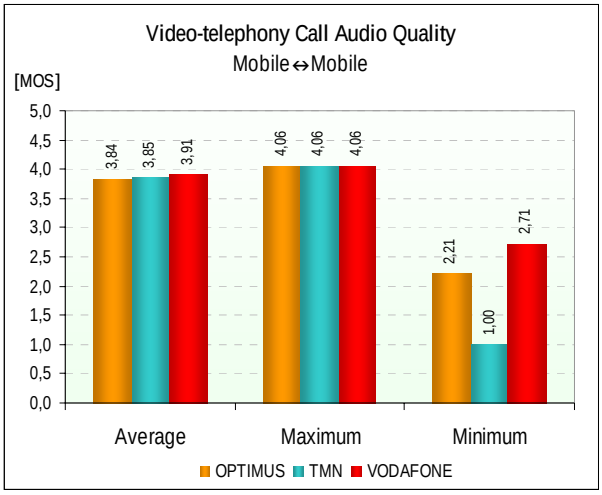
4.2.1.2.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



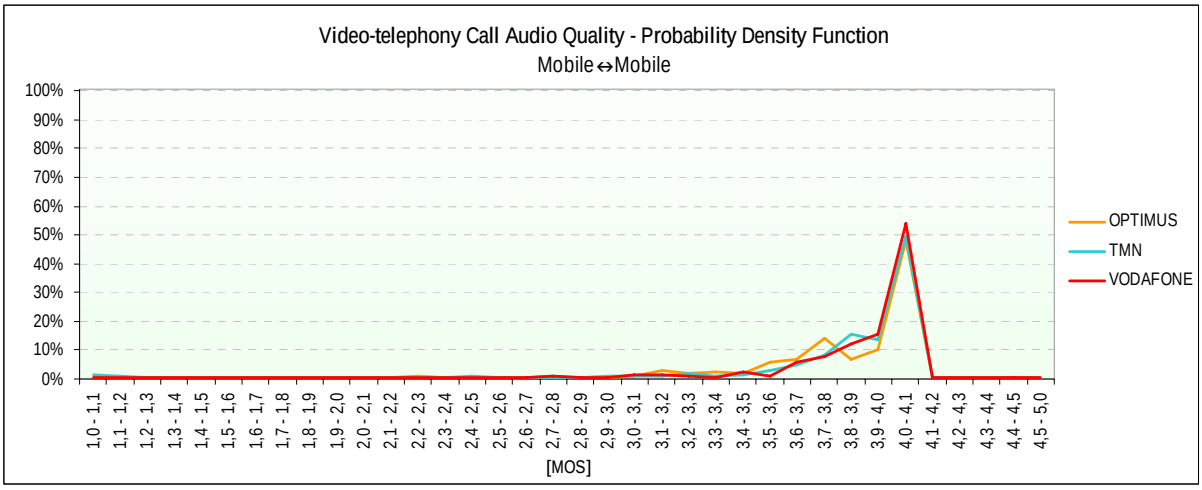
4.2.1.2.2 *CALL SET UP TIME* INDICATOR



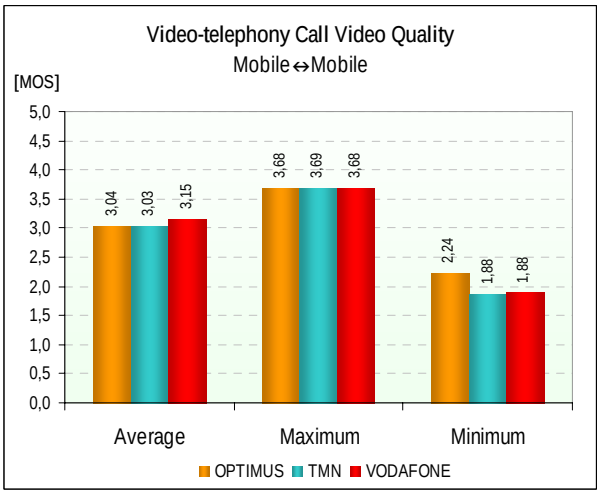
4.2.1.2.3 *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



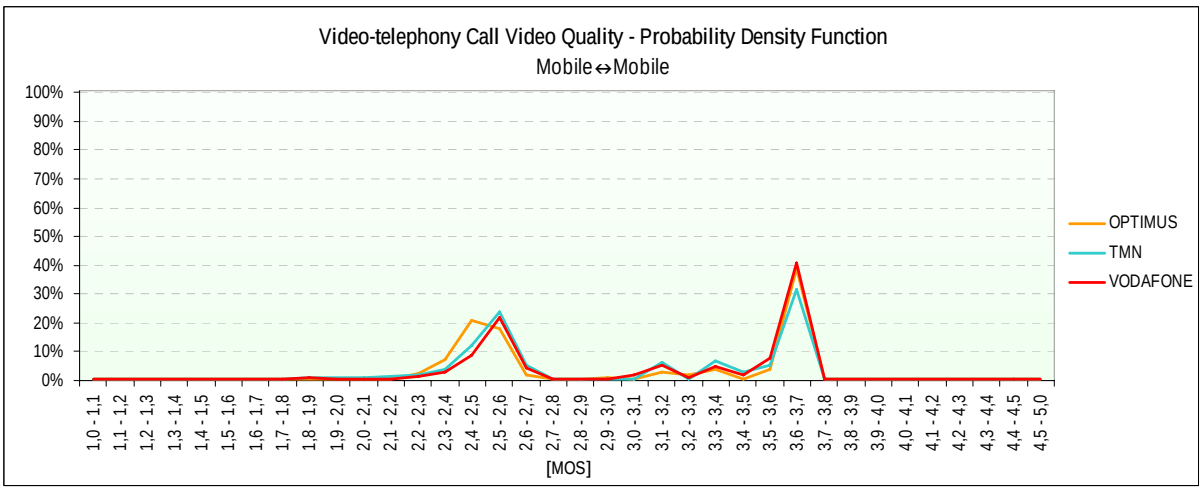
4.2.1.2.4 PROBABILITY DENSITY FUNCTION OF *THE VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



4.2.1.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



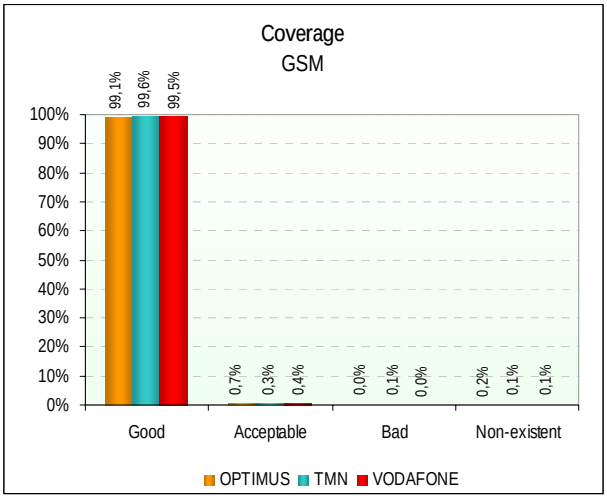
4.2.1.2.6 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



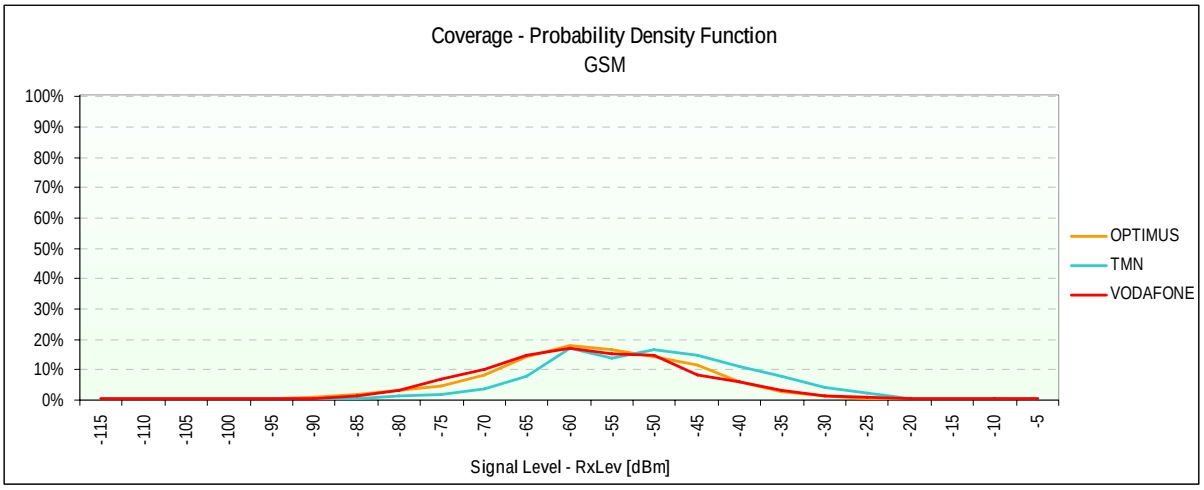
4.2.1.3 NETWORK COVERAGE

		GSM			WCDMA		
		OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Coverage	Number of Samples (Measurements)	22.249	22.321	22.249	8.910	8.916	8.912
	Signal Average Level [dBm]	-55	-48	-55	-75	-68	-73
	Signal Maximum Level [dBm]	-14	-7	-12	-36	-23	-29
	Signal Minimum Level [dBm]	-115	-115	-115	-120	-111	-118
	Standard Deviation [dBm]	12	12	12	12	12	14
	Good	99,1%	99,6%	99,5%	95,3%	97,9%	94,8%
	Acceptable	0,7%	0,3%	0,4%	4,2%	1,9%	4,6%
	Bad	0,0%	0,1%	0,0%	0,4%	0,2%	0,5%
	Non-existent	0,2%	0,1%	0,1%	0,0%	0,0%	0,0%

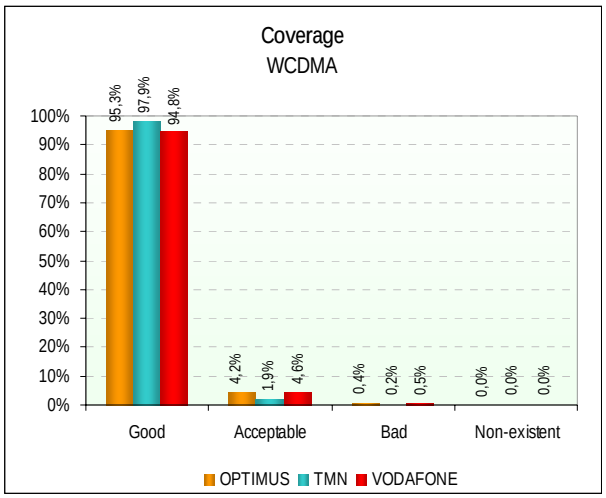
4.2.1.3.1 GSM



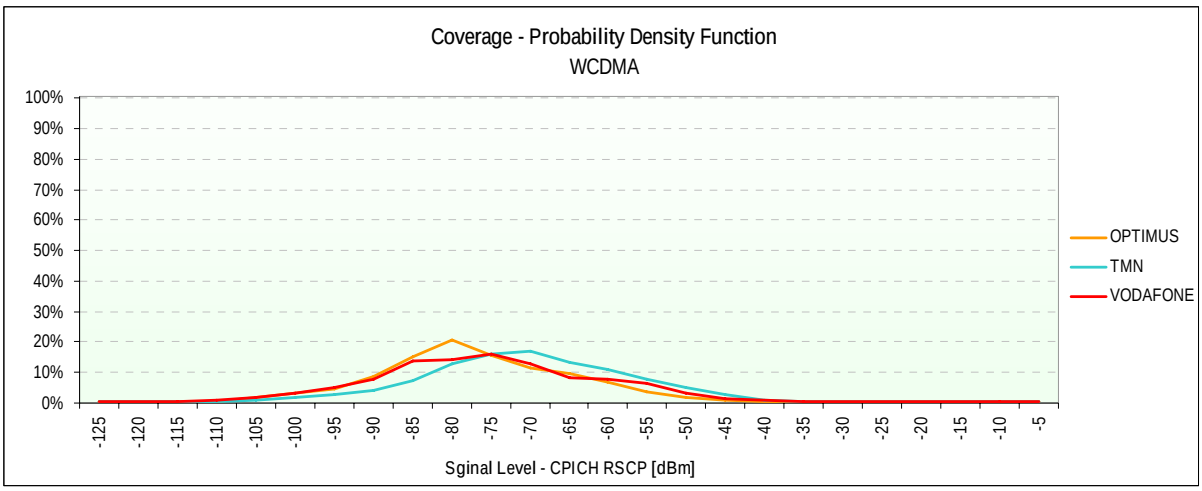
4.2.1.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.2.1.3.3 WCDMA



4.2.1.3.4 WCDMA – PROBABILITY DENSITY FUNCTION

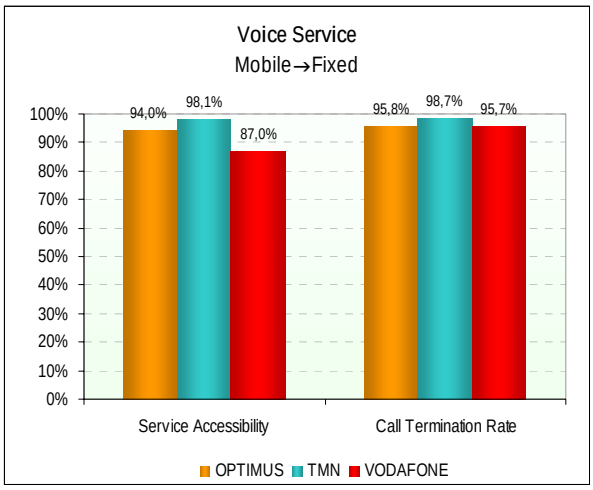


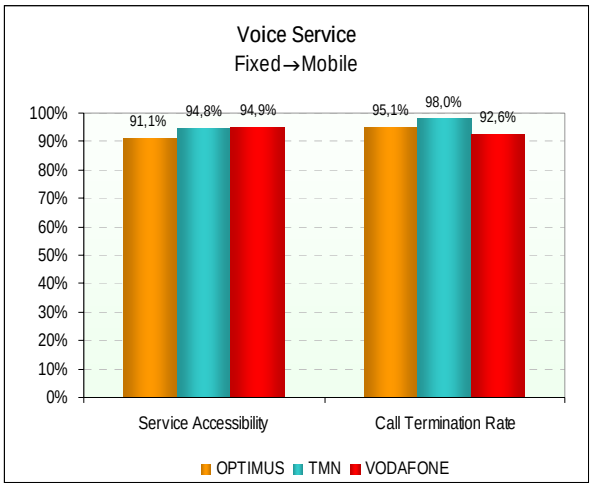
4.2.2 MAJOR ROADS

4.2.2.1 VOICE SERVICE (GSM)

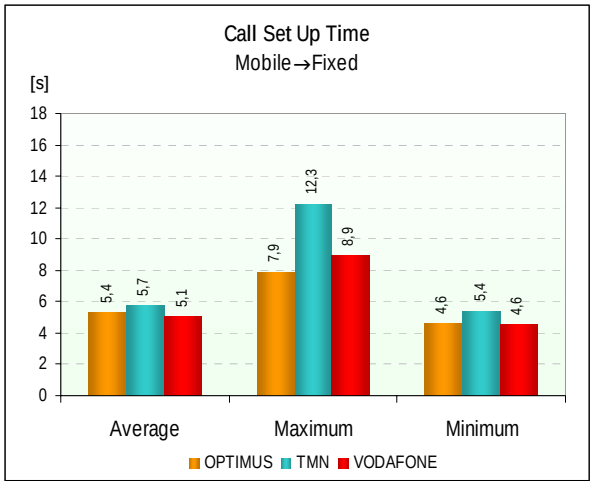
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	151	157	159	155	161	157
	Dropped on Set Up	9	14	3	8	21	8
	Dropped during Call	6	7	2	3	6	11
	With Normal Termination	136	136	154	144	134	138
	Service Accessibility	94,0%	91,1%	98,1%	94,8%	87,0%	94,9%
	Call Termination Rate	95,8%	95,1%	98,7%	98,0%	95,7%	92,6%
Call Set Up	Number of Samples (Calls)	142	143	156	147	140	149
	Average Time [s]	5,4	6,1	5,7	7,3	5,1	7,1
	Maximum Time [s]	7,9	14,4	12,3	13,6	8,9	15,6
	Minimum Time [s]	4,6	5,2	5,4	6,3	4,6	6,0
	Standard Deviation [s]	0,4	0,9	0,6	0,8	0,5	0,9
Audio Quality	Number of Samples (Calls)	272	272	298	298	272	272
	Average [MOS]	3,81	3,82	3,92	3,89	3,80	3,81
	Maximum [MOS]	3,96	3,97	3,95	3,95	3,96	3,97
	Minimum [MOS]	3,41	3,20	3,45	3,19	3,35	3,16
	Standard Deviation [MOS]	0,09	0,10	0,05	0,10	0,08	0,09

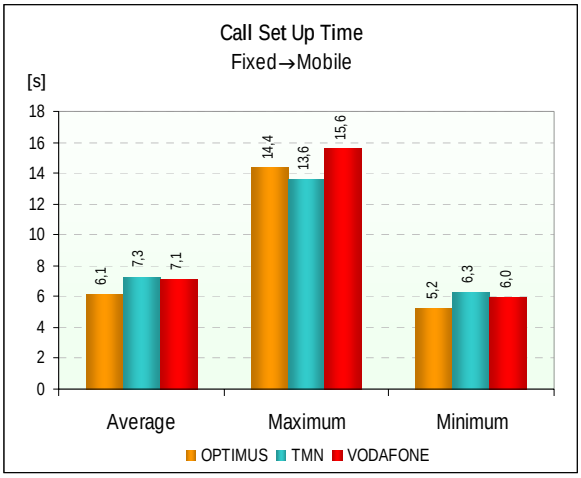
4.2.2.1.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



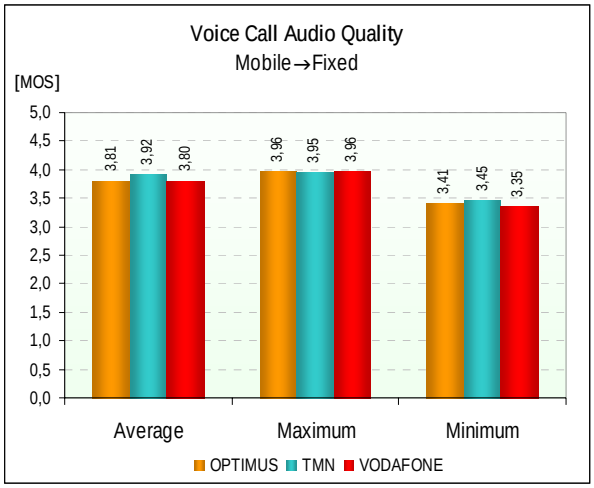


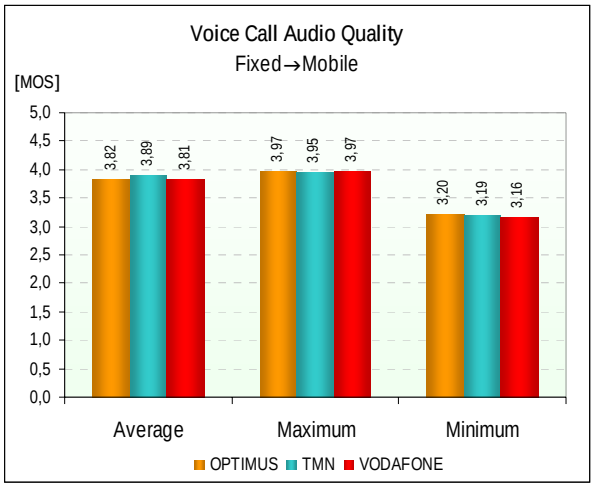
4.2.2.1.2 *CALL SET UP TIME* INDICATOR



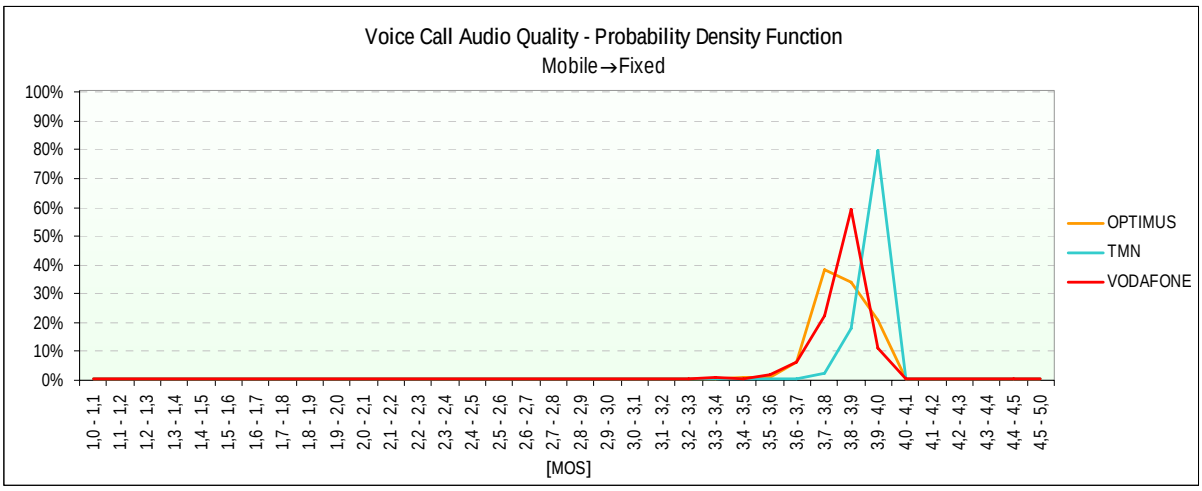


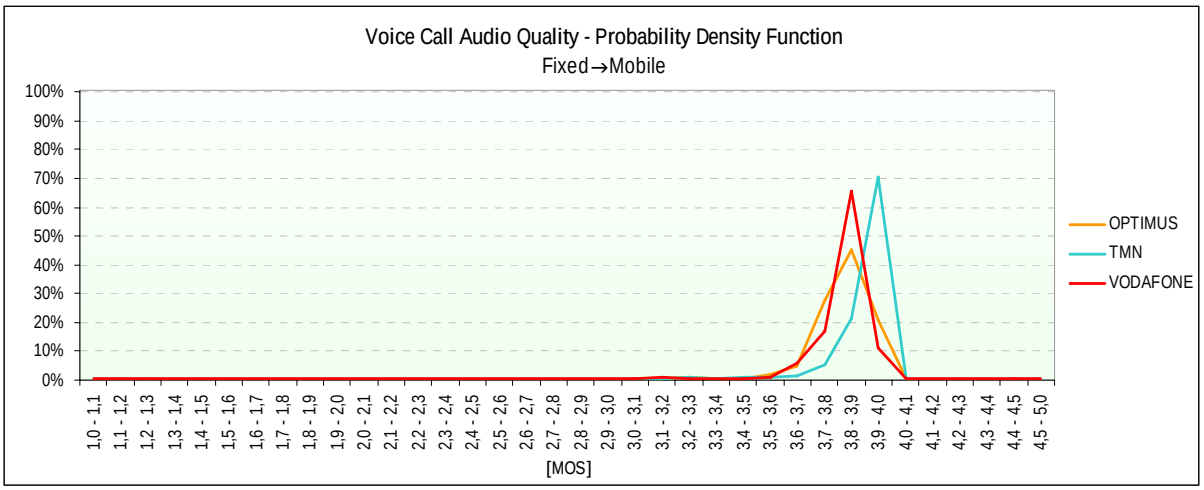
4.2.2.1.3 *VOICE CALL AUDIO QUALITY* INDICATOR





4.2.2.1.4 PROBABILITY DENSITY FUNCTION OF THE *VOICE CALL AUDIO QUALITY* INDICATOR

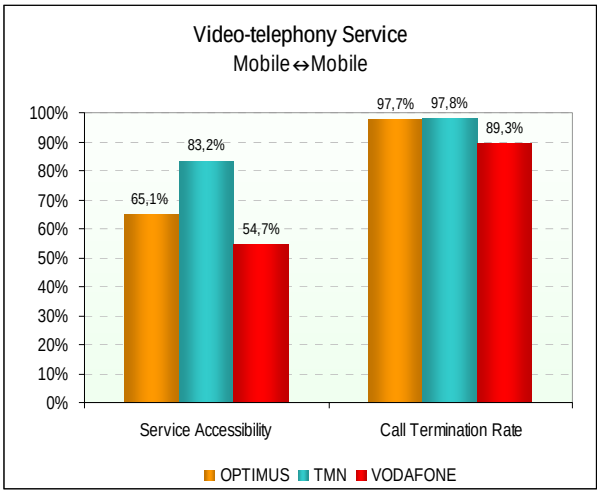




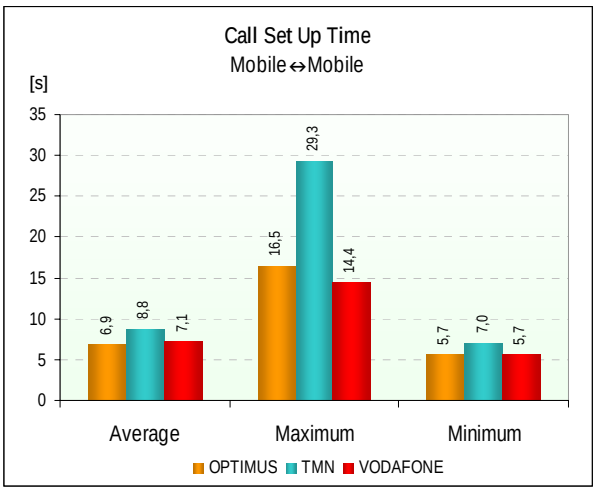
4.2.2.2 VIDEO-TELEPHONY SERVICE (UMTS)

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	272	274	274
	Dropped on Set Up	95	46	124
	Dropped during Call	4	5	16
	With Normal Termination	173	223	134
	Service Accessibility	65,1%	83,2%	54,7%
	Call Termination Rate	97,7%	97,8%	89,3%
Call Set Up	Number of Samples (Calls)	177	228	150
	Average Time [s]	6,9	8,8	7,1
	Maximum Time [s]	16,5	29,3	14,4
	Minimum Time [s]	5,7	7,0	5,7
	Standard Deviation [s]	1,6	2,2	1,5
Audio Quality	Number of Samples (Calls)	342	432	268
	Average [MOS]	3,82	3,86	3,89
	Maximum [MOS]	4,06	4,06	4,06
	Minimum [MOS]	1,00	1,00	1,00
	Standard Deviation [MOS]	0,40	0,46	0,43
Video Quality	Number of Samples (Calls)	340	431	268
	Average [MOS]	3,07	3,05	3,19
	Maximum [MOS]	3,68	3,68	3,69
	Minimum [MOS]	1,90	1,79	1,40
	Standard Deviation [MOS]	0,57	0,55	0,56

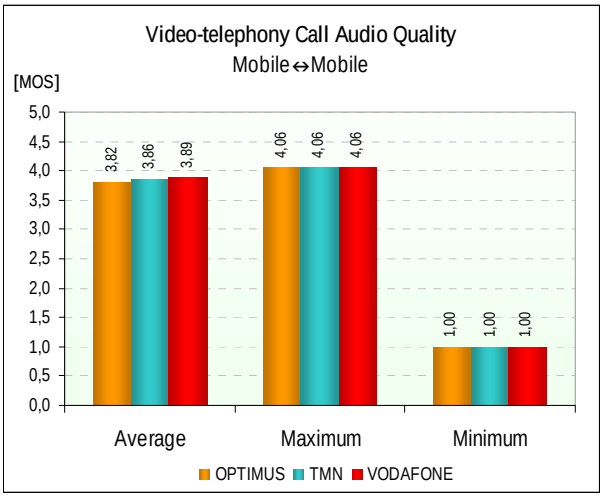
4.2.2.2.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



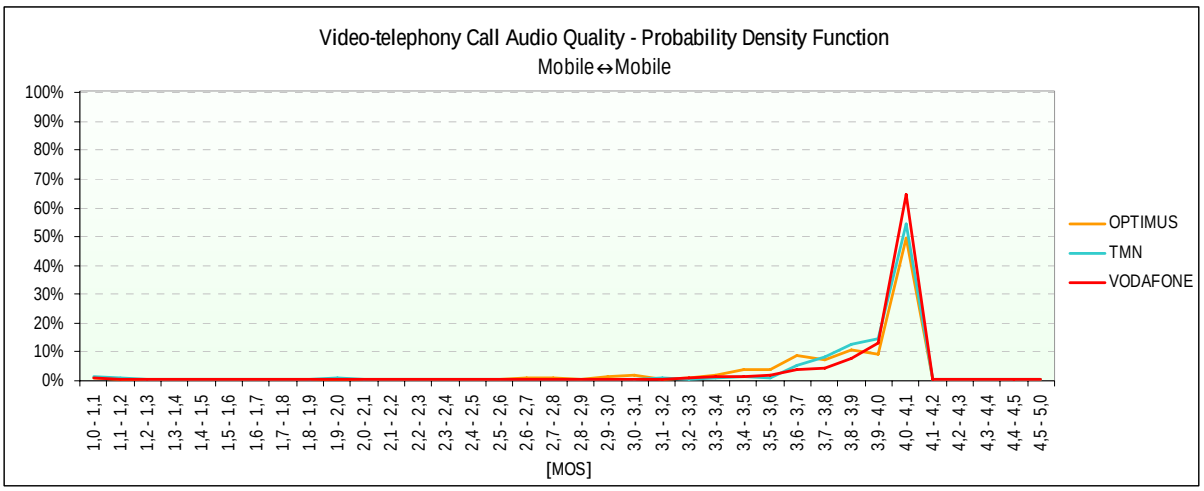
4.2.2.2.2 *CALL SET UP TIME* INDICATOR



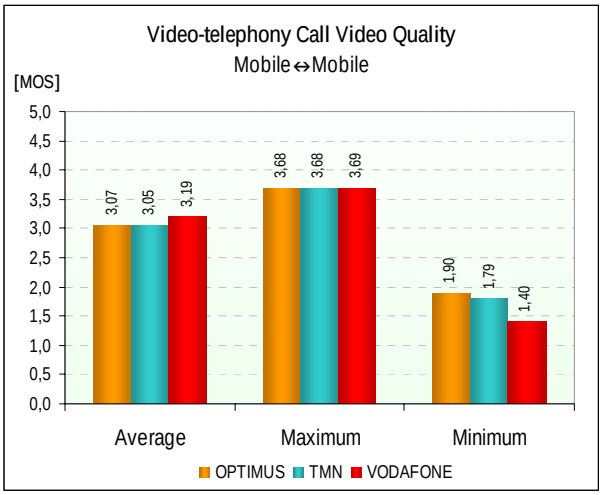
4.2.2.2.3 *VIDEO-TELEPHONY CALL VOICE QUALITY* INDICATOR



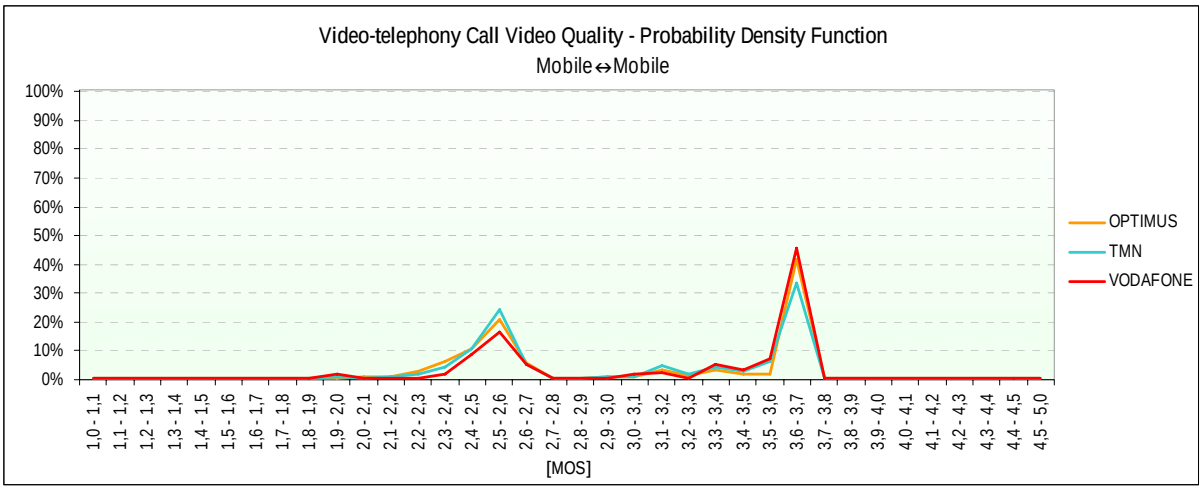
4.2.2.2.4 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



4.2.2.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



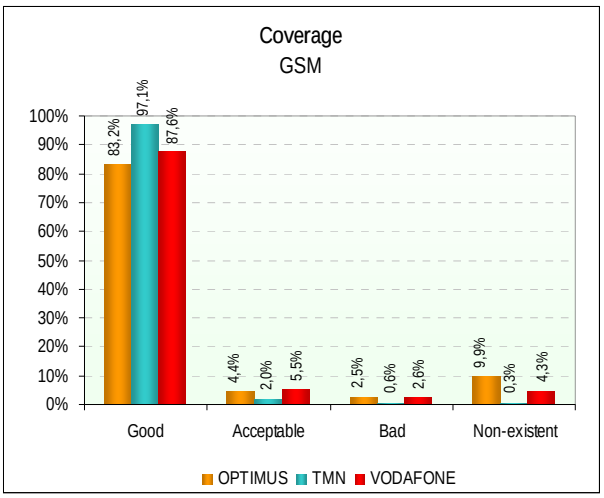
4.2.2.2.6 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



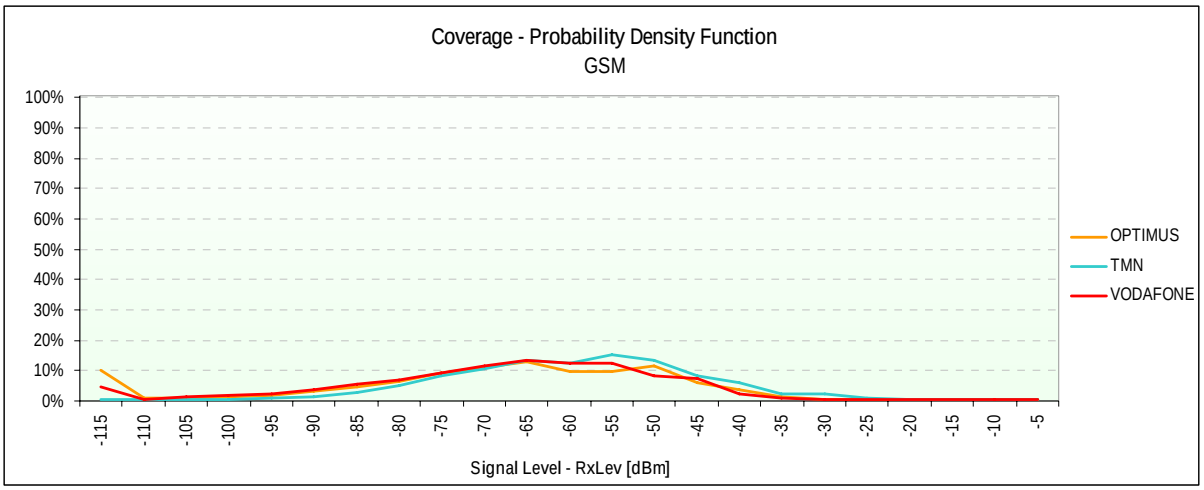
4.2.2.3 NETWORK COVERAGE

		GSM			WCDMA		
		OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Coverage	Number of Samples (Measurements)	58.424	57.960	58.424	23.400	23.222	23.393
	Signal Average Level [dBm]	-68	-57	-65	-82	-81	-93
	Signal Maximum Level [dBm]	-11	-12	-11	-34	-30	-35
	Signal Minimum Level [dBm]	-115	-115	-115	-126	-137	-137
	Standard Deviation [dBm]	21	14	18	20	17	22
	Good	83,2%	97,1%	87,6%	78,6%	80,2%	56,1%
	Acceptable	4,4%	2,0%	5,5%	8,2%	11,2%	9,7%
	Bad	2,5%	0,6%	2,6%	2,8%	4,2%	7,9%
	Non-existent	9,9%	0,3%	4,3%	10,4%	4,4%	26,3%

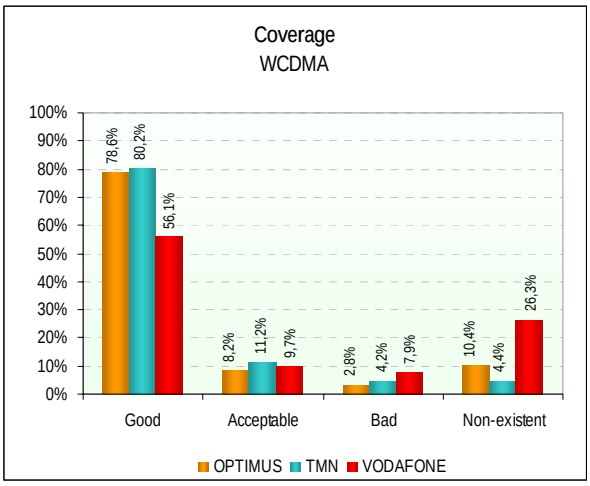
4.2.2.3.1 GSM



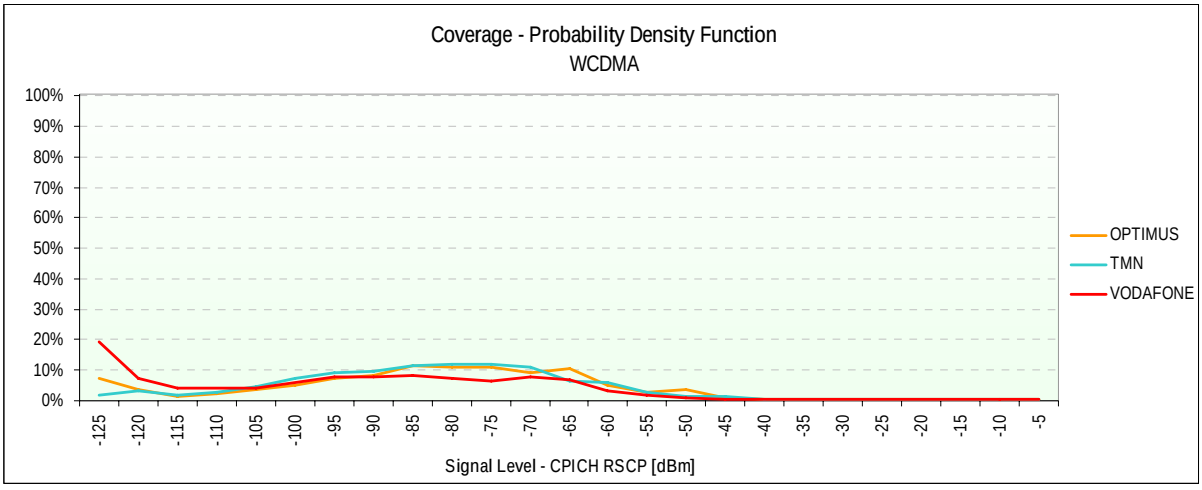
4.2.2.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.2.2.3.3 WCDMA



4.2.2.3.4 WCDMA – PROBABILITY DENSITY FUNCTION



4.2.3 GLOBAL

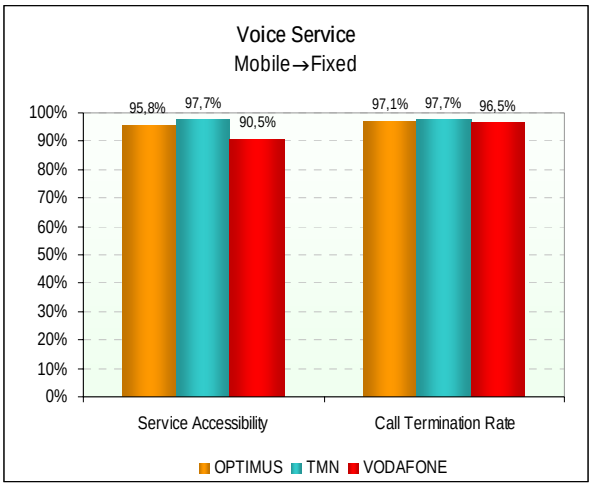
4.2.3.1 VOICE SERVICE (GSM)

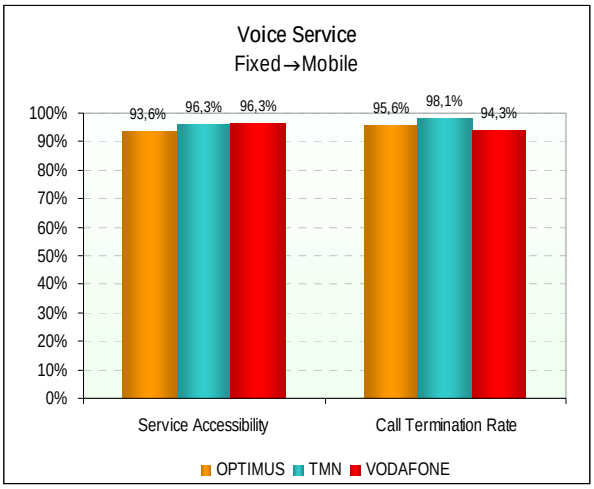
		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Calls Made	Number of Calls	213	218	221	215	221	218
	Dropped on Set Up	9	14	5	8	21	8
	Dropped during Call	6	9	5	4	7	12
	With Normal Termination	198	195	211	203	193	198
	Service Accessibility	95,8%	93,6%	97,7%	96,3%	90,5%	96,3%
	Call Termination Rate	97,1%	95,6%	97,7%	98,1%	96,5%	94,3%
Call Set Up	Number of Samples (Calls)	204	204	216	207	200	210
	Average Time [s]	5,4	6,1	5,8	7,5	5,1	7,1
	Maximum Time [s]	7,9	14,4	12,3	13,6	9,6	15,6
	Minimum Time [s]	4,6	5,2	5,3	6,3	4,5	6,0
	Standard Deviation [s]	0,4	0,8	0,7	1,0	0,5	0,9
Audio Quality	Number of Samples (Calls)	393	393	414	414	391	391
	Average [MOS]	3,80	3,80	3,91	3,88	3,79	3,79
	Maximum [MOS]	3,96	3,97	3,95	3,95	3,96	3,97
	Minimum [MOS]	3,39	3,20	3,45	3,19	3,30	2,81
	Standard Deviation [MOS]	0,10	0,12	0,05	0,11	0,10	0,13

		OPTIMUS		TMN		VODAFONE	
		Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile	Mobile→Fixed	Fixed→Mobile
Error	Service Accessibility	3,6%	4,1%	2,9%	3,5%	4,7%	3,4%
	Call Termination Rate	3,4%	3,8%	3,0%	2,9%	3,6%	4,1%
	Call Set Up Time	0,055	0,107	0,088	0,133	0,074	0,122
	Audio Quality [MOS]	0,010	0,011	0,005	0,011	0,009	0,013

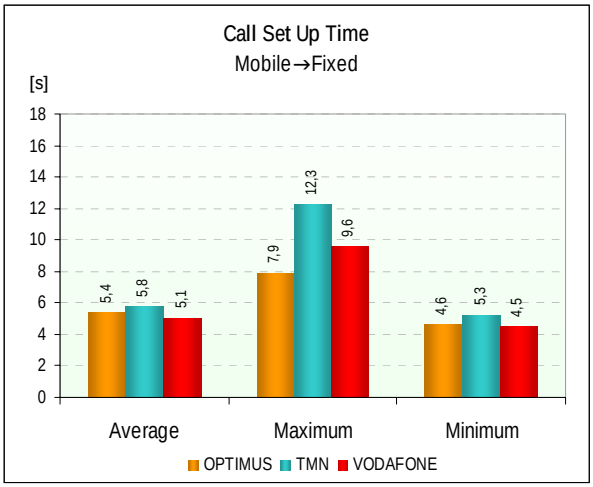
Confidence Level = 95 %

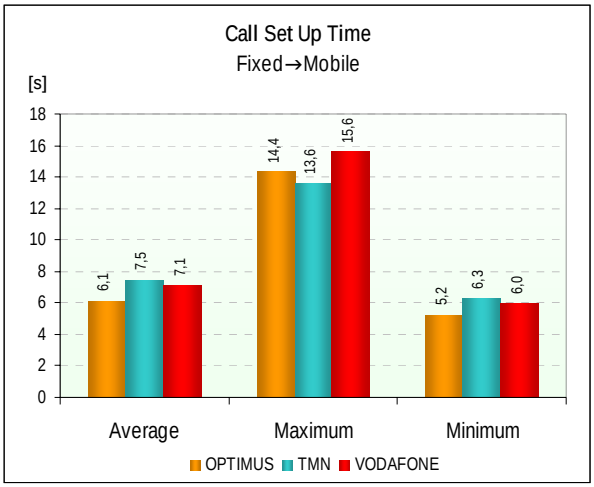
4.2.3.1.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



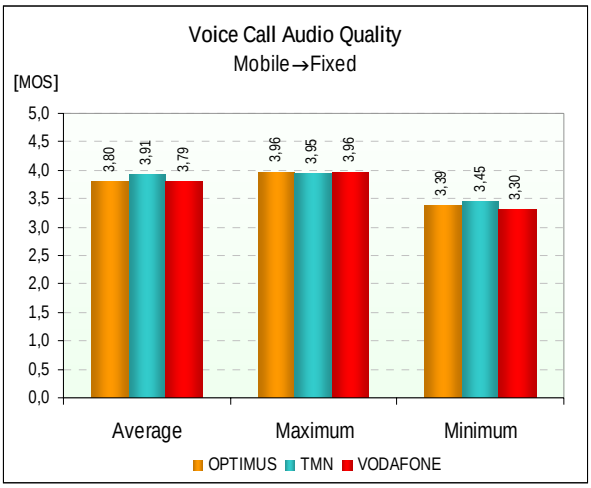


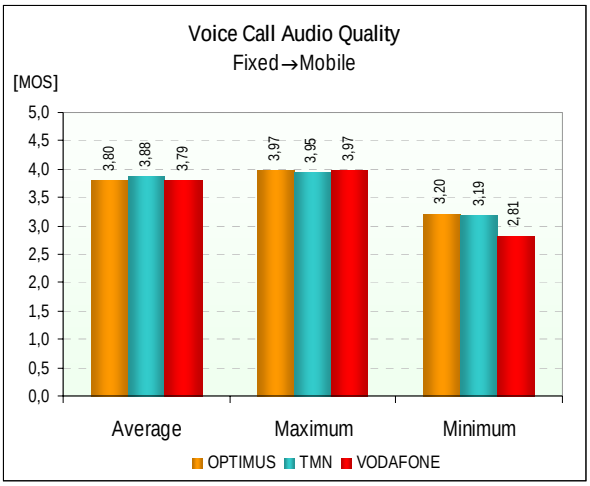
4.2.3.1.2 *CALL SET UP TIME INDICATOR*



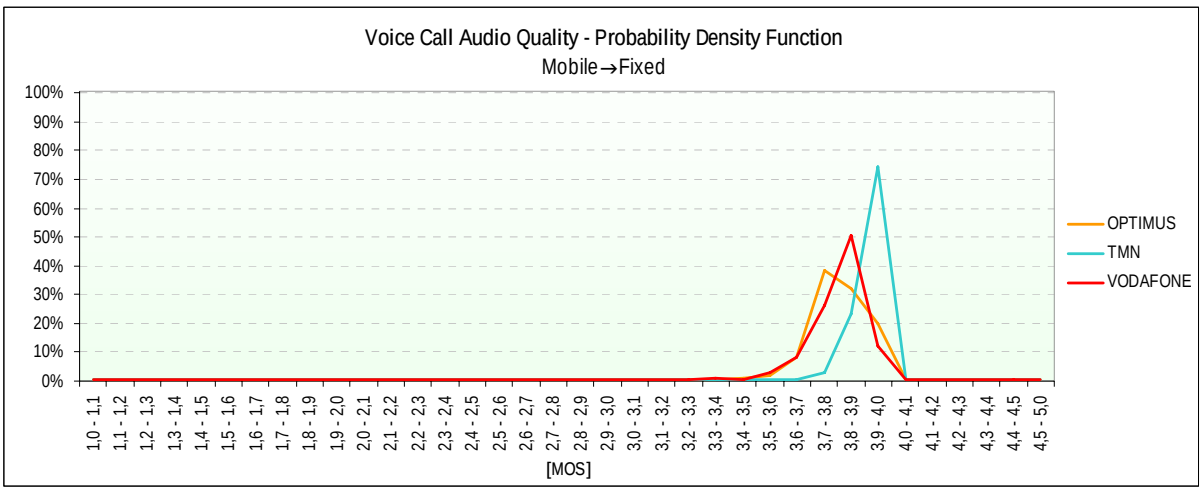


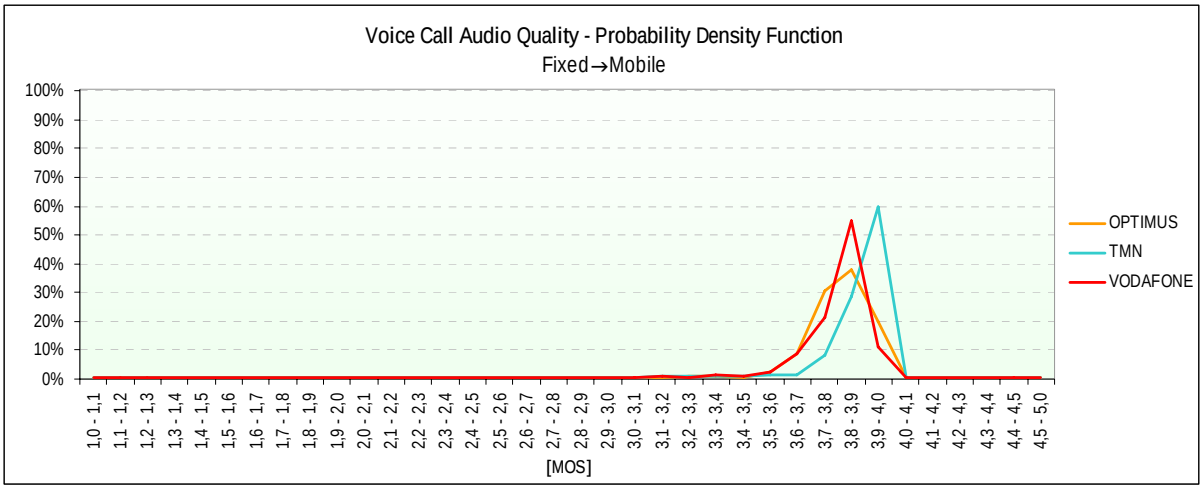
4.2.3.1.3 *VOICE CALL AUDIO QUALITY* INDICATOR





4.2.3.1.4 PROBABILITY DENSITY FUNCTION OF *THE VOICE CALL AUDIO QUALITY* INDICATOR



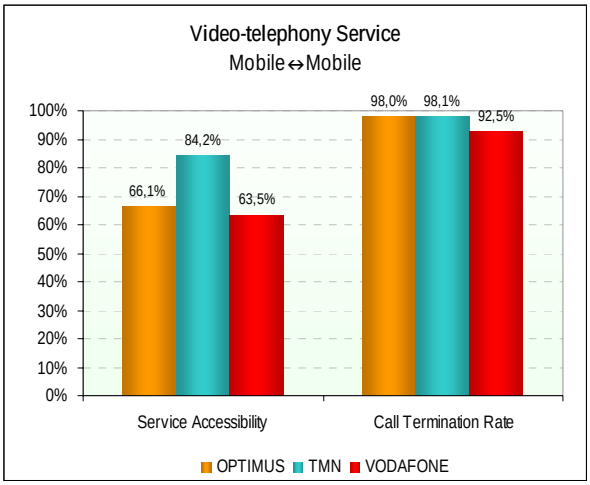


4.2.3.2 VIDEO-TELEPHONY SERVICE (UMTS)

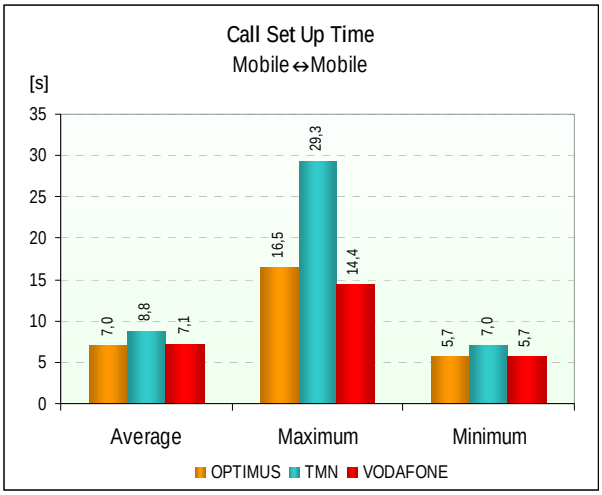
		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Calls Made	Number of Calls	375	379	378
	Dropped on Set Up	127	60	138
	Dropped during Call	5	6	18
	With Normal Termination	243	313	222
	Service Accessibility	66,1%	84,2%	63,5%
	Call Termination Rate	98,0%	98,1%	92,5%
Call Set Up	Number of Samples (Calls)	248	319	240
	Average Time [s]	7,0	8,8	7,1
	Maximum Time [s]	16,5	29,3	14,4
	Minimum Time [s]	5,7	7,0	5,7
	Standard Deviation [s]	1,5	2,0	1,5
Audio Quality	Number of Samples (Calls)	482	611	444
	Average [MOS]	3,83	3,86	3,90
	Maximum [MOS]	4,06	4,06	4,06
	Minimum [MOS]	1,00	1,00	1,00
	Standard Deviation [MOS]	0,37	0,45	0,36
Video Quality	Number of Samples (Calls)	480	610	444
	Average [MOS]	3,06	3,04	3,18
	Maximum [MOS]	3,68	3,69	3,69
	Minimum [MOS]	1,90	1,79	1,40
	Standard Deviation [MOS]	0,57	0,55	0,55

		OPTIMUS	TMN	VODAFONE
		Mobile↔Mobile	Mobile↔Mobile	Mobile↔Mobile
Error	Service Accessibility	5,0%	4,1%	5,1%
	Call Termination Rate	2,6%	2,2%	4,1%
	Call Set Up Time	0,191	0,217	0,187
	Audio Quality [MOS]	0,033	0,036	0,034
	Confidence Level = 95 %	0,051	0,044	0,051

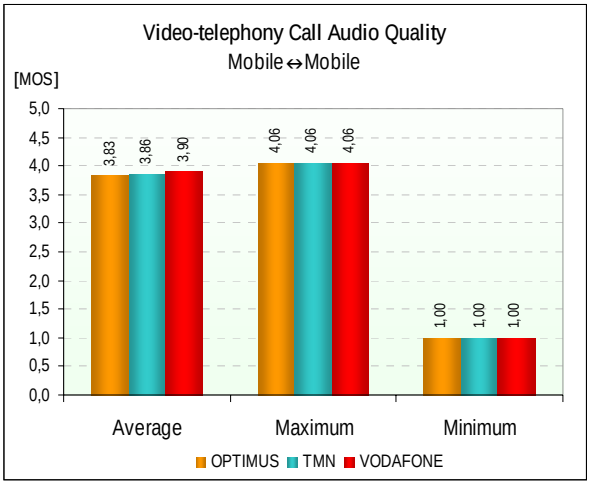
4.2.3.2.1 *SERVICE ACCESSIBILITY* AND *CALL TERMINATION RATE* INDICATORS



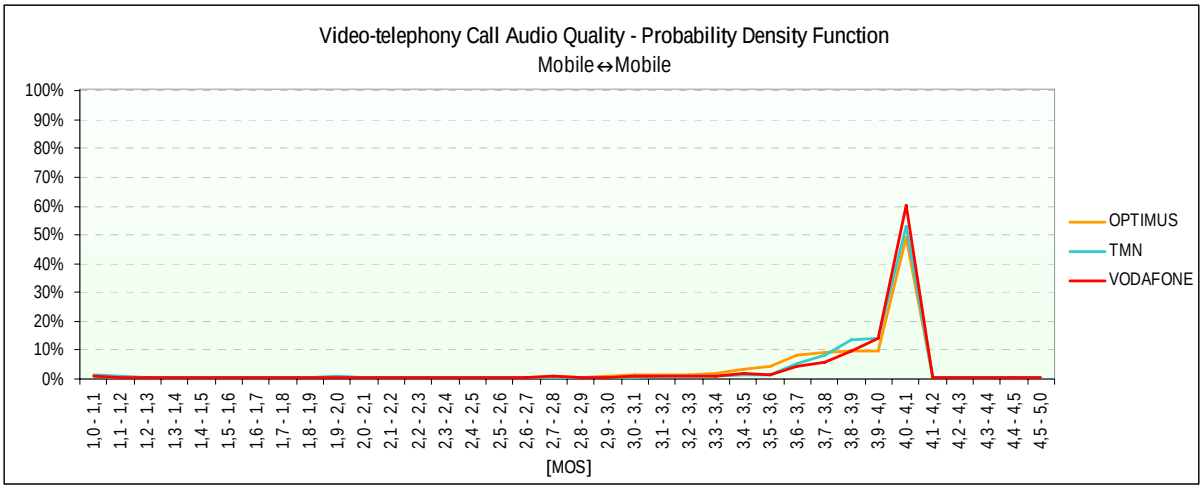
4.2.3.2.2 *CALL SET UP TIME* INDICATOR



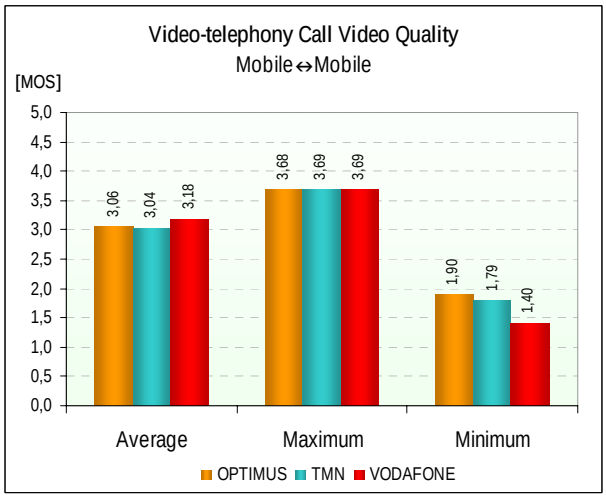
4.2.3.2.3 *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



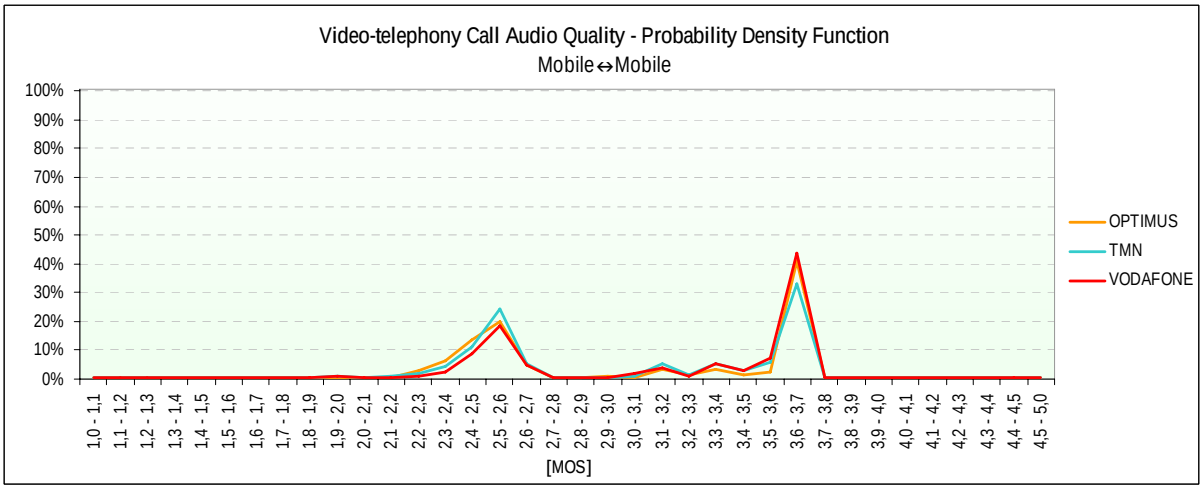
4.2.3.2.4 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL AUDIO QUALITY* INDICATOR



4.2.3.2.5 *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



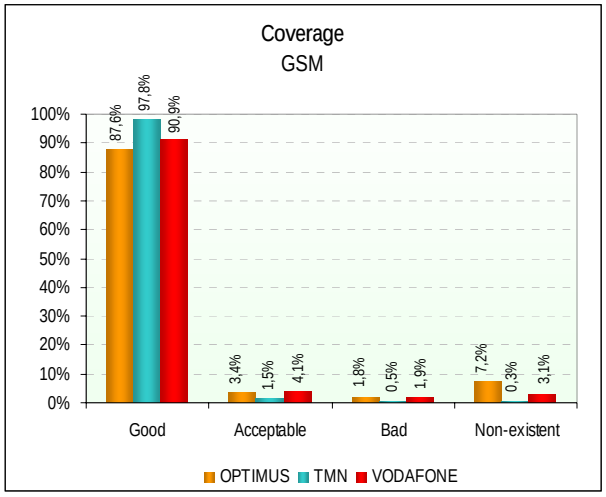
4.2.3.2.6 PROBABILITY DENSITY FUNCTION OF THE *VIDEO-TELEPHONY CALL VIDEO QUALITY* INDICATOR



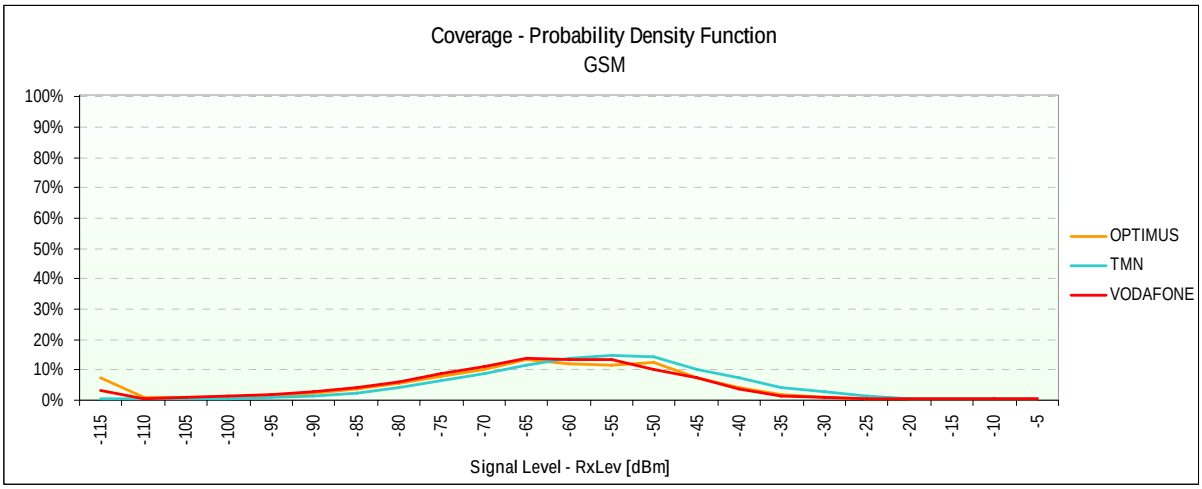
4.2.3.3 NETWORK COVERAGE

		GSM			WCDMA		
		OPTIMUS	TMN	VODAFONE	OPTIMUS	TMN	VODAFONE
Coverage	Number of Samples (Measurements)	80.673	80.281	80.673	32.310	32.138	32.305
	Signal Average Level [dBm]	-64	-55	-63	-80	-77	-87
	Signal Maximum Level [dBm]	-11	-7	-11	-34	-23	-29
	Signal Minimum Level [dBm]	-115	-115	-115	-126	-137	-137
	Standard Deviation [dBm]	20	14	17	18	17	22
	Good	87,6%	97,8%	90,9%	83,2%	85,1%	66,8%
	Acceptable	3,4%	1,5%	4,1%	7,1%	8,6%	8,3%
	Bad	1,8%	0,5%	1,9%	2,2%	3,1%	5,9%
	Non-existent	7,2%	0,3%	3,1%	7,5%	3,2%	19,0%

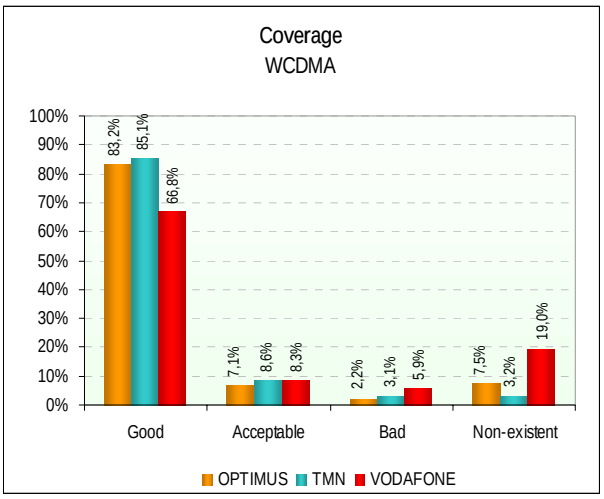
4.2.3.3.1 GSM



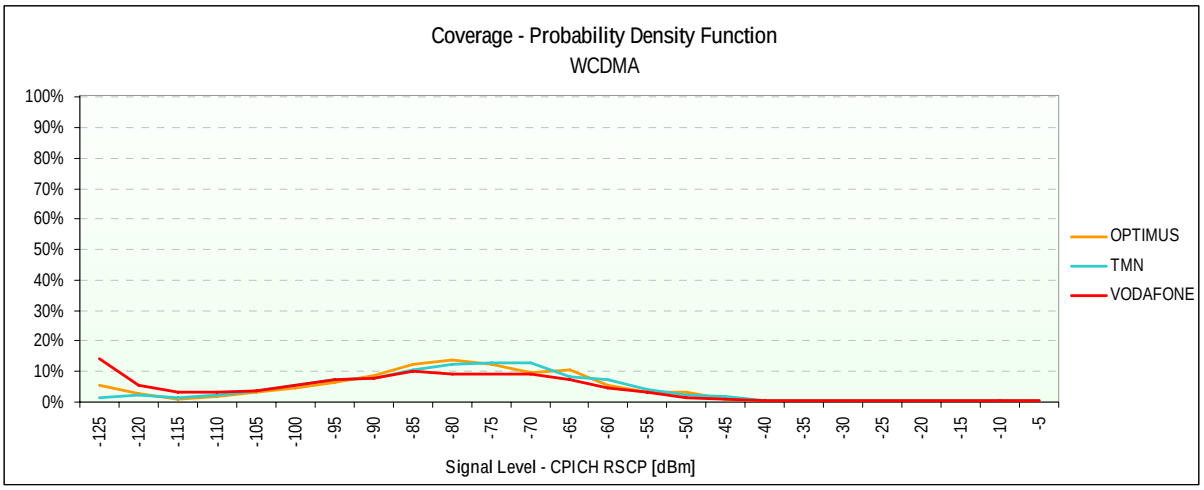
4.2.3.3.2 GSM – PROBABILITY DENSITY FUNCTION



4.2.3.3.3 WCDMA



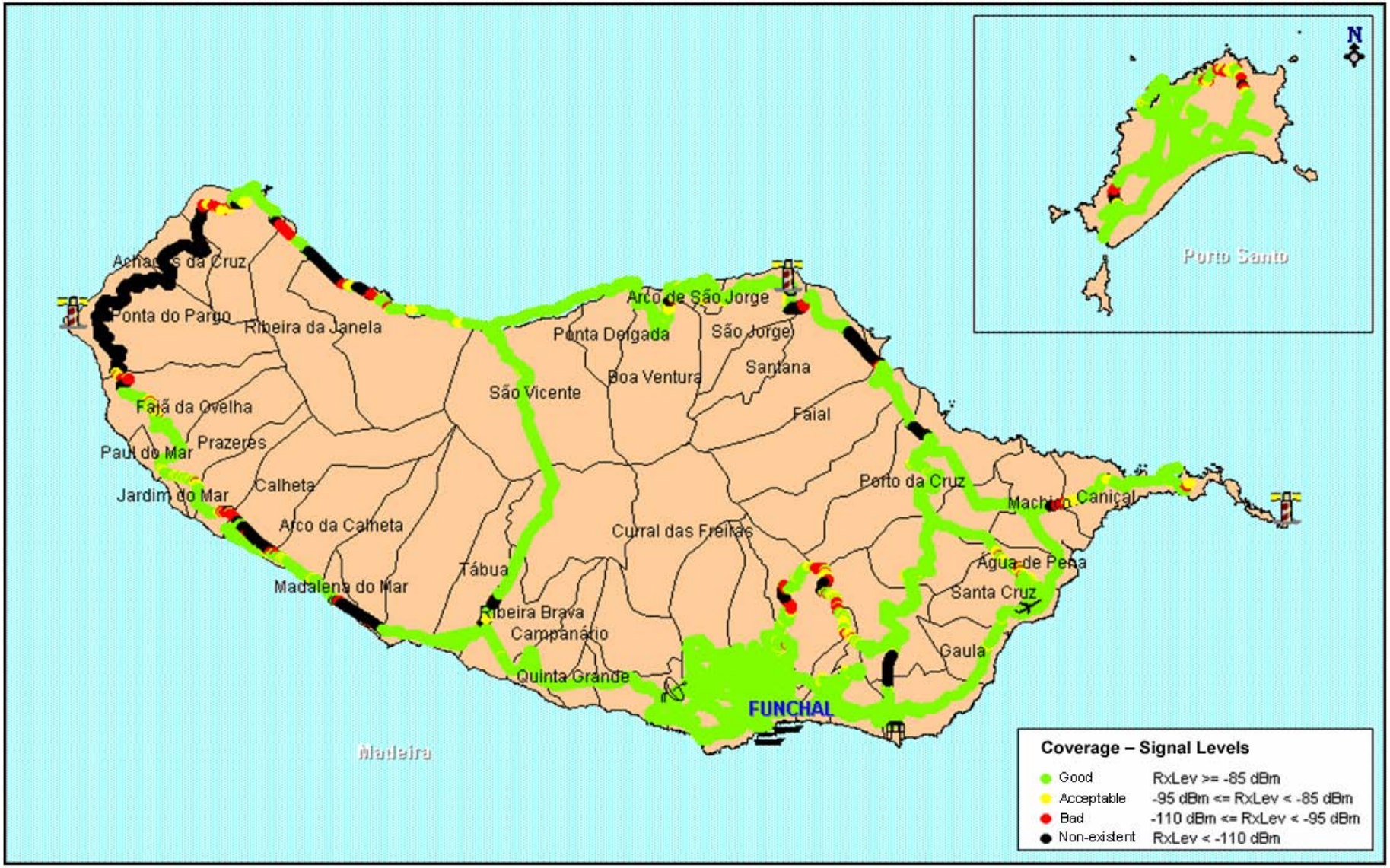
4.2.3.3.4 WCDMA – PROBABILITY DENSITY FUNCTION



4.2.3.3.5 COVERAGE MAPS

(Following pages)

OPTIMUS – GSM Coverage

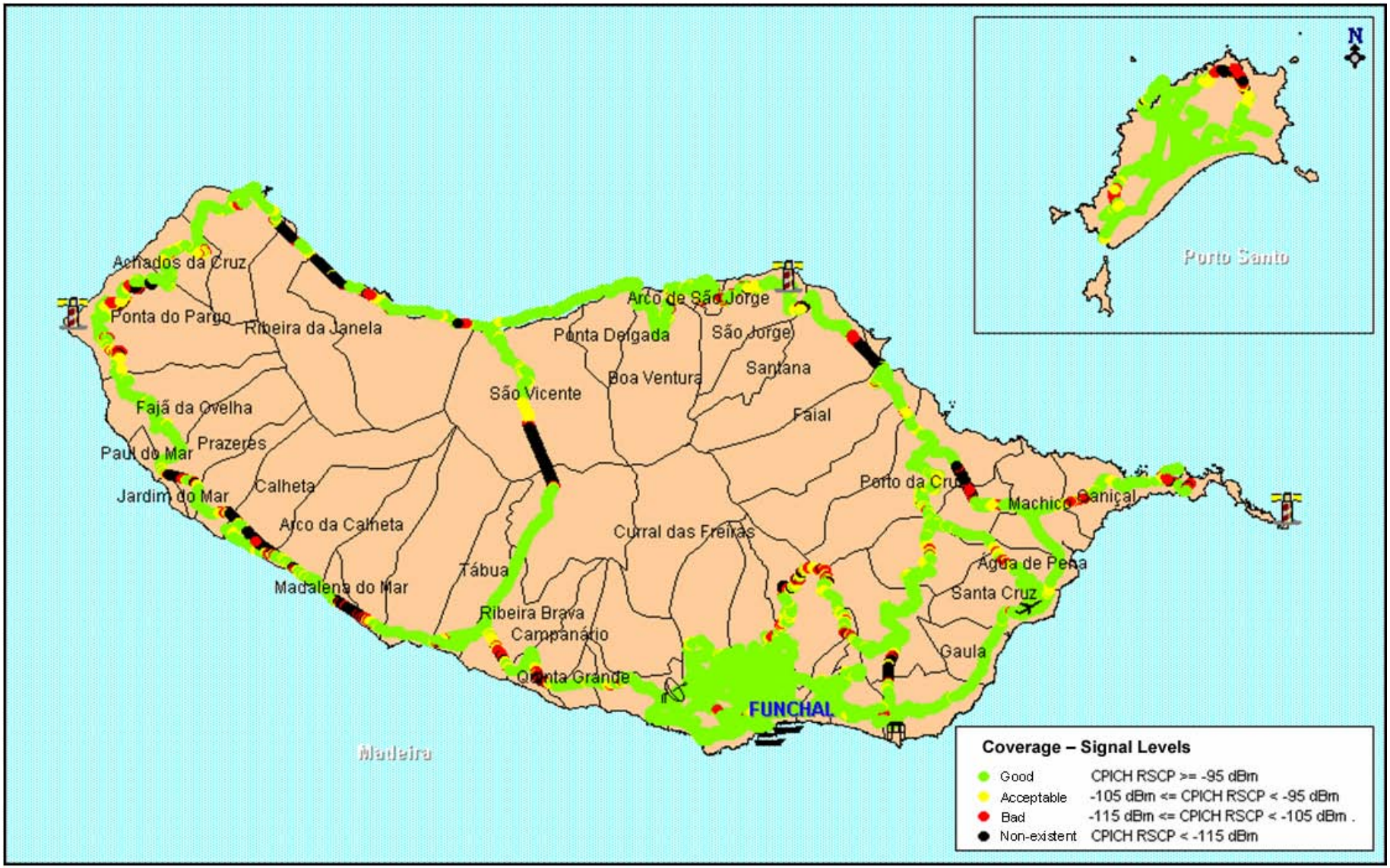


TMN – GSM Coverage

VODAFONE – GSM Coverage

OPTIMUS – WCDMA Coverage

TMN – WCDMA Coverage



VODAFONE – WCDMA Coverage