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GSM Mobile Networks

Quality of Service Survey

Global Study

(Mainland Portugal)

September / October 2005

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 $\wedge$ <= -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.

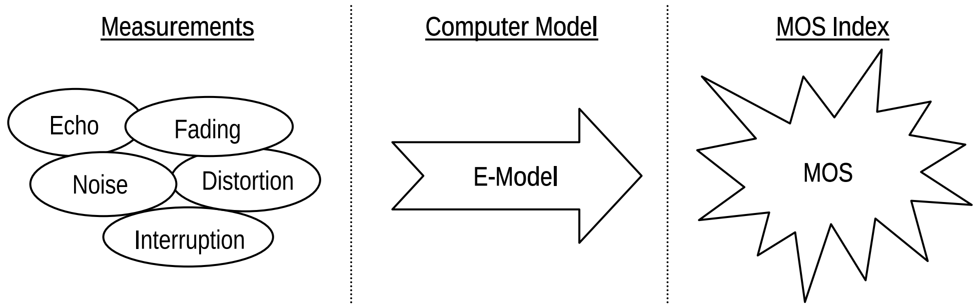

Figure 5 - Methodology used for audio quality monitoring.

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);

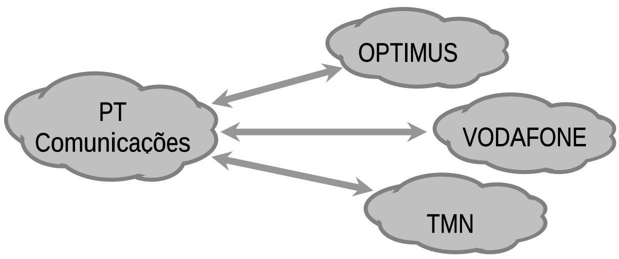
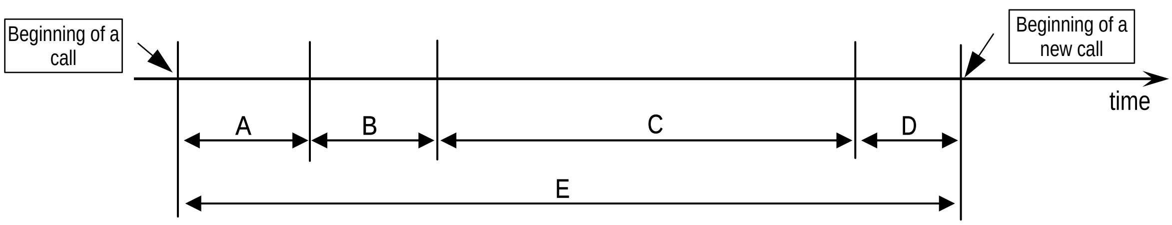


Figure 1 – Origin and Destination of test calls.

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
Setúbal		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.