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http://www.anacom.pt/template12.jsp?categoryId=163202

GSM Mobile Networks

Quality of Service Survey

Rail Axels

November 2005

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I EXECUTIVE SUMMARY

I.I FRAMEWORK

In the framework of the activities planned for 2005, ANACOM carried out a survey on the quality of the GSM mobile services provided by the Portuguese operators on rail axels, by analyzing technical parameters that translate the quality perception from the Consumer's standpoint.

The survey analyzed the main Portuguese rail axels: *Braga-Lisbon*, *Lisbon-Faro* and *Lisbon-Coimbra-Guarda*.

The measurements took place on working days, from 15 to 21 November 2005. 3,038 test calls were made, corresponding to 46 hours and 30 minutes of measurements along 2,185 kilometres.

Global results by operator have maximum precision errors below 3.03%, 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, in order to identify 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 third quarter of 2005, a criterion used to select the conversation time for the tests;

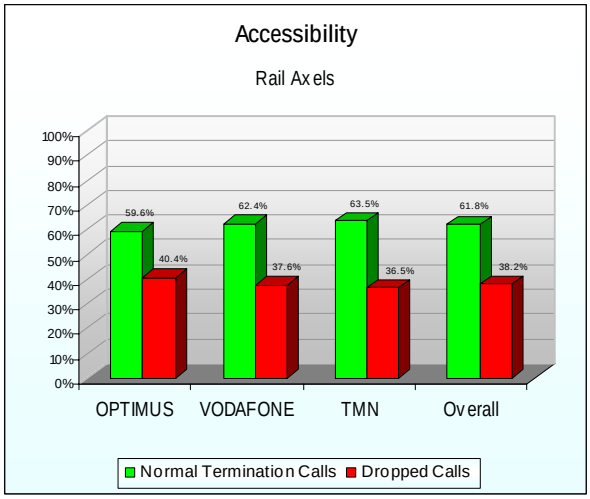
- The results of the study only reflect the behaviour of the networks on the places and moments of the measurements;

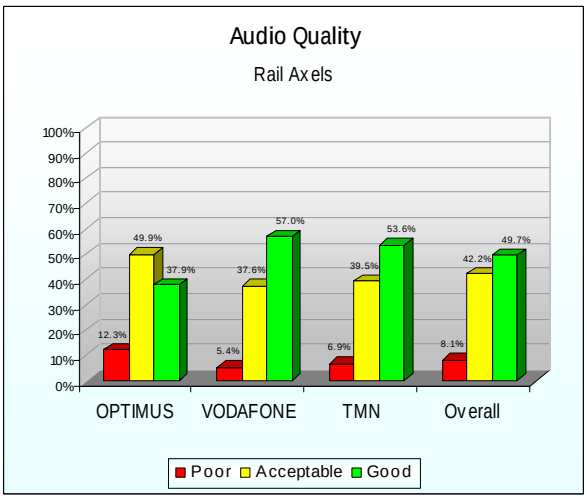
- On the other hand, operators are permanently improving their networks. The technical interventions necessary for these improvements can cause momentary degradations of the service in the geographic area of intervention.

I.II MAIN CONCLUSIONS

This survey's results show that the GSM mobile networks have a not satisfactory performance on rail axels.

Only 61.8% of test calls were successfully made and adequately kept, and ended normally (by disconnection) at the end of the pre-established time (110 seconds).





Indicator precision, at a 95% confidence level:

	OPTIMUS	VODAFONE	TMN	Global
Accessibility	3.03%	2.98%	2.96%	1.73%
Poor Audio Quality	1.66%	1.12%	1.25%	0.78%
Acceptable Audio Quality	2.53%	2.40%	2.41%	1.42%
Good Audio Quality	2.45%	2.45%	2.46%	1.44%

Figure 1 - Performance of GSM Mobile Networks, on Rail Axels

Regarding the perceptiveness of voice communications in these networks, about 92% of test calls had good or acceptable *Audio Quality* average values. However, the number of calls with poor or bad average values (around 8%) is substantial.

The analysis of results by operator does not show important differences regarding the *Accessibility* indicator. Concerning *Audio Quality*, VODAFONE and TMN have similar results. OPTIMUS stands out negatively, with 12.3% of test calls made through this network with poor or bad average *Audio Quality* values.

The poor results registered on rail axles are mainly due to serious coverage deficiencies and to some

situations of total absence of radio signal, especially in the Lisbon-Faro route (see Figure 2 and coverage maps on Section 2).

On this rail axel, only 57.6% of the attempted calls were successfully established and only 33.6% of calls were adequately kept during the pre-established time (110 seconds) and ended normally.

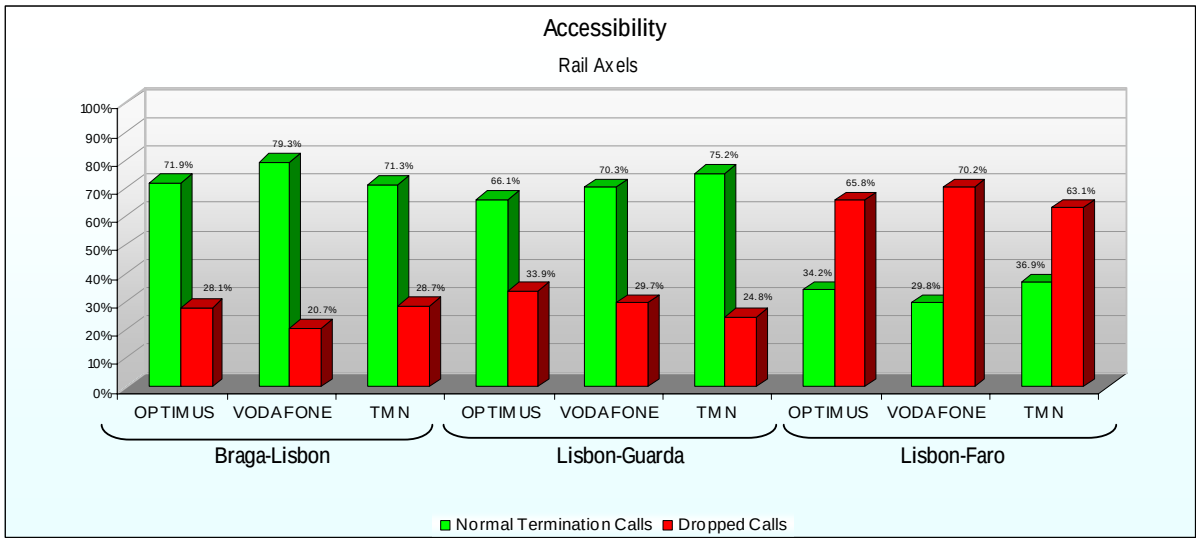


Figure 2 – *Accessibility* on each analyzed Rail Axel.

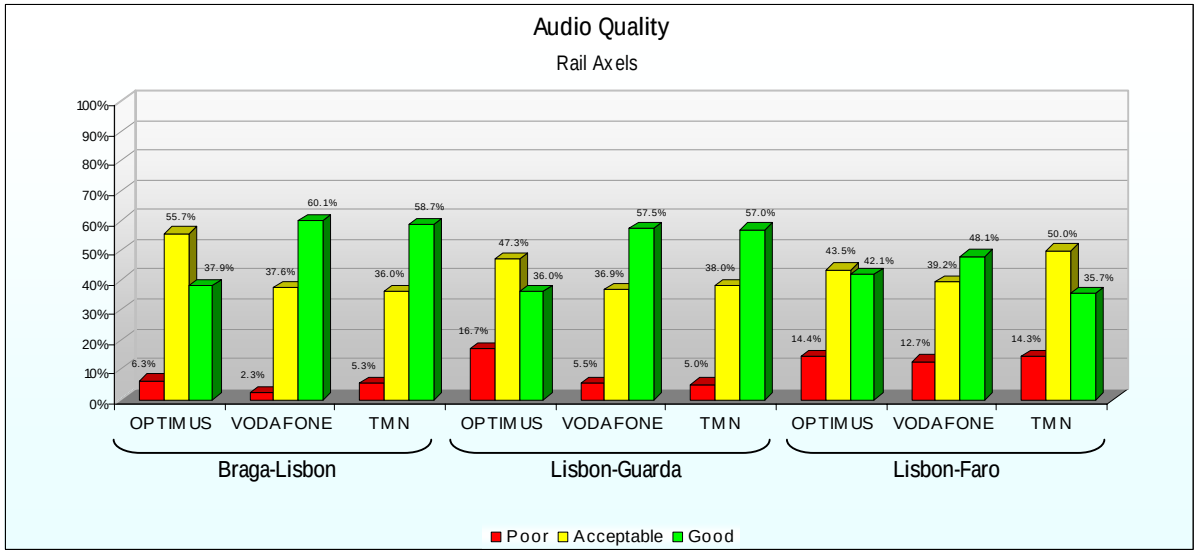


Figure 3 – *Audio Quality* on each analyzed Rail Axel.

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: Verification of 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.

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

c) Audio Quality: Verification of 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, which is 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.

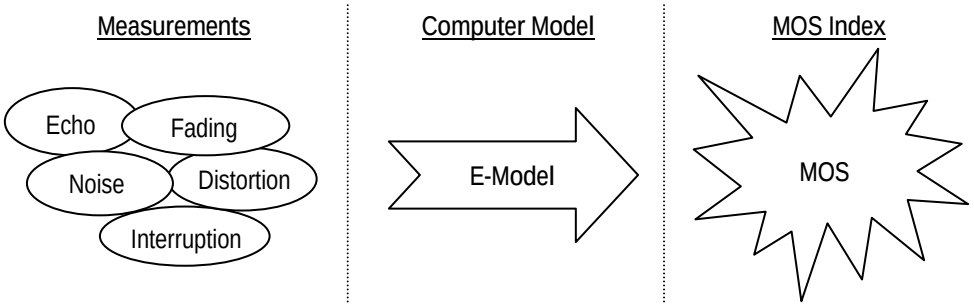


Figure 4 - Methodology used for audio quality monitoring.

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.

[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 the GSM Mobile Network terminals and a Fixed Telephone Network (Mobile-Fixed);

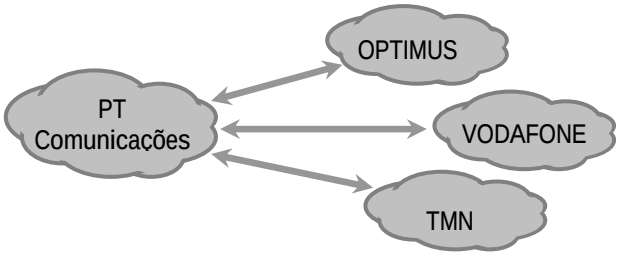
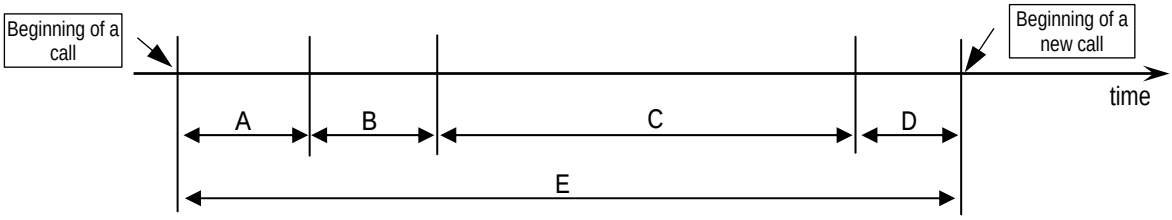


Figure 1 – Origin and Destination of test calls.

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 110 seconds (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

The following main Portuguese rail axels where analyzed for this first set of tests:

- Braga-Lisbon;
- Lisbon-Faro;
- Lisbon-Guarda.

1.3 SAMPLE SIZE

Table 3 – Length of measurement collection

Rail Axel	Hours of Measurements
Braga-Lisbon	15 h 59
Lisbon-Faro	12 h 54
Lisbon-Guarda	17 h 37
Total	46 h 30

1.4 DATA COLLECTION CONDITIONS

Data collection took place during normal working hours on working days and included 4 runs by each rail axle.

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 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.

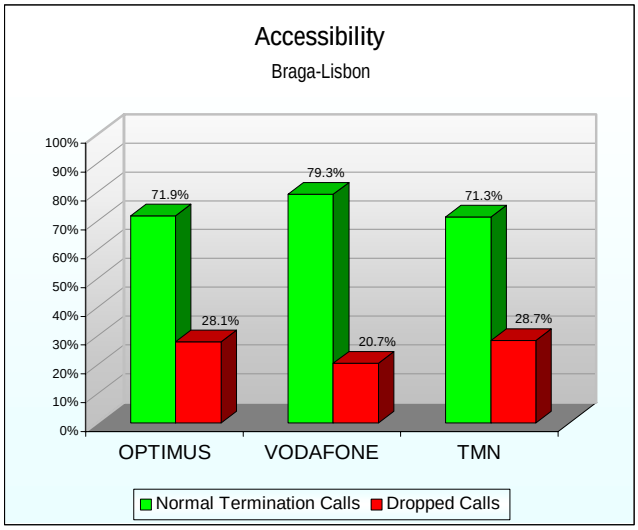
2 RESULTS

2.1 BRAGA-LISBON

Measurement Sessions on:
- 15 November 2005 between 7h18 and 11h26 and between 13h49 and 17h46
- 16 November 2005 between 7h16 and 11h28 and between 13h51 and 17h44

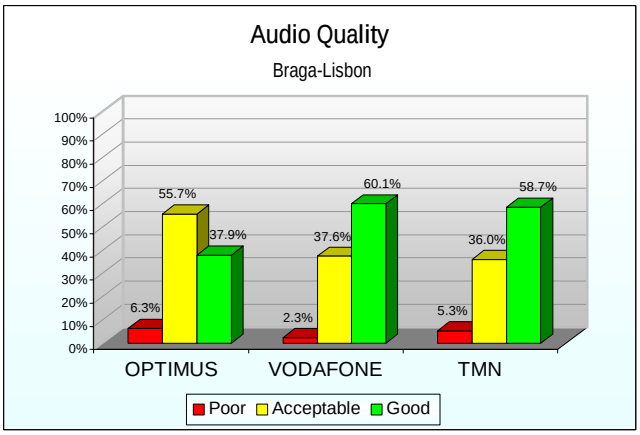
2.1.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	349 100%	352 100%	349 100%
Routed Calls		Total	304 87.1%	327 92.9%	314 90.0%
		Abandoned During Conversation	53 15.2%	48 13.6%	65 18.6%
		Normal Termination Calls	251 71.9%	279 79.3%	249 71.3%
Non-Routed Calls			45 12.9%	25 7.1%	35 10.0%
Dropped Calls		Total	98 28.1%	73 20.7%	100 28.7%
	Call Ending Causes	No Service	10 2.9%	1 0.3%	5 1.4%
		Congestion	53 15.2%	40 11.4%	38 10.9%
		Radio Link Failure	19 5.4%	24 6.8%	28 8.0%
		Other	16 4.6%	8 2.3%	29 8.3%



2.1.2 AUDIO QUALITY

	Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements	Total	583 100%	641 100%	605 100%
Audio Quality (MOS)	Poor	37 6.3%	15 2.3%	32 5.3%
	Acceptable	325 55.7%	241 37.6%	218 36.0%
	Good	221 37.9%	385 60.1%	355 58.7%

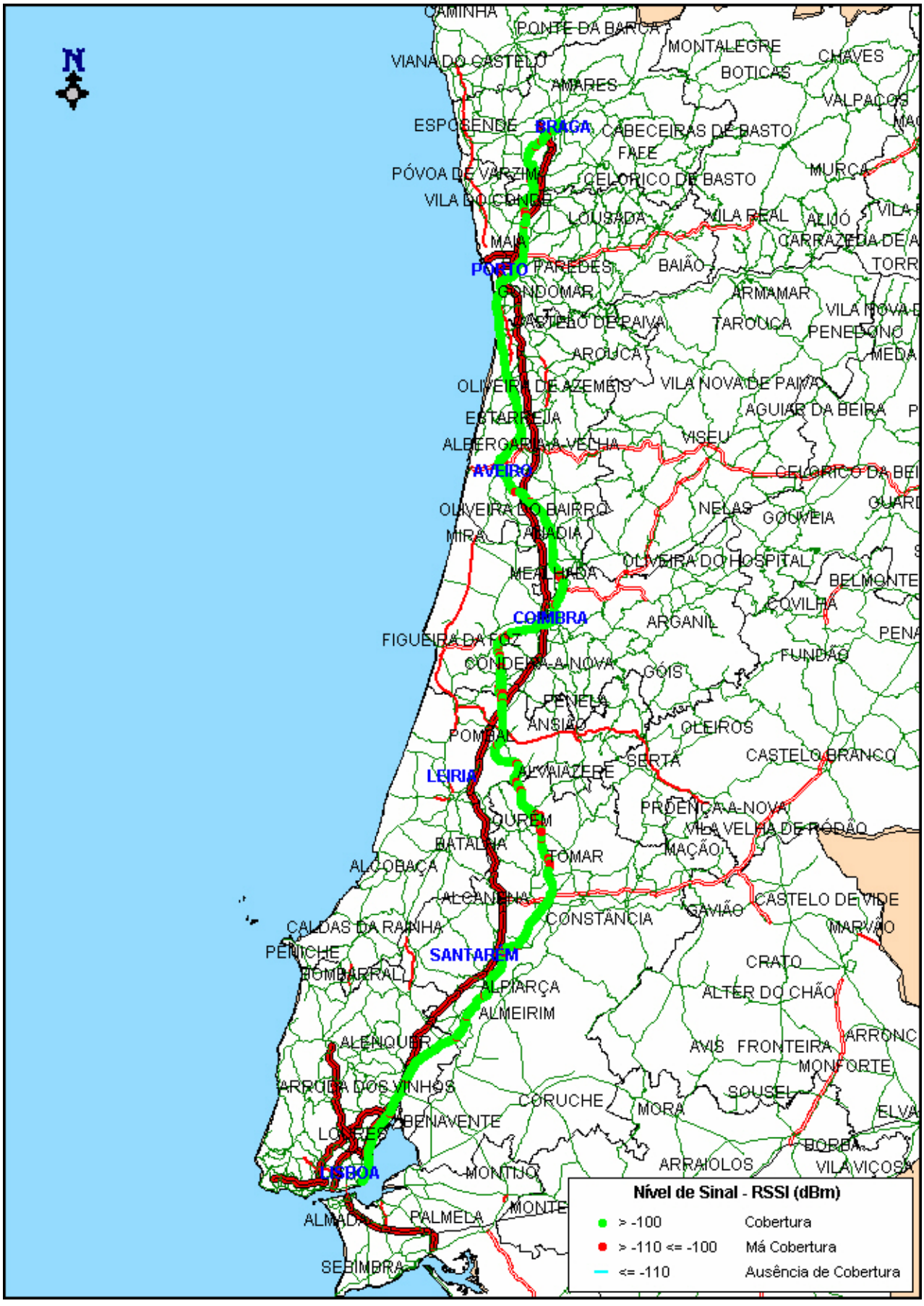


2.1.3 COVERAGE

(Following pages)

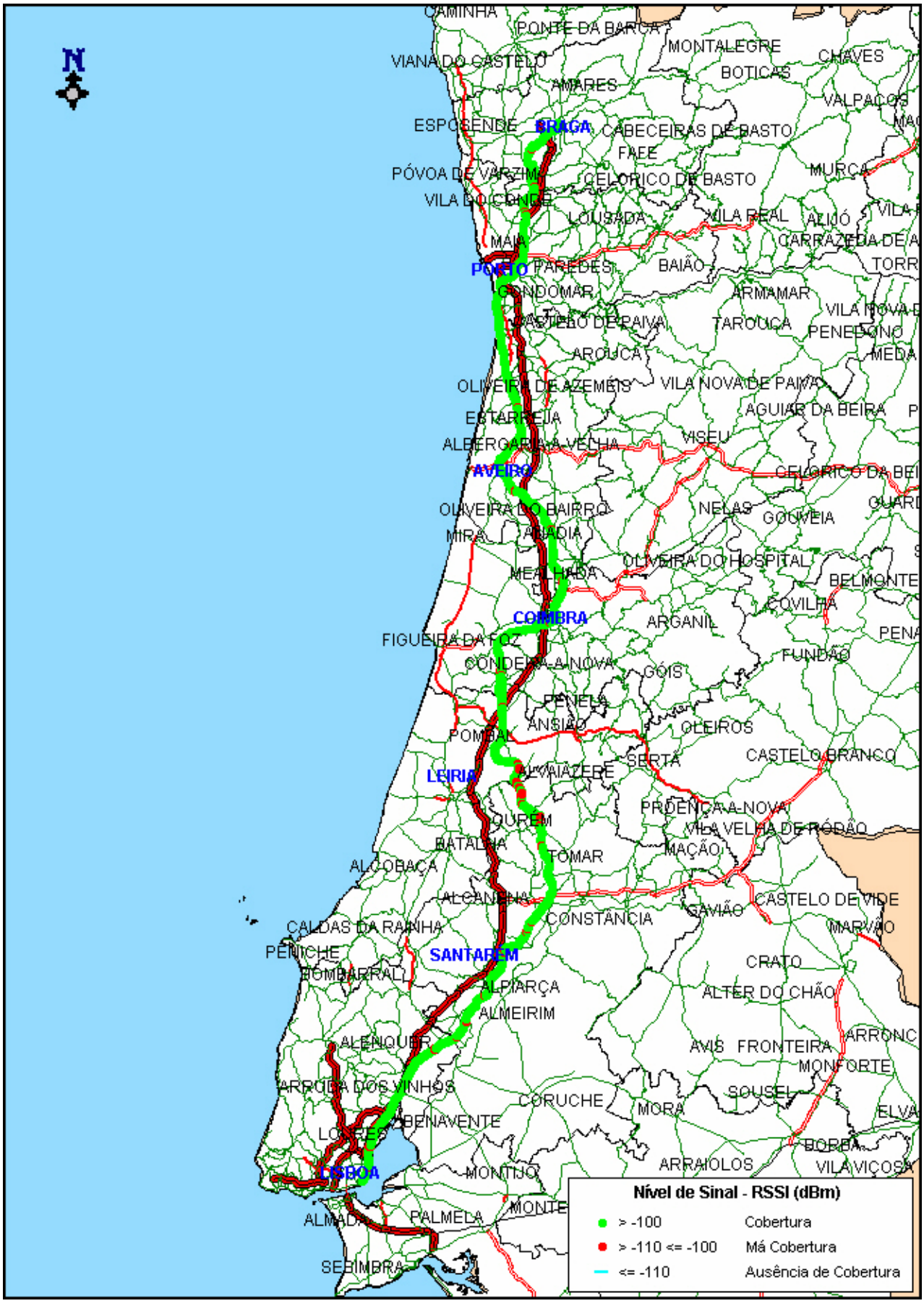
BRAGA-LISBON

OPTIMUS – PSTN



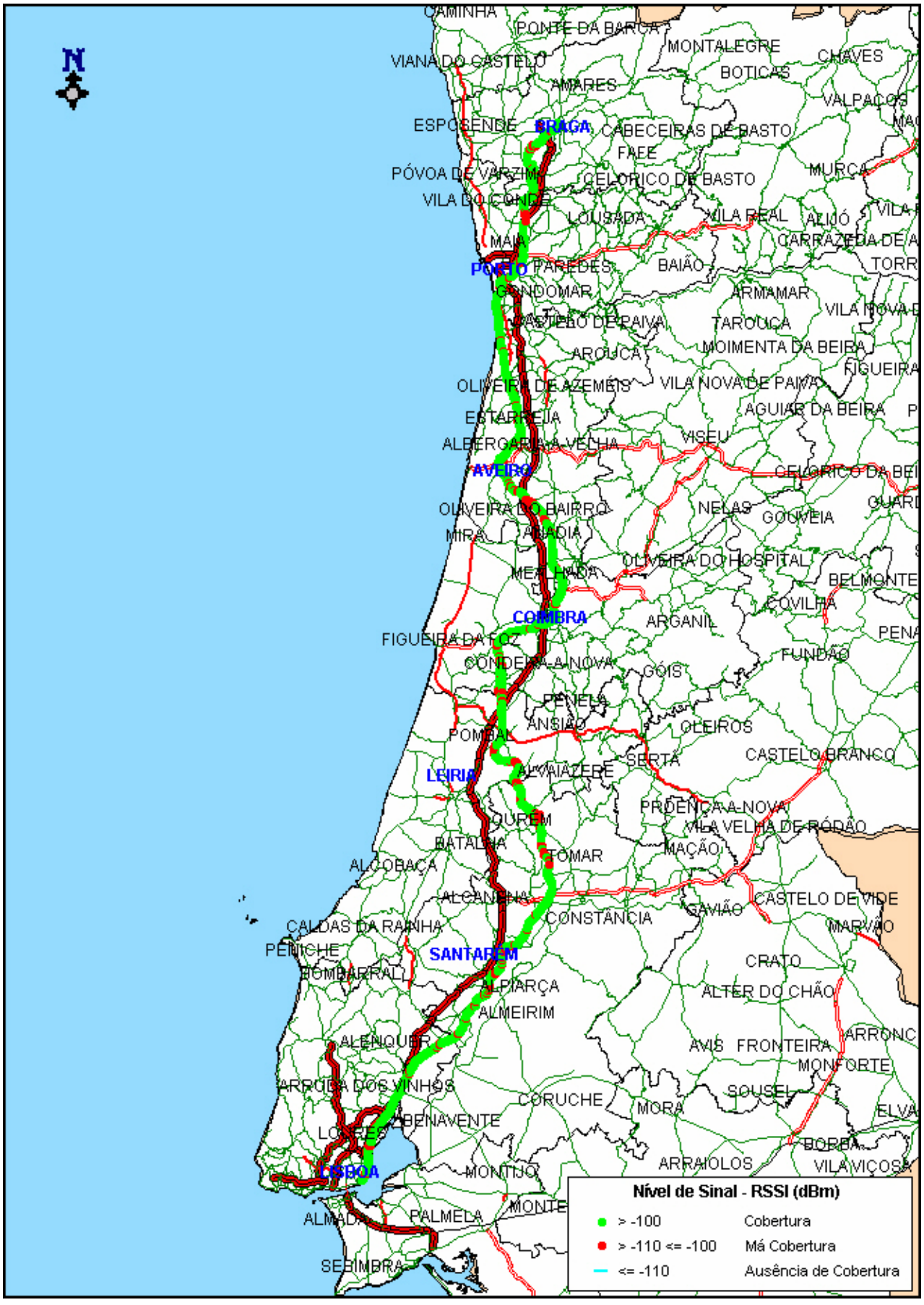
BRAGA-LISBON

VODAFONE – PSTN



BRAGA-LISBON

TMN – PSTN



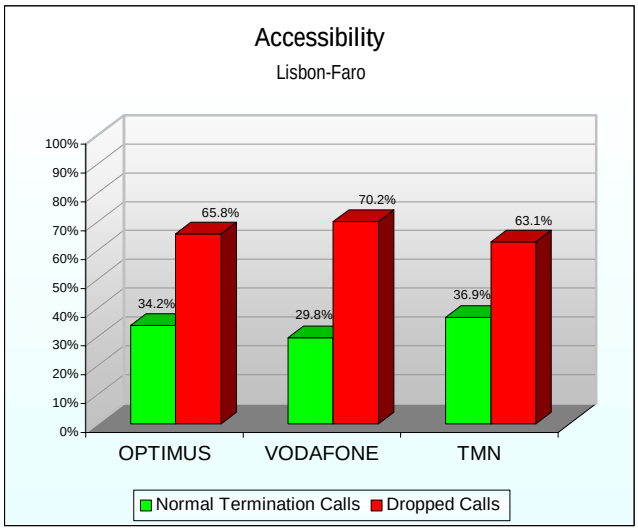
2.2 LISBON-FARO

Measurement Sessions on:

- 15 November 2005 between 17h15 and 20h36
- 16 November 2005 between 6h35 and 9h55
- 17 November 2005 between 17h10 and 20h16
- 18 November 2005 between 6h34 and 9h41

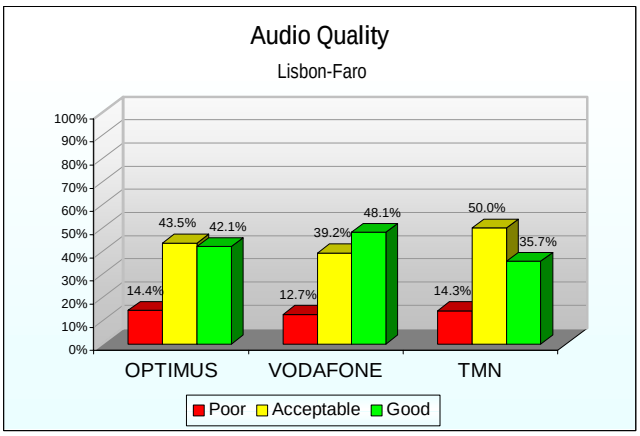
2.2.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	269 100%	275 100%	274 100%
Routed Calls		Total	159 59.1%	146 53.1%	166 60.6%
		Abandoned During Conversation	67 24.9%	64 23.3%	65 23.7%
		Normal Termination Calls	92 34.2%	82 29.8%	101 36.9%
Non-Routed Calls			110 40.9%	129 46.9%	108 39.4%
Dropped Calls		Total	177 65.8%	193 70.2%	173 63.1%
	Call Ending Causes	No Service	22 8.2%	33 12.0%	31 11.3%
		Congestion	95 35.3%	101 36.7%	32 11.7%
		Radio Link Failure	11 4.1%	32 11.6%	36 13.1%
		Other	49 18.2%	27 9.8%	74 27.0%



2.2.2 AUDIO QUALITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements		Total	278 100%	260 100%	300 100%
Audio Quality (MOS)		Poor	40 14.4%	33 12.7%	43 14.3%
		Acceptable	121 43.5%	102 39.2%	150 50.0%
		Good	117 42.1%	125 48.1%	107 35.7%



2.2.3 COVERAGE

(Following pages)

LISBON-FARO

OPTIMUS – PSTN

LISBON-FARO

VODAFONE – PSTN

LISBON-FARO

TMN – PSTN

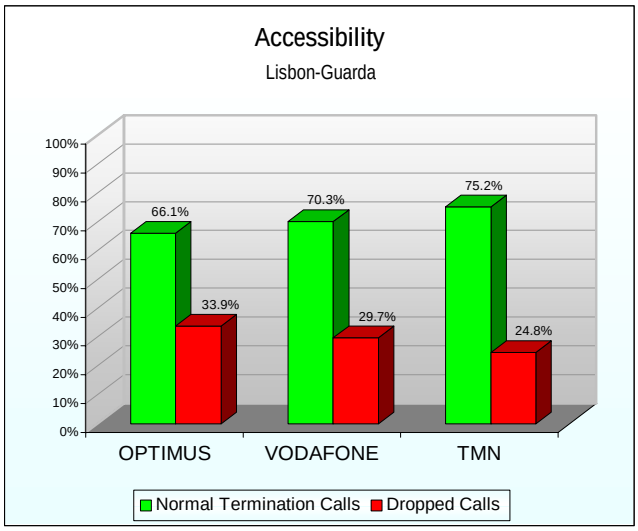
2.3 LISBON-GUARDA

Measurement Sessions on:

- 15 November 2005 between 8h05 and 12h16
- 16 November 2005 between 11h52 and 16h26
- 17 November 2005 between 7h54 and 12h23
- 21 November 2005 between 11h50 and 16h13

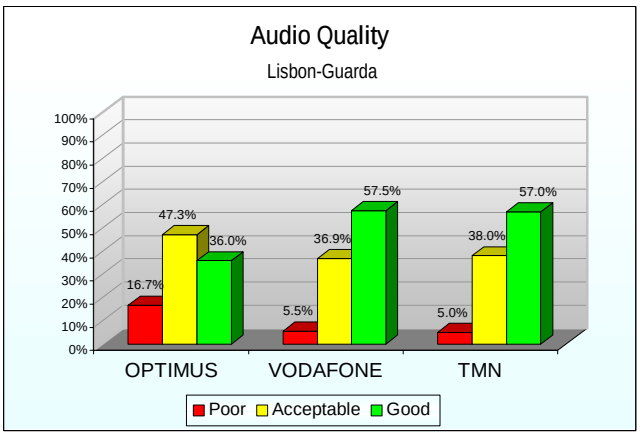
2.3.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	389 100%	390 100%	391 100%
Routed Calls		Total	338 86.9%	346 88.7%	345 88.2%
		Abandoned During Conversation	81 20.8%	72 18.5%	51 13.0%
		Normal Termination Calls	257 66.1%	274 70.3%	294 75.2%
Non-Routed Calls			51 13.1%	44 11.3%	46 11.8%
Dropped Calls		Total	132 33.9%	116 29.7%	97 24.8%
	Call Ending Causes	No Service	6 1.5%	7 1.8%	5 1.3%
		Congestion	65 16.7%	56 14.4%	30 7.7%
		Radio Link Failure	26 6.7%	43 11.0%	30 7.7%
		Other	35 9.0%	10 2.6%	32 8.2%



2.3.2 AUDIO QUALITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements		Total	639 100%	669 100%	679 100%
Audio Quality (MOS)		Poor	107 16.7%	37 5.5%	34 5.0%
		Acceptable	302 47.3%	247 36.9%	258 38.0%
		Good	230 36.0%	385 57.5%	387 57.0%

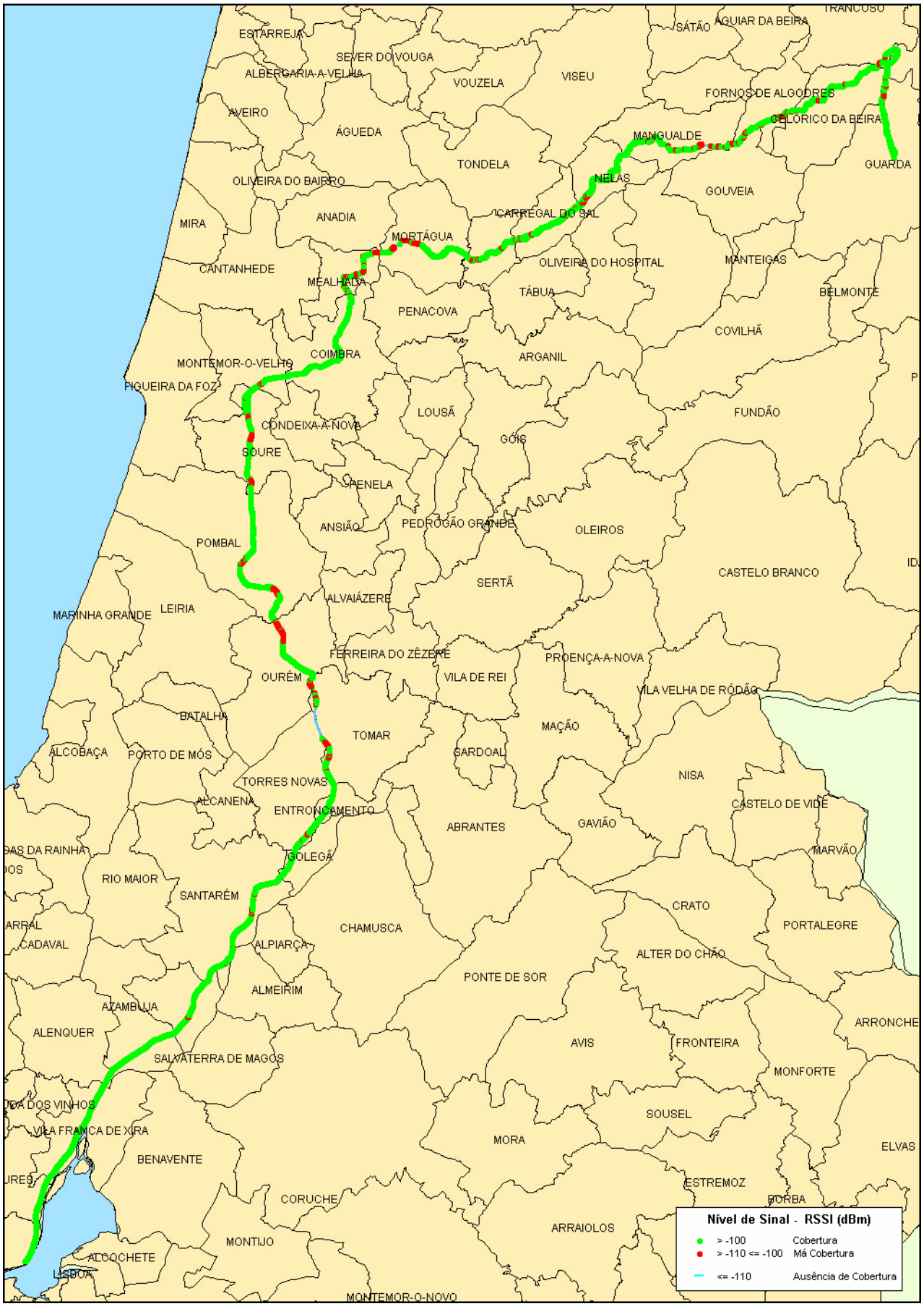


2.3.3 COVERAGE

(Following pages)

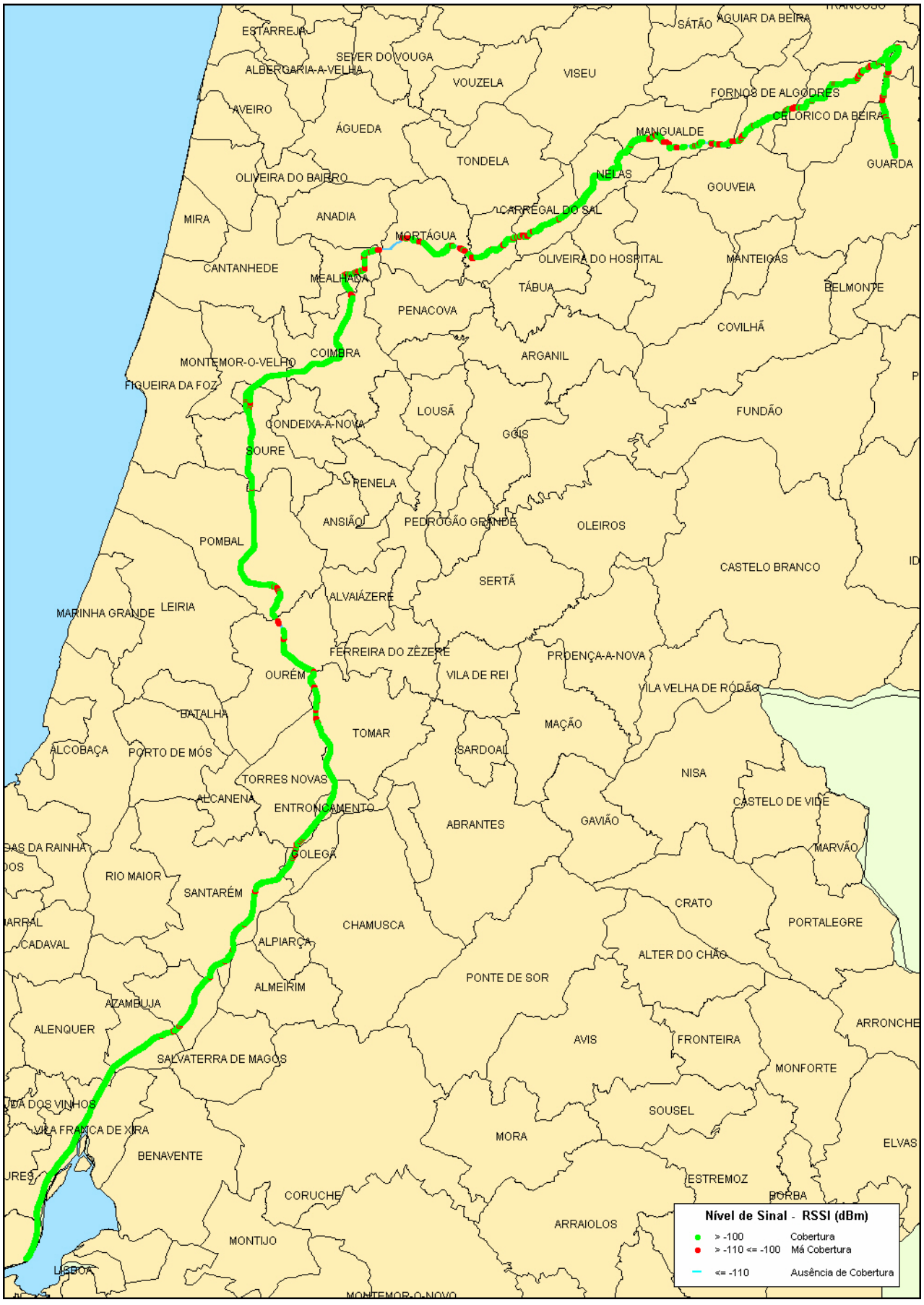
LISBON-GUARDA

OPTIMUS – PSTN



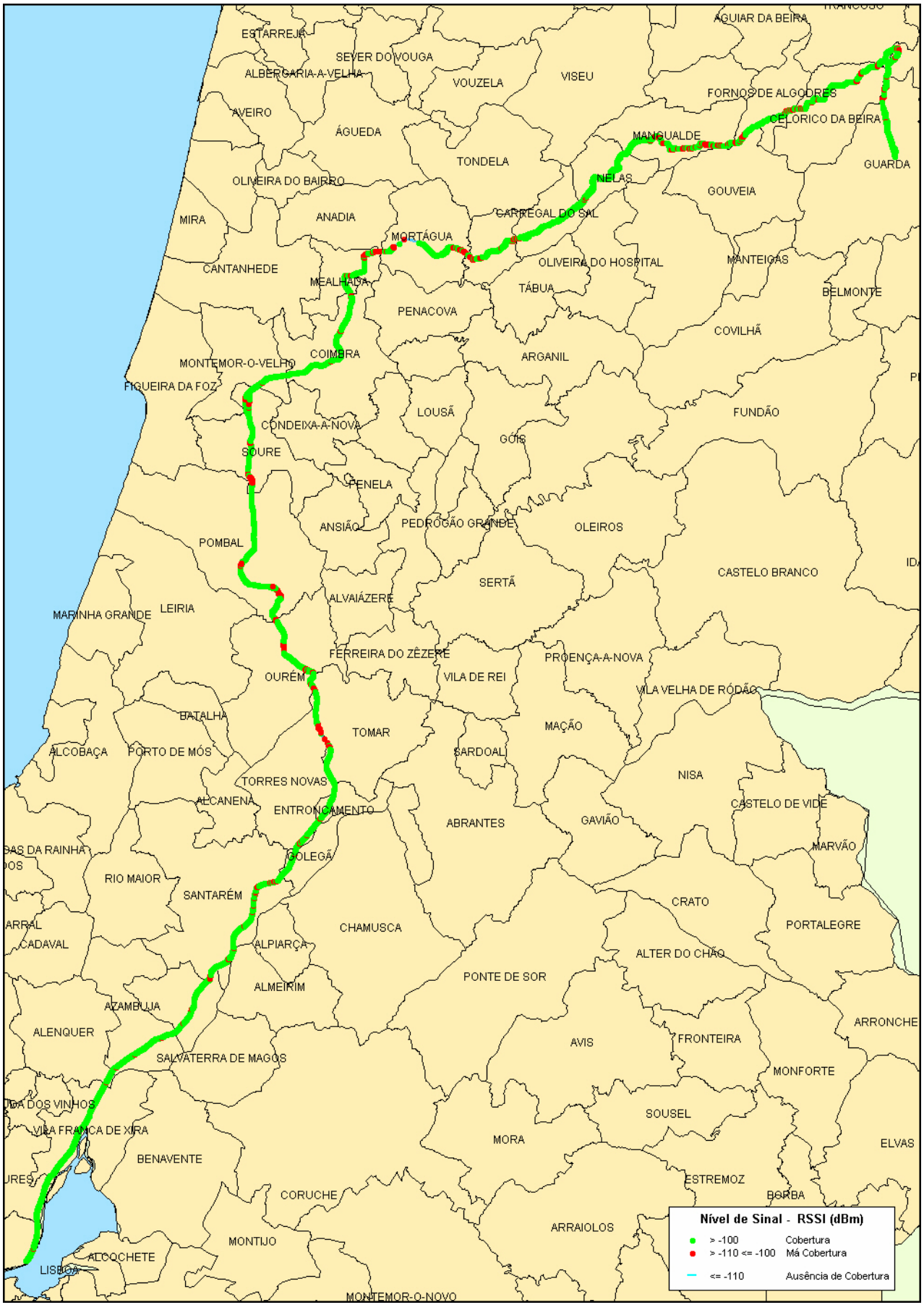
LISBON-GUARDA

VODAFONE – PSTN



LISBON-GUARDA

TMN – PSTN



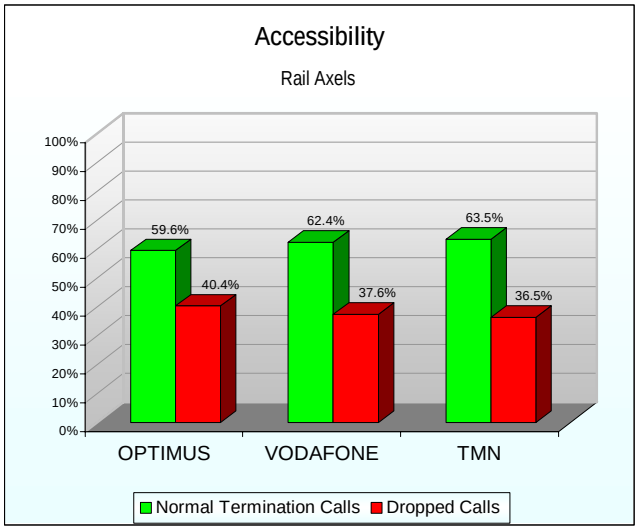
2.4 OVERALL RAIL AXELS

Indicator precision, at a 95% confidence level:

	OPTIMUS	VODAFONE	TMN
Accessibility	3.03%	2.98%	2.96%
Poor Audio Quality	1.66%	1.12%	1.25%
Acceptable Audio Quality	2.53%	2.40%	2.41%
Good Audio Quality	2.45%	2.45%	2.46%

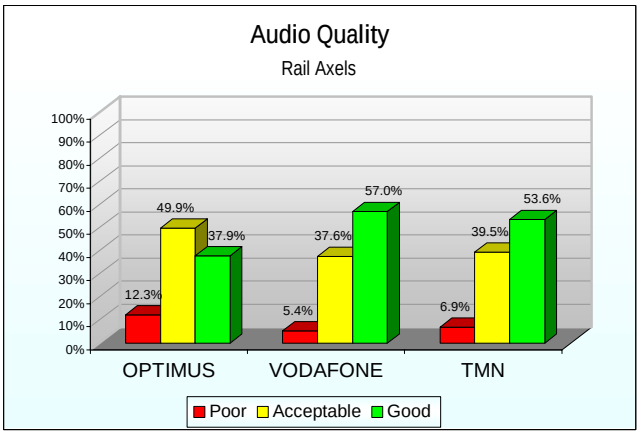
2.4.1 ACCESSIBILITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls Made		Total	1,007 100%	1,017 100%	1,014 100%
Routed Calls		Total	801 79.5%	819 80.5%	825 81.4%
		Abandoned During Conversation	201 20.0%	184 18.1%	181 17.9%
		Normal Termination Calls	600 59.6%	635 62.4%	644 63.5%
Non-Routed Calls			206 20.5%	198 19.5%	189 18.6%
Dropped Calls		Total	407 40.4%	382 37.6%	370 36.5%
	Call Ending Causes	No Service	38 3.8%	41 4.0%	41 4.0%
		Congestion	213 21.2%	197 19.4%	100 9.9%
		Radio Link Failure	56 5.6%	99 9.7%	94 9.3%
		Other	100 9.9%	45 4.4%	135 13.3%



2.4.2 AUDIO QUALITY

		Operator	OPTIMUS	VODAFONE	TMN
Calls with Measurements		Total	1,500 100%	1,570 100%	1,584 100%
Audio Quality (MOS)		Poor	184 12.3%	85 5.4%	109 6.9%
		Acceptable	748 49.9%	590 37.6%	626 39.5%
		Good	568 37.9%	895 57.0%	849 53.6%



2.4.3 COVERAGE

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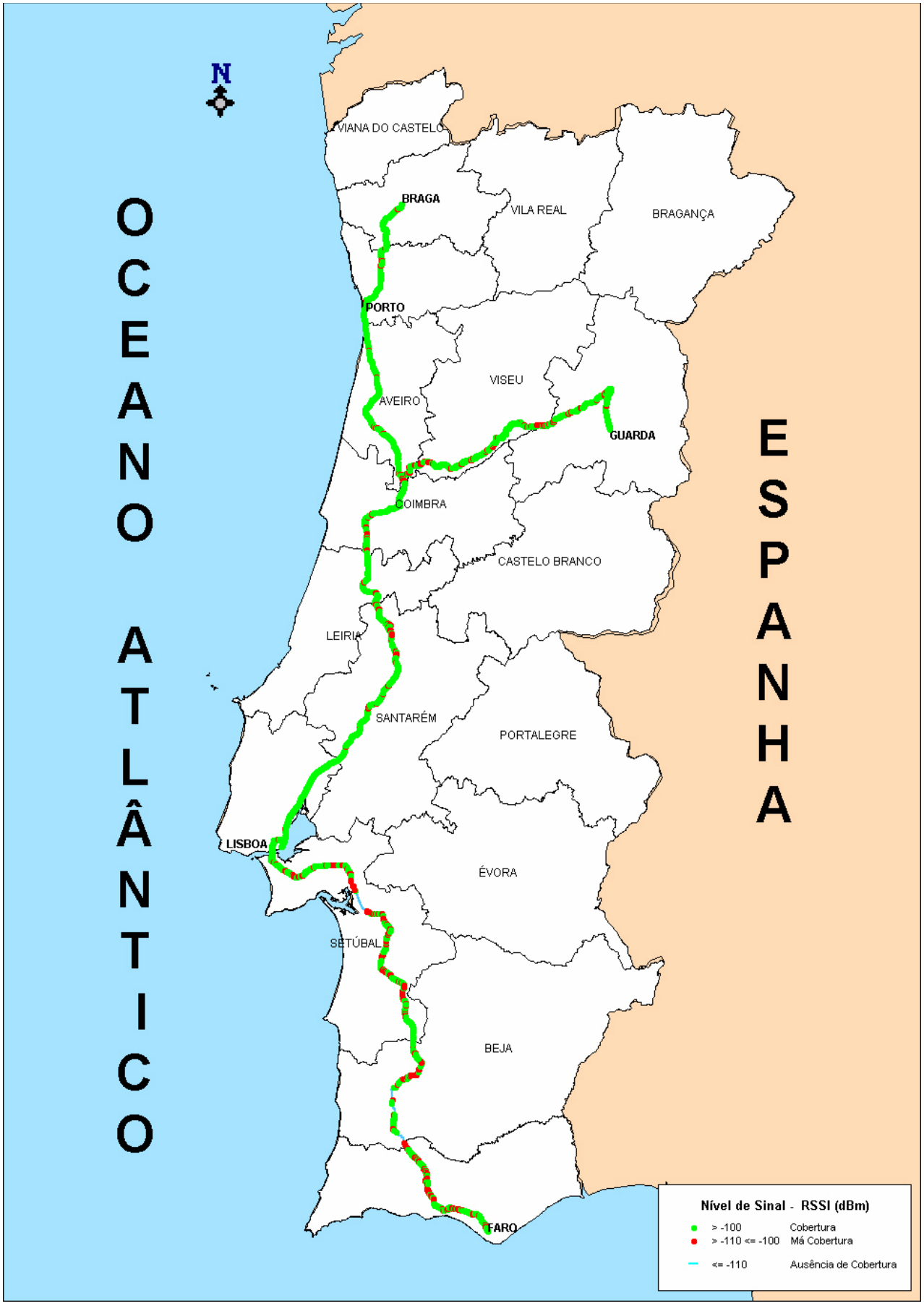
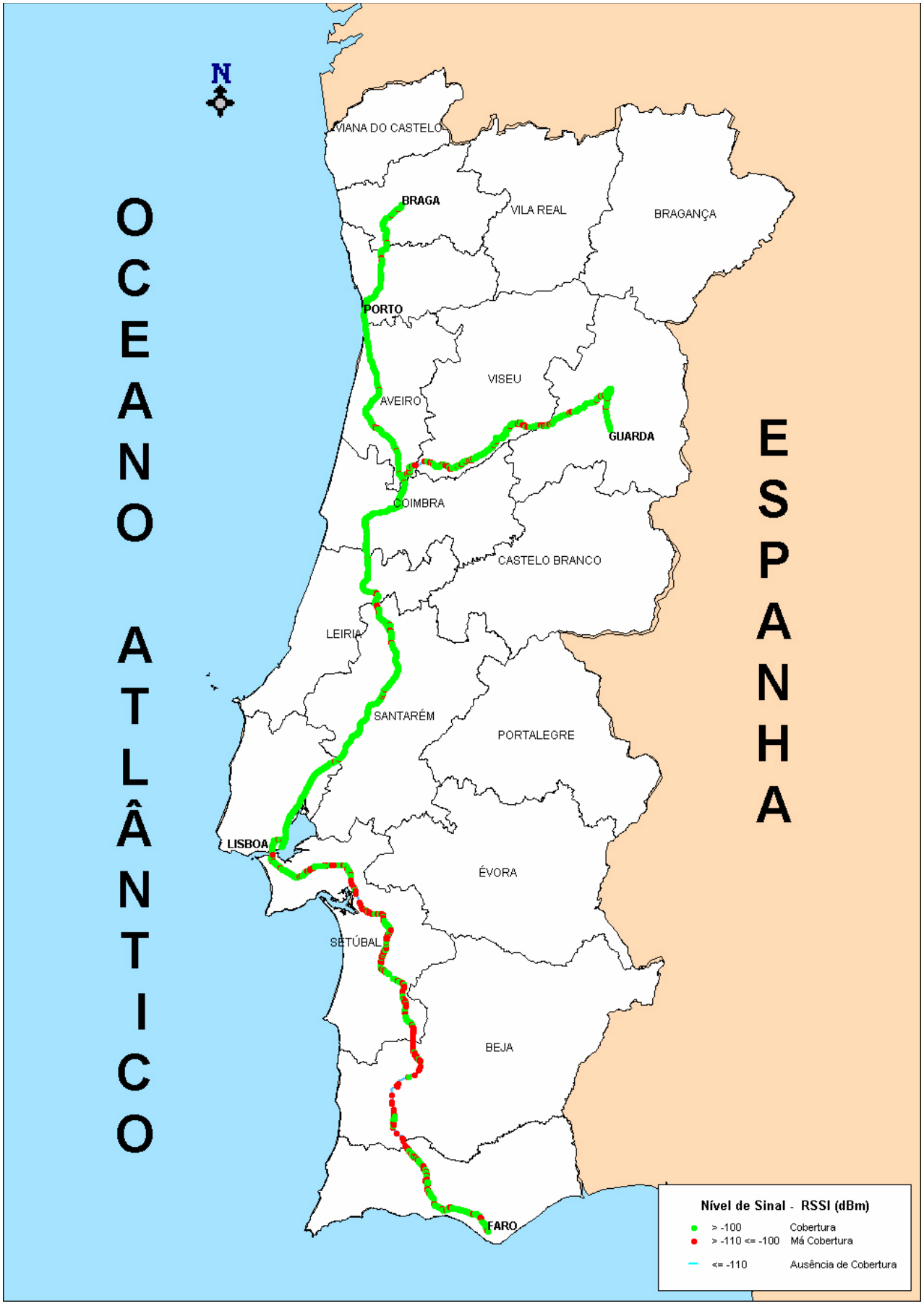
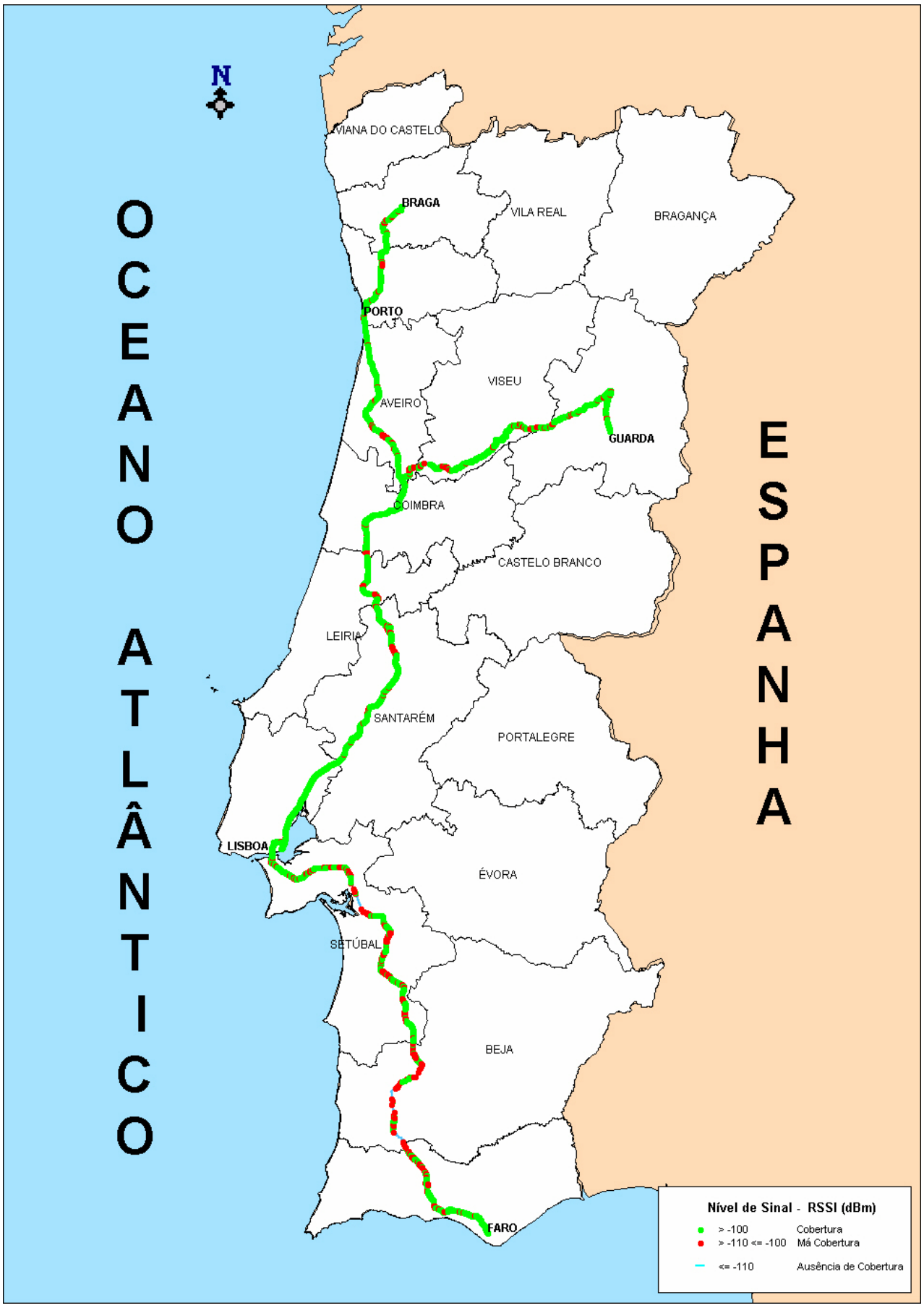
OPTIMUS – PSTN



VODAFONE – PSTN



TMN – PSTN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OCEANO ATLÂNTICO
ESPANHA
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BRAGA
VILA REAL
BRAGANÇA
PORTO
VISEU
AVEIRO
GUARDA
COIMBRA
CASTELO BRANCO
LEIRIA
SANTARÉM
PORTALEGRE
LISBOA
ÉVORA
SETÚBAL
BEJA
FARO
Nível de Sinal - RSSI (dBm)
> -100 Cobertura
> -110 <= -100 Má Cobertura
<= -110 Ausência de Cobertura

Appendix

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.

White