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GSM Mobile Networks

Quality of Service Survey

Global Study

(Mainland Portugal)

September / October 2005

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I EXECUTIVE SUMMARY

I.I FRAMEWORK

Autoridade Nacional de Comunicações (ANACOM) carried out during 2005 a survey on the quality of the GSM mobile services provided by operators OPTIMUS, VODAFONE and TMN, by analyzing technical parameters that translate the quality perception from the consumer's standpoint.

Although new approaches have been made to the performed analysis, such as studies of long calls and the evaluation of the short message service (SMS), the framework of the studies made during the last 5 years was kept for the "Global Study", providing an indicator of the evolution of GSM mobile networks.

The selection of locations for measurements in this "Global Study" followed criteria related namely with the highest service usage rates, i.e., larger urban agglomerations and main road axels. Another criterion of the same importance was the geographical distribution of locations as to include inland regions. This approach means a richer sample, avoiding the effect of results exclusively based on measurements on the most densely populated areas of Lisbon and the northern coastline.

Thus, tests were made in all of mainland Portugal's district capitals, and the collection area was broadened to the metropolitan areas of greatest Lisbon and Porto and to mainland's main road axels.

Regarding previous years, another road axel – *Lisbon-Leiria (A8)* – was added to the sample, and the road axel *Lisbon-Castelo Branco (A23)* was stretched to Guarda.

The population of the urban agglomerations that make up the selected sample stand for 41.7% of the total Portuguese population, according to the results of the last Census (2001 Census).

Data collection took place on working days, during normal working hours, between 19 September and 20 October 2005. 14,139 test calls were made, corresponding to about 213 hours of measurements along 8,693 kilometres.

Using a representative sample provided global results by operator, on urban agglomerations and on road axels, with a maximum precision error below 2%, for a 95% confidence level.

Three mobile network indicators of capital importance were analyzed, considering the quality perspective from the user/consumer's standpoint:

a. Coverage;

b. Accessibility;

c. Audio Quality.

This survey's methodology is based on automatic end-to-end tests, thus identifying the quality of service on the field and providing the most realistic perspective on the networks' performance, from the user's standpoint.

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

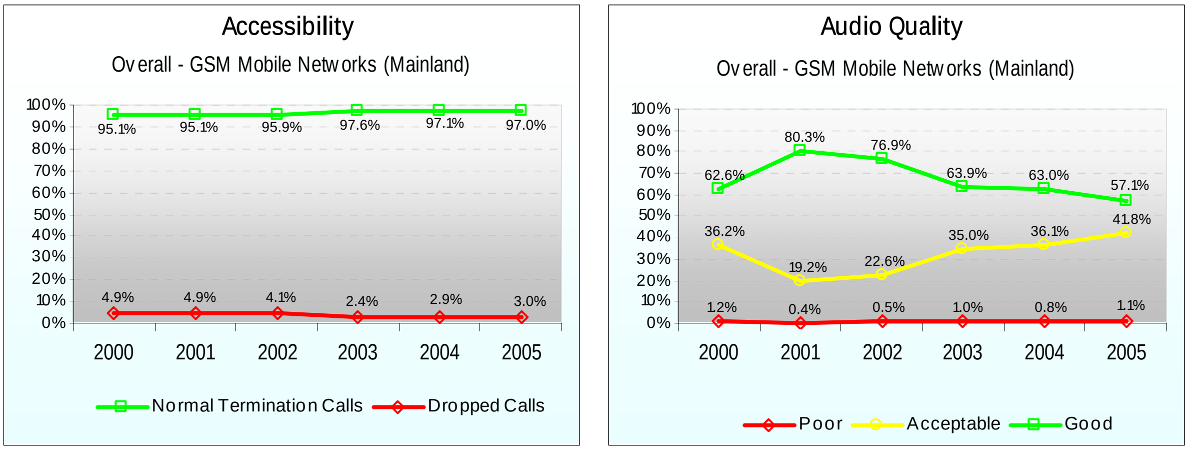
Technical and methodological options of this study directly influenced its results and must be taken into account when analyzing the results, namely the following:

- It used EFR Dual-Band terminal equipment;
- 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 3 operators and eliminating the subjectivity inherent to the human user;
- Tests were carried out in moving vehicles and with outdoor antennas;
- A compromise conversation time of 110 seconds was used to simultaneously analyze accessibility and audio quality in conversations. That time is close to the average conversation time of communications using the networks under analysis, in the second quarter of 2005, a criterion used to select the conversation time for the tests;
- The results of the study only reflect the behaviour of the networks on the places 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 CONCLUSIONS

This survey's results show that the GSM mobile networks have good coverage and performance levels.



Indicator precision, at a 95% confidence level:

	2000	2001	2002	2003	2004	2005
Accessibility	0.28%	0.22%	0.19%	0.24%	0.28%	0.28%
Poor Audio Quality	0.10%	0.05%	0.05%	0.12%	0.11%	0.12%
Acceptable Audio Quality	0.45%	0.29%	0.28%	0.55%	0.57%	0.58%
Good Audio Quality	0.45%	0.29%	0.28%	0.55%	0.58%	0.58%

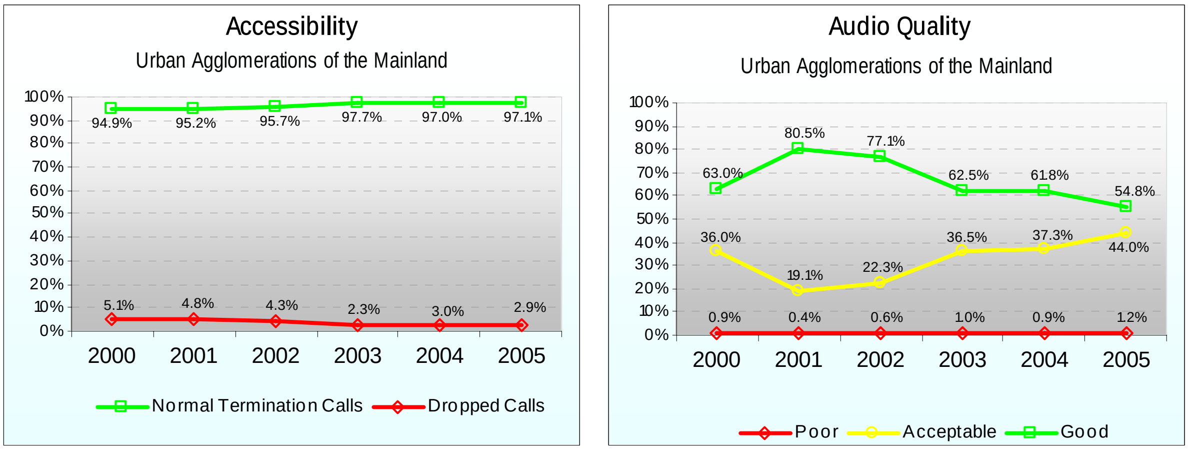
Figure 1 – Evolving performance of the GSM mobile networks, in Mainland Portugal.

The levels reached by the *Accessibility* indicator are very good, maintaining the trend of the latest years. 97% of test calls on urban agglomerations and road axels were successfully made and adequately kept during the conversational phase, ending normally by disconnection, at the end of the pre-established time.

Regarding the *Audio Quality* indicator, about 99% of test calls had good or acceptable average values. Only around 1% of the reached values were poor or bad. However, this indicator's decay trend since 2002 continues.

The performance of mobile networks concerning the *Accessibility* indicator does not show significant differences between urban agglomerations and road axels.

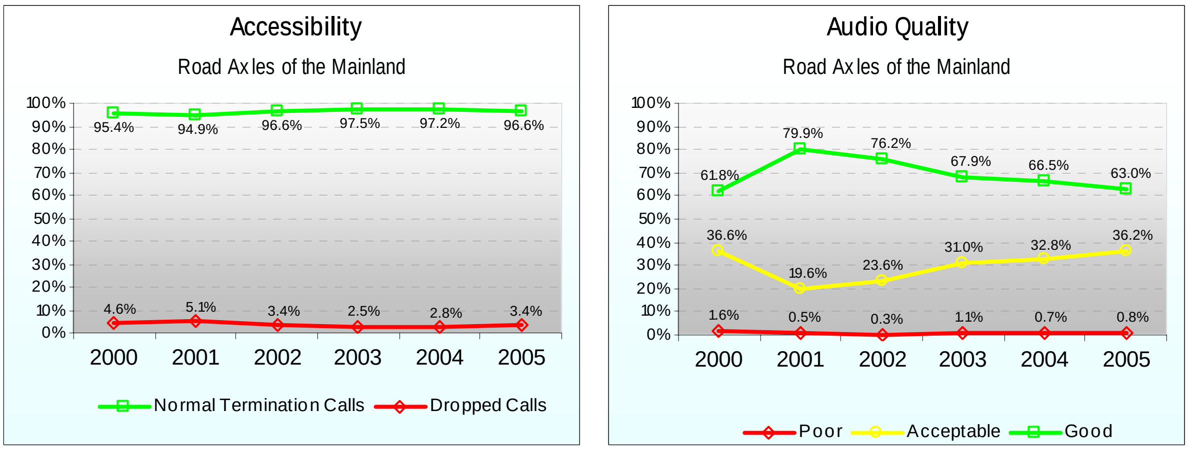
In the latest years, the *Audio Quality* indicator suffered a stronger degradation in urban agglomerations than on road axels. Thus, on the latest studies, this indicator's levels are worse in urban agglomerations.



Indicator precision, at a 95% confidence level:

	2000	2001	2002	2003	2004	2005
Accessibility	0.35%	0.25%	0.21%	0.28%	0.33%	0.33%
Poor Audio Quality	0.11%	0.06%	0.06%	0.13%	0.13%	0.15%
Acceptable Audio Quality	0.55%	0.33%	0.31%	0.65%	0.68%	0.69%
Good Audio Quality	0.56%	0.34%	0.32%	0.65%	0.68%	0.69%

Figure 2 – Evolving networks' performance in urban agglomerations.

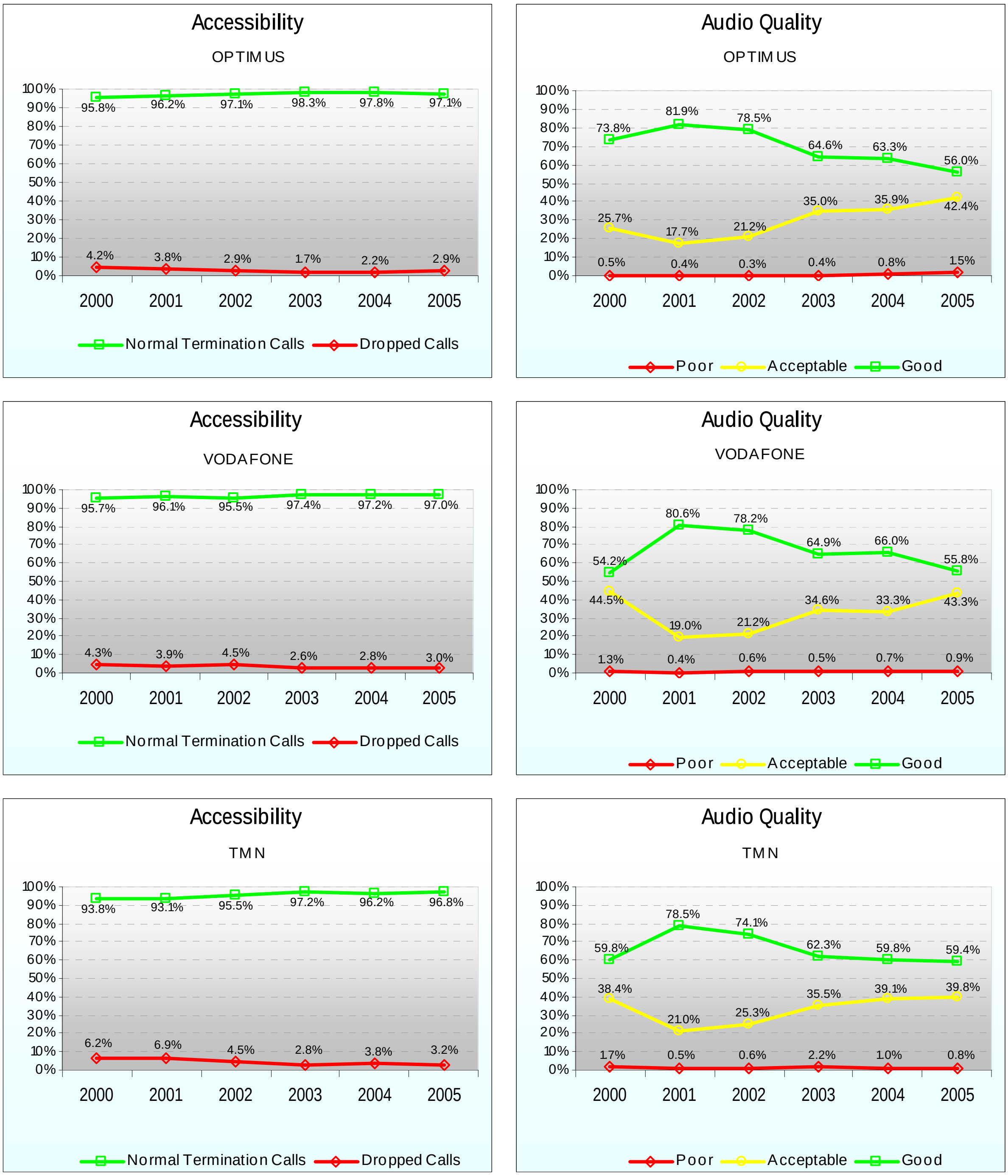


Indicator precision, at a 95% confidence level:

	2000	2001	2002	2003	2004	2005
Accessibility	0.45%	0.46%	0.39%	0.48%	0.53%	0.57%
Poor Audio Quality	0.19%	0.10%	0.08%	0.23%	0.19%	0.20%
Acceptable Audio Quality	0.75%	0.60%	0.65%	1.02%	1.08%	1.08%
Good Audio Quality	0.75%	0.61%	0.65%	1.03%	1.09%	1.08%

Figure 3 – Evolving networks' performance on road axels.

The Coverage indicator has good levels, both in the urban zones and on the road axels that were analyzed, as shown on the maps in the appendix.



Indicator precision, at a 95% confidence level:

	OPTIMUS						VODAFONE						TMN					
	2000	2001	2002	2003	2004	2005	2000	2001	2002	2003	2004	2005	2000	2001	2002	2003	2004	2005
Accessibility	0.45%	0.34%	0.27%	0.36%	0.42%	0.48%	0.45%	0.34%	0.34%	0.44%	0.48%	0.49%	0.53%	0.45%	0,34%	0.46%	0.55%	0.50%
Poor Audio Quality	0.11%	0.08%	0.07%	0.12%	0.18%	0.25%	0.18%	0.08%	0.09%	0.14%	0.17%	0.20%	0.21%	0.09%	0,09%	0.29%	0.21%	0.18%
Acceptable Audio Quality	0.70%	0.49%	0.48%	0.95%	0.99%	1.01%	0.80%	0.50%	0.48%	0.95%	0.98%	1.01%	0.78%	0.53%	0,51%	0.95%	1.01%	1.00%
Good Audio Quality	0.71%	0.49%	0.48%	0.95%	1.00%	1.01%	0.80%	0.51%	0.48%	0.95%	0.98%	1.01%	0.79%	0.53%	0,51%	0.97%	1.02%	1.00%

Figure 4 – Evolving overall networks' performance by operator.

The analysis to the global results of this survey shows that differences between operators are not significant for all of the studied indicators. The same is true for the analysis to the results in urban agglomerations.

On road axels, VODAFONE and TMN didn't show important performance differences regarding the several studied indicators. Neither did OPTIMUS regarding *Coverage* and *Accessibility*, although it had worse results in the *Audio Quality* indicator.

1 TECHNICAL ASPECTS

1.1 METHODOLOGY

1.1.1 FUNDAMENTALS

This study's methodology is based on 3 main aspects:

a) **End-to-end measurements**: Measurements are carried out between a mobile network terminal point and a fixed network terminal point;

b) **Impartiality**: Measurements are carried out simultaneously, in time and space, for the three operators (OPTIMUS, VODAFONE and TMN), thus guaranteeing equality of testing conditions;

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

1.1.2 QUALITY OF SERVICE INDICATORS

With this study three mobile network indicators of basic importance are analyzed, considering quality from the user's standpoint:

a) **Coverage**: Verification of the signal levels.

The testing and measurement equipment that was used measures the level of signal received by the mobile terminal. All these measurements are geo-referenced and then described on a map, thereby making it easy to view the coverage levels of each operator on the several studied routes.

Table 1 - Signal level

Signal Level (dBm)	
> -100	Coverage
> -110 ∧ <= -100	Poor Coverage
<= -110	No Coverage

b) Accessibility: It verifies a mobile network's ability to establish and maintain calls.

It analyses the ability to successfully establish voice communications between two ends, a mobile network terminal and a fixed network terminal, and the ability of networks to maintain this call during a pre-established period of time.

When it was not possible to establish communication or communication was dropped during the conversational phase, the cause for this failure or drop is identified.

c) Audio Quality: It verifies the perceptivity of conversations by means of establishing a successful connection and during a period of time.

In order to evaluate this indicator, the system simulates a telephone conversation between two users.

The method to evaluate audio quality, such as perceived by users, is based on the "E-Model" model, recommended by international bodies such as ETSI[1] (ETR 250) and ITU[2] (ITU-T *Recommendation* G.107). The reckoning of the *MOS* (*Mean Opinion Score*) index is based on this model.

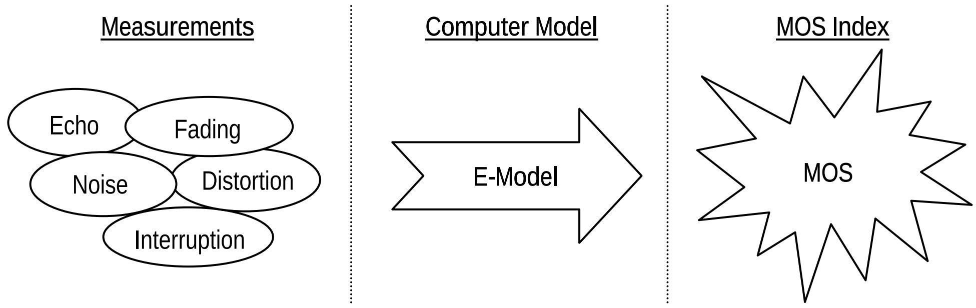


Figure 5 - Methodology used for audio quality monitoring.

The MOS scale quantifies the effort that it takes to understand a conversation. Its value is 0 when there is no communication and 5 when the communication is perfect. Values 0 and 5 are only theoretical and, therefore, they never show in the results of the measurements.

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[1] European Telecommunications Standards Institute.
[2] International Telecommunications Union.

Table 2 - MOS Scale

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

1.1.3 MEASUREMENT PROCEDURES

The tests are indeed the establishment and maintenance of voice calls under the following conditions:

1. Between GSM Mobile Network terminals and a Fixed Telephone Network (Mobile-to-Fixed);

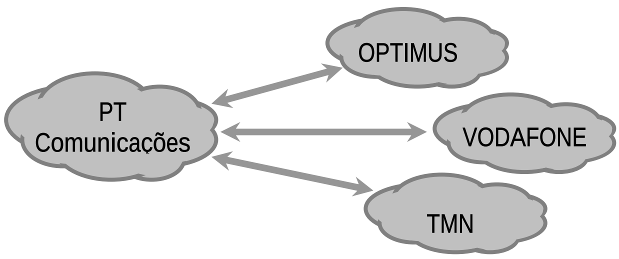
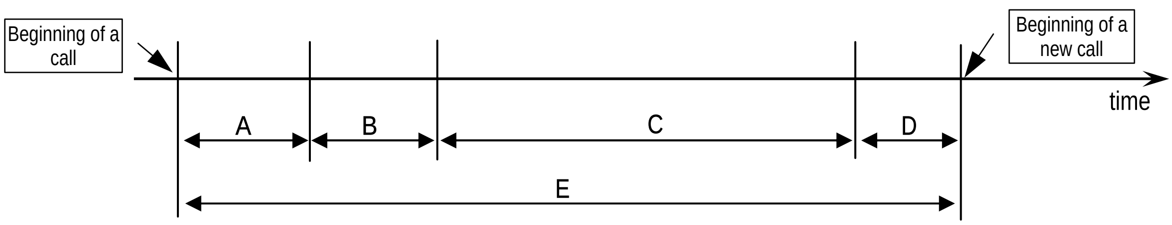


Figure 1 – Origin and Destination of test calls.

2. During the collection of measurements, the mobile terminal equipment (1 per operator) moves along the studied route;
3. Calls are made in alternation from mobile and fixed terminals;
4. The time gap between consecutive calls is 160 seconds;



A - Dialing and routing of call (between 5 and 15 seconds, depending on each network)
B - Verification of routing (about 15 seconds)
C - Conversation (programmable, 4 hours maximum)
D - Disconnection of call and interval between consecutive calls (10 seconds minimum)
E - Interval between calls

Figure 7 – Time structure of a voice call using the Datamat M366plus equipment.

5. After the successful establishment of a call, a conversational phase (a real conversation is simulated) takes place, with a maximum length of 5 minutes[3] (inferior if the call was dropped or the dialing time too long);

6. During the conversational phase, audio quality measurements (MOS) are made for each of the ends of the call.

1.2 TESTED AREAS

Since the purpose of this study is to monitor the GSM mobile service's quality, such as it is perceived by the consumer, it would be desirable to take measurements on every location where this kind of telecommunication is or might be used. In the extreme, we should take into account the whole of Portugal's territory, not forgetting the interior of buildings. Understandably, making tests on all these locations is unfeasible.

However, the purpose is not to make exhaustive measures, but to collect an adequate sample that can be used as an indicator of the networks' overall performance. In this sense, locations where the service is more intensely used were chosen, i.e., the larger urban agglomerations and the main road axels.

Table 3 – Road Axels

Road Axels	Approximate Length (Km)
Lisbon-Cascais-Sintra-Lisbon (A5 / IC19)	60
Lisbon-Porto (A1)	320
Lisbon-Castelo Branco-Guarda (A1 / A23)	300
Lisbon-Vila Real de Sto. António (A2 / A22)	337
Vila Real de Sto. António-Faro-Lagos (EN125)	138
Lisbon-Évora-Elvas (A2 / A6)	223
Porto-Braga-Valença-Viana do Castelo-Porto (A3 / IC1)	240
Porto-Bragança (A4 / IP4)	270
Aveiro- Viseu-Vilar Formoso (IP5 / A25)	211
Vila Real-Figueira da Foz (IP3 / A24 / A14)	230
Lisbon-Leiria (A8)	137
Total	2,466

However, the exclusive adoption of this criterion would lead to an excessive concentration of

[3] Value close to the average conversation time of communications using the analyzed networks in the 2nd quarter of 2005

measurements in the coastline's most densely populated areas, and therefore, besides this criterion, we decided to consider a geographical distribution of the locations, as a way to contemplate inland regions.

Thus, tests were made in all of the country's district capitals (Mainland), thereby broadening the collection area in the greatest Lisbon and Porto areas and in the main road axles.

Table 4 – Locations and corresponding population.

Territorial Unit		Resident Population	Present Population
Aveiro		73,136	76,415
Beja		35,659	37,001
Braga		163,981	165,048
Bragança		34,689	37,170
Castelo Branco		55,909	56,280
Coimbra		148,122	159,039
Évora		56,359	58,564
Faro		57,151	59,527
Guarda		43,759	44,593
Leiria		119,319	119,065
Portalegre		25,814	26,511
Santarém		63,418	63,106
Setúbal		113,480	112,227
Viana do Castelo		88,409	86,355
Vila Real		49,928	52,129
Viseu		93,259	93,041
	Total	1,222,392	1,246,071
Greatest Porto			
Porto		262,928	266,790
Gondomar		163,462	159,547
Maia		119,718	117,539
Matosinhos		166,275	162,671
Vila Nova de Gaia		287,597	280,466
	Total	999,980	987,013
Greatest Lisbon			
Lisbon		556,797	559,248
Amadora		174,788	169,507
Cascais		168,827	166,539
Loures		198,685	193,320
Oeiras		160,147	157,152
Sintra		363,556	351,976
Almada		159,550	156,746
Seixal		150,095	146,843
Odivelas		132,971	130,569
	Total	2,065,416	2,031,900
	Overall Total	4,287,788	4,264,984

Source: Instituto Nacional de Estatística (National Statistical Institute)

The population of the urban agglomerations that make up the selected sample stand for 41.7% of the total Portuguese population, according to the results of the last Census (2001).

1.3 SAMPLE SIZE

Using the results of the 2004 GSM mobile networks quality of service survey, the variation of the "*Accessibility*" and "*Audio Quality*" indicators was reckoned for urban agglomerations and road axles, by mobile operator.

The considered Universe was the "Number of GSM Calls" per year in Mainland Portugal which, for practical purposes of this calculation, is considered "*infinite"*, and an approach to the Normal distribution is used. Variances were then used for the estimation of the minimum sample size (test calls) needed to reach *E* precision, at a 95% confidence level, for urban agglomerations and road axles and operator.

$$n = \left[\frac{Z(\alpha / 2) * \sigma}{E} \right]^2$$

Several E precision indicators were tested for the "*Accessibility*" and "*Audio Quality*" indicators, until the best precision vs. sample size compromise solution was reached. The value found for *E* was +/-3%. It should be noted that after a certain point, the marginal gains resulting from increasing the sample size are almost null.

After converting the number of sample calls needed on urban agglomerations per time values, and considering the need to also analyze the "*Coverage*" indicator, option was made for making a full day of measurements in each urban agglomeration. In Greatest Lisbon and Greatest Porto, considering the areas under analysis and the resident population, data collection was widened do 5 and 2.5 days, respectively. On road axels, the option was to collect data in two series of runs.

Thus we managed to optimize the sample's size and the consequent data collection time.

1.4 DATA COLLECTION CONDITIONS

Data collection took place during normal hours on working days.

In the Greatest Lisbon and Greatest Porto regions, two measurement sessions were made on each day: from 8h00 to 11h30 and from 16h30 to 20h00. In the remaining urban agglomerations, measurement sessions took 3 hours and were made during mornings and afternoons.

Regarding road axels, data collection was made in two series of runs.

Table 5 – Length of measurement collection

		Hours of Measurements	
		Foreseen	Taken
Urban Agglomerations	Aveiro	6 h 00	6 h 15
	Beja	6 h 00	6 h 10
	Braga	6 h 00	6 h 13
	Bragança	6 h 00	6 h 06
	Castelo Branco	6 h 00	6 h 14
	Coimbra	6 h 00	6 h 10
	Évora	6 h 00	6 h 09
	Faro	6 h 00	6 h 28
	Guarda	6 h 00	6 h 15
	Leiria	6 h 00	6 h 04
	Portalegre	6 h 00	6 h 06
	Santarém	6 h 00	6 h 11
	Setúbal	6 h 00	6 h 07
	Viana do Castelo	6 h 00	6 h 11
	Vila Real	6 h 00	6 h 09
	Viseu	6 h 00	6 h 16
	Greatest Porto	17 h 30	18 h 00
	Greatest Lisbon	35 h 00	36 h 49
Road Axels	Lisbon-Cascais-Sintra-Lisbon (A5 / IC19)	7 h 00	7 h 11
	Lisbon-Porto (A1)	6 h 00	5 h 35
	Lisbon-Castelo Branco-Guarda (A1 / A23)	6 h 00	6 h 27
	Lisbon-Vila Real de Sto. António (A2 / A22)	6 h 00	6 h 05
	Vila Real de Sto. António-Faro-Lagos (EN125)	5 h 00	4 h 48
	Lisbon-Évora-Elvas (A2 / A6)	4 h 00	4 h 24
	Lisbon-Leiria (A8)	4 h 00	3 h 01
	Porto-Braga-Valença-Viana do Castelo-Porto (A3 / IC1)	5 h 30	6 h 01
	Porto-Bragança (A4 / IP4)	6 h 00	5 h 47
	Aveiro-Vilar Formoso (IP5 / A25)	5 h 30	4 h 46
	Vila Real-Figueira da Foz (IP3 / A24 / A14)	5 h 00	4 h 58
	Total	208 h 30	212 h 56

1.5 Testing and Measurement Equipment

For the conduction of these tests, ANACOM used the *DATAMAT M366plus* testing and measurement equipment, which is a Quality of Service analyzer for GSM networks.

1.6 POST-PROCESSING TOOLS

There is a software tool named “Report” that is associated to the M366plus equipment, which stores, organizes and generates statistics from the information previously collected by the measurement units.

The M366plus equipment includes a GPS receiver that enables geo-referencing for all of the measurements made. This information is handled by the “GeoReport” tool which, in parallel with a third tool – “MAPINFO” – enables viewing of the statistical information generated by “REPORT”, on digital geographical charts.

2 AGGREGATED RESULTS

2.1 DEFINITIONS

MOS	*Mean Opinion Score* – Audio quality rate of an end-to-end type of communication. Its value is 0 when there is no communication and 5 when the communication is perfect. Values 0 and 5 are only theoretical and thus never show on the measurements. Data presented refers to average values per call.
Routed Calls:	Telephone calls successfully established by the network and between the two relevant ends ("The call reached the called terminal").
Abandoned during Conversation:	Telephone calls successfully established by the network but dropped during the conversational phase.
Normal Termination:	Telephone calls successfully established by the network and terminated normally.
Not Routed Calls:	Telephone calls not established between the two relevant ends ("The call did not reach the called terminal").
Dropped Calls:	Calls that were dropped, either in the establishment phase or in the conversational phase.
Call Ending Causes:	Reasons leading to the communications drop.
No Service:	Out of service (no signal).
Congestion:	Network congestion.
Radio Link Failure:	Failure in the Radio link between the mobile terminal and the base station. It may occur when crossing a shadow zone of the network.
Other :	Other causes for call dropping.
RSSI Signal Level (dBm):	Received Signal Strength Indication – Indicates the strength of the signal received at the mobile terminal.
BCCH	*Broadcast Control Channel* – Routs information to all mobile terminals (MSs) served by a certain BTS (*Base Transceiver Station*). It is downlinked and carries several parameters, such as: CI (*Cell Identity*), LAC (*Local Area Code*), MCC (*Mobile Country Code*), MNC (*Mobile Network Code*), FH (*Frequency Hopping*) Algorithm.
FTS	Fixed Telephone Service.
PSTN	Public Switched Telephone Network.

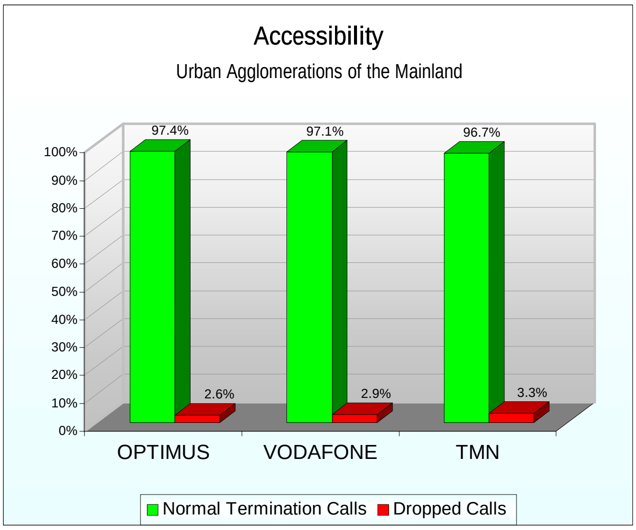
2.2 URBAN AGGLOMERATIONS

Indicator precision, at a 95% confidence level:

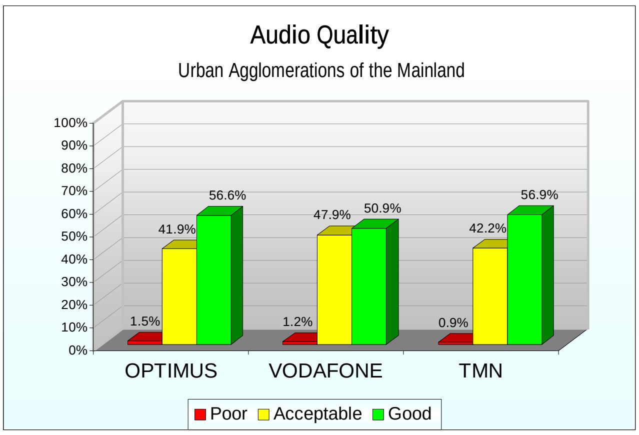
	OPTIMUS	VODAFONE	TMN
Accessibility	0.53%	0.56%	0.60%
Poor Audio Quality	0.29%	0.26%	0.22%
Acceptable Audio Quality	1.18%	1.20%	1.19%
Good Audio Quality	1.19%	1.20%	1.19%

2.2.1 ACCESSIBILITY

			OPTIMUS	VODAFONE	TMN
Calls Made		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	3,407 100%	3,409 100%	3,413 100%
Routed Calls		Total	3,356 98.5%	3,349 98.2%	3,347 98.1%
Routed Calls		Abandoned During Conversation	36 1.1%	39 1.1%	46 1.3%
Routed Calls		Normal Termination Calls	3,320 97.4%	3,310 97.1%	3,301 96.7%
Non-Routed Calls			51 1.5%	60 1.8%	66 1.9%
Dropped Calls		Total	87 2.6%	99 2.9%	112 3.3%
Dropped Calls	Call Ending Causes	No Service	1 0.0%	0 0.0%	2 0.1%
Dropped Calls	Call Ending Causes	Congestion	44 1.3%	63 1.8%	48 1.4%
Dropped Calls	Call Ending Causes	Radio Link Failure	13 0.4%	13 0.4%	9 0.3%
Dropped Calls	Call Ending Causes	Other	29 0.9%	23 0.7%	53 1.6%



2.2.2 AUDIO QUALITY



		OPTIMUS	VODAFONE	TMN
Calls with Measurements	Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements	Total	6,683 100%	6,670 100%	6,665 100%
Audio Quality (MOS)	Poor	101 1.5%	77 1.2%	58 0.9%
Audio Quality (MOS)	Acceptable	2,799 41.9%	3,197 47.9%	2,815 42.2%
Audio Quality (MOS)	Good	3,783 56.6%	3,396 50.9%	3,792 56.9%

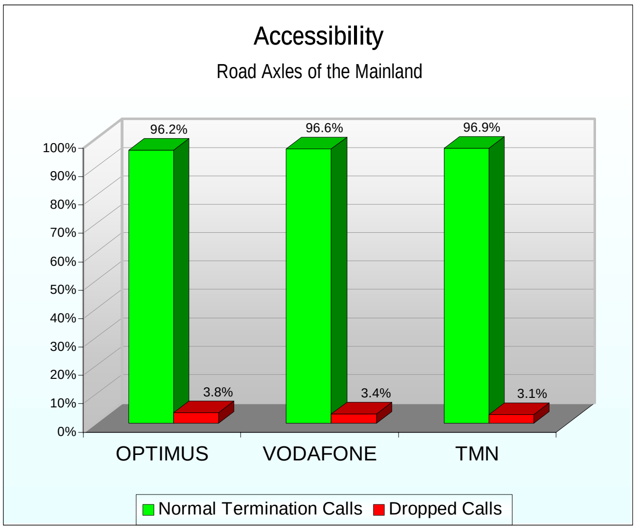
2.3 ROAD AXELS

Indicator precision, at a 95% confidence level:

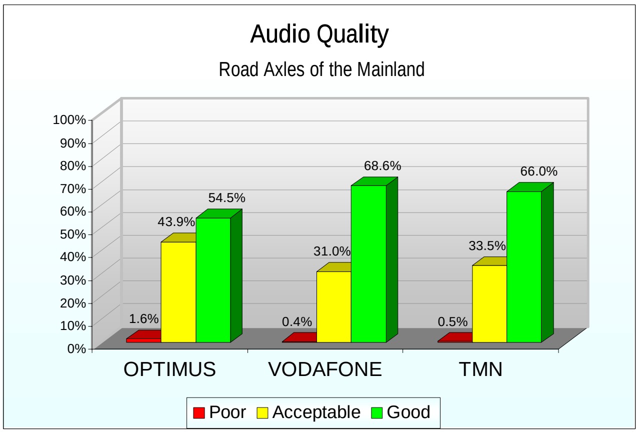
	OPTIMUS	VODAFONE	TMN
Accessibility	1.03%	0.98%	0.94%
Poor Audio Quality	0.49%	0.24%	0.26%
Acceptable Audio Quality	1.93%	1.80%	1.83%
Good Audio Quality	1.94%	1.80%	1.83%

2.3.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	1,304 100%	1,303 100%	1,303 100%
Routed Calls		Total	1,275 97.8%	1,278 98.1%	1,285 98.6%
Routed Calls		Abandoned During Conversation	20 1.5%	19 1.5%	22 1.7%
Routed Calls		Normal Termination Calls	1,255 96.2%	1,259 96.6%	1,263 96.9%
Non-Routed Calls			29 2.2%	25 1.9%	18 1.4%
Dropped Calls		Total	49 3.8%	44 3.4%	40 3.1%
Dropped Calls	Call Ending Causes	No Service	0 0.0%	0 0.0%	0 0.0%
Dropped Calls	Call Ending Causes	Congestion	29 2.2%	31 2.4%	21 1.6%
Dropped Calls	Call Ending Causes	Radio Link Failure	6 0.5%	8 0.6%	3 0.2%
Dropped Calls	Call Ending Causes	Other	14 1.1%	5 0.4%	16 1.2%



2.3.2 AUDIO QUALITY



	Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements	Total	2,535 100%	2,545 100%	2,562 100%
Audio Quality (MOS)	Poor	40 1.6%	10 0.4%	12 0.5%
Audio Quality (MOS)	Acceptable	1,114 43.9%	790 31.0%	859 33.5%
Audio Quality (MOS)	Good	1,381 54.5%	1,745 68.6%	1,691 66.0%

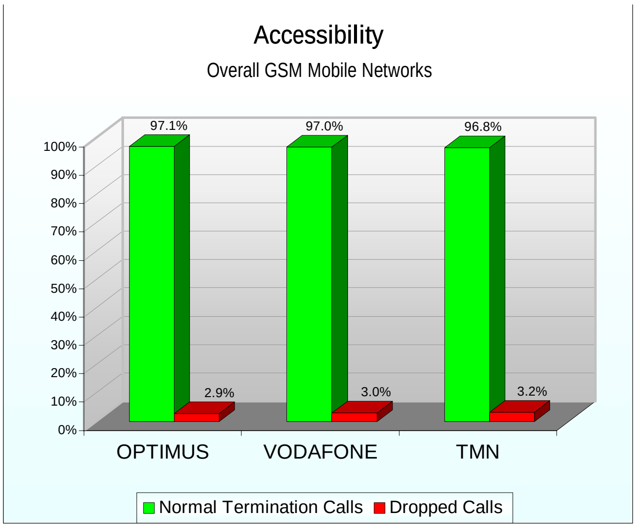
2.4 Overall

Indicator precision, at a 95% confidence level:

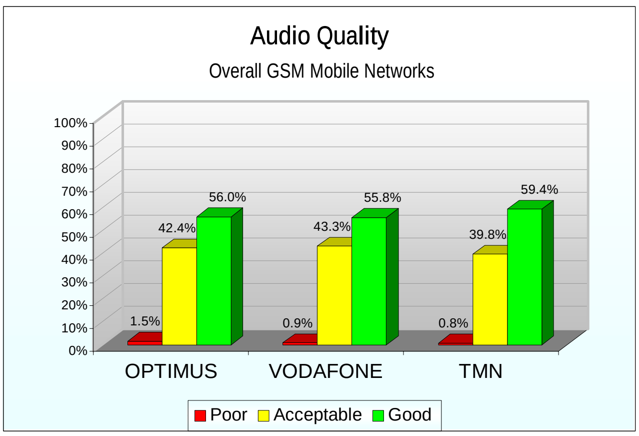
	OPTIMUS	VODAFONE	TMN
Accessibility	0.48%	0.49%	0.50%
Poor Audio Quality	0.25%	0.20%	0.18%
Acceptable Audio Quality	1.01%	1.01%	1.00%
Good Audio Quality	1.01%	1.01%	1.00%

2.4.1 Accessibility

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	4,711 100%	4,712 100%	4,716 100%
Routed Calls		Total	4,631 98.3%	4,627 98.2%	4,632 98.2%
Routed Calls		Abandoned During Conversation	56 1.2%	58 1.2%	68 1.4%
Routed Calls		Normal Termination Calls	4,575 97.1%	4,569 97.0%	4,564 96.8%
Non-Routed Calls			80 1.7%	85 1.8%	84 1.8%
Dropped Calls		Total	136 2.9%	143 3.0%	152 3.2%
Dropped Calls	Call Ending Causes	No Service	1 0.0%	0 0.0%	2 0.0%
Dropped Calls	Call Ending Causes	Congestion	73 1.5%	94 2.0%	69 1.5%
Dropped Calls	Call Ending Causes	Radio Link Failure	19 0.4%	21 0.4%	12 0.3%
Dropped Calls	Call Ending Causes	Other	43 0.9%	28 0.6%	69 1.5%



2.4.2 Audio Quality



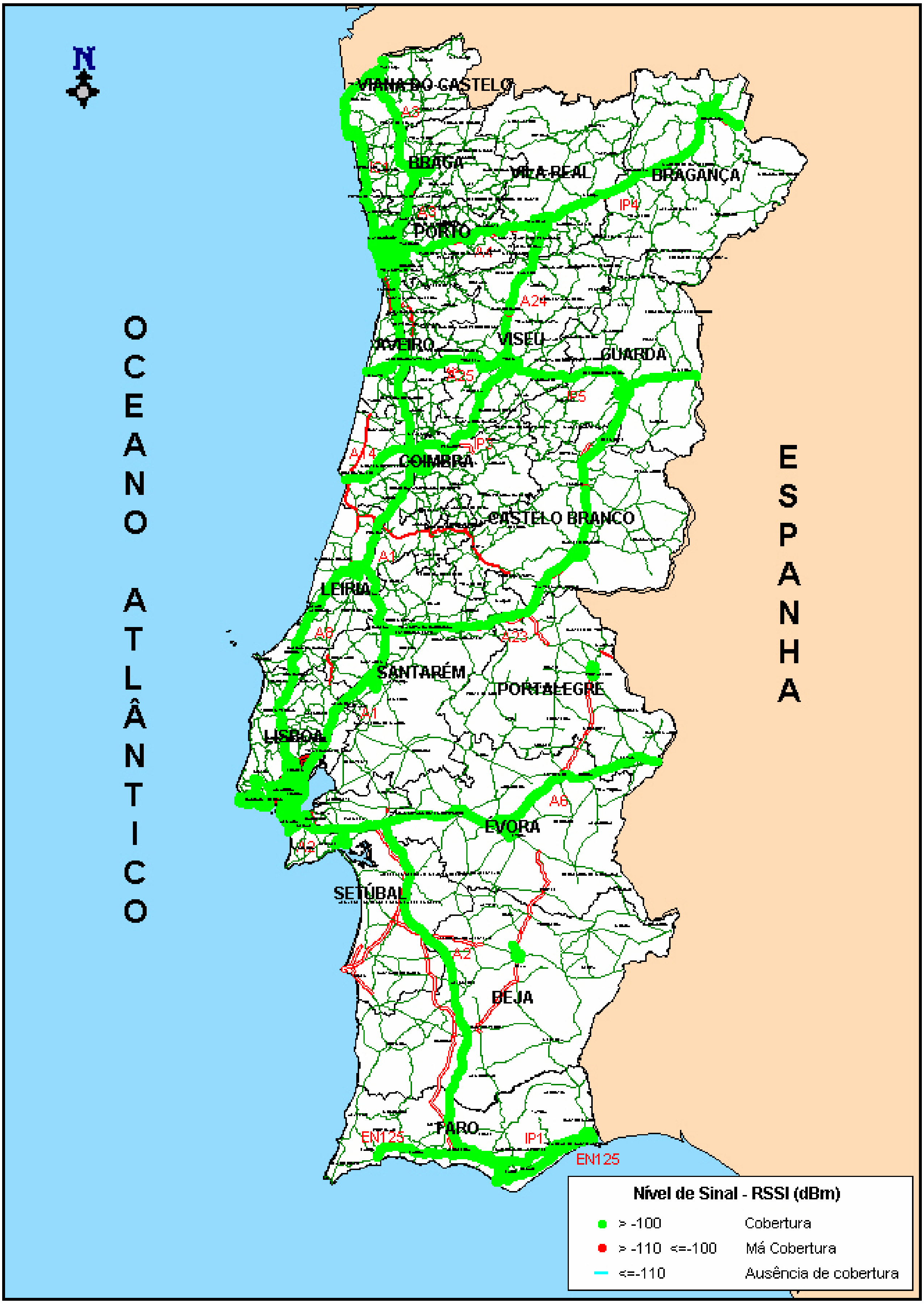
	Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements	Total	9,218 100%	9,215 100%	9,227 100%
Audio Quality (MOS)	Poor	141 1.5%	87 0.9%	70 0.8%
Audio Quality (MOS)	Acceptable	3,913 42.4%	3,987 43.3%	3,674 39.8%
Audio Quality (MOS)	Good	5,164 56.0%	5,141 55.8%	5,483 59.4%

2.4.3 Coverage

(Following pages)

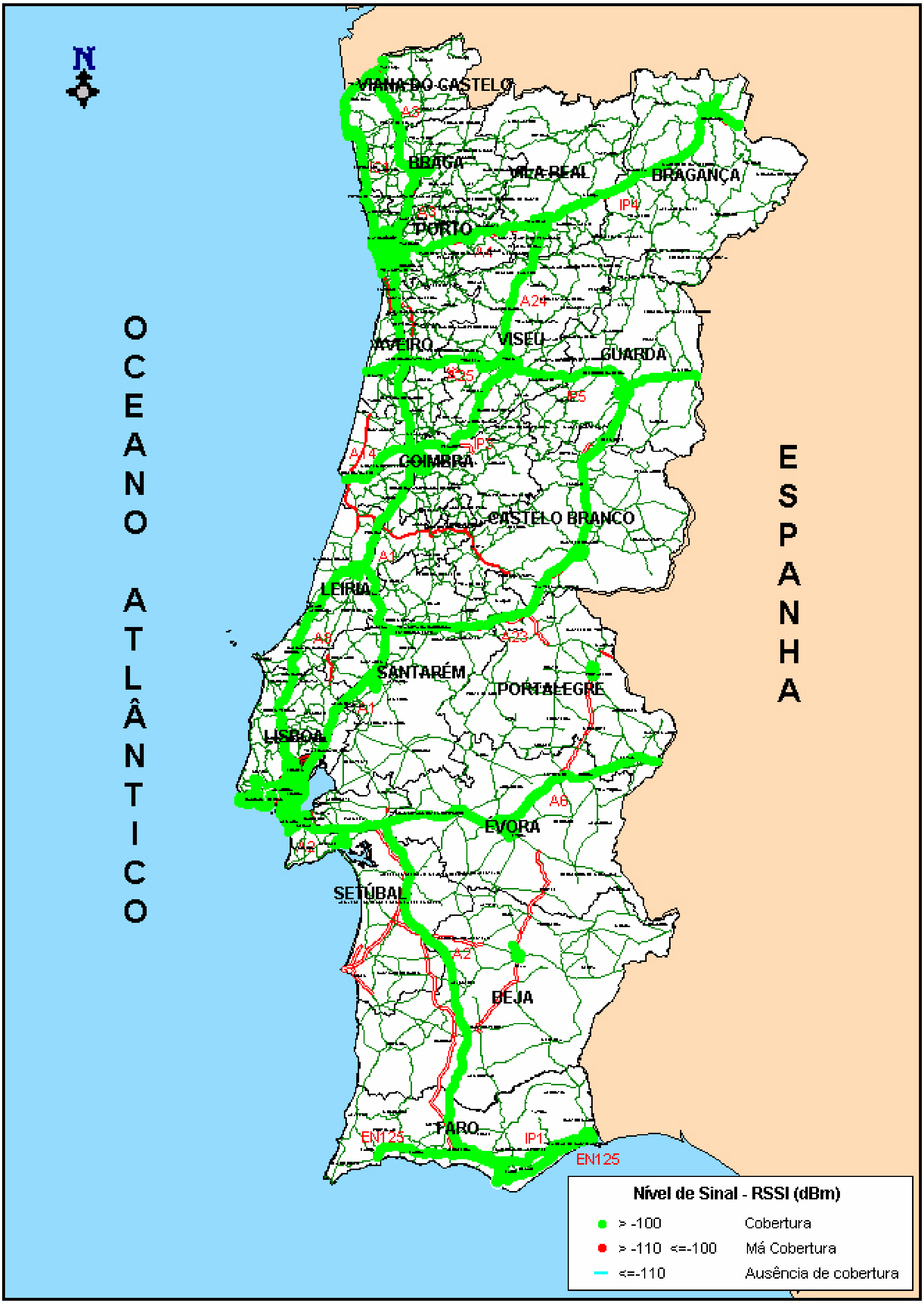
MAINLAND PORTUGAL

OPTIMUS – PSTN



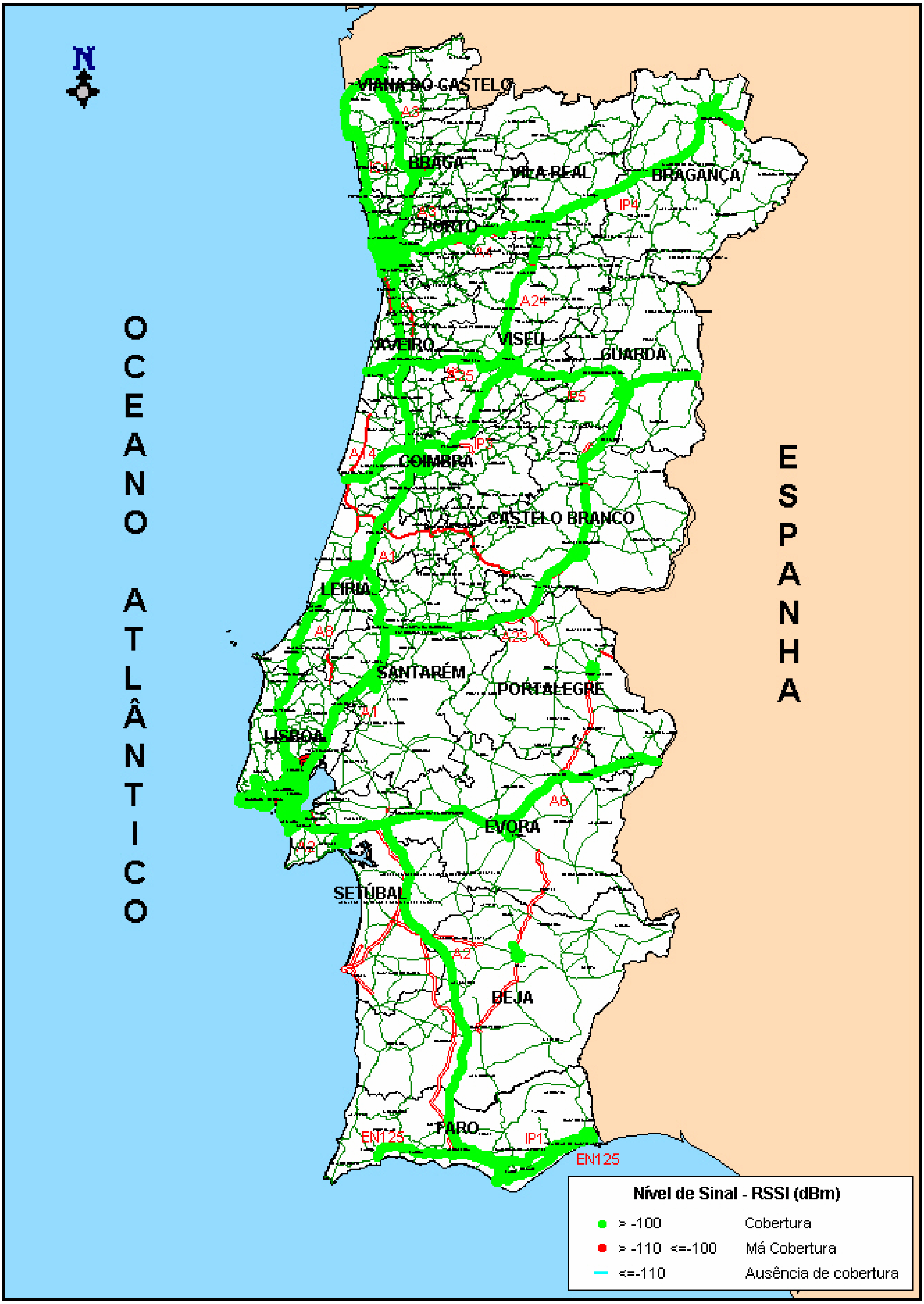
MAINLAND PORTUGAL

VODAFONE – PSTN



MAINLAND PORTUGAL

TMN – PSTN



White