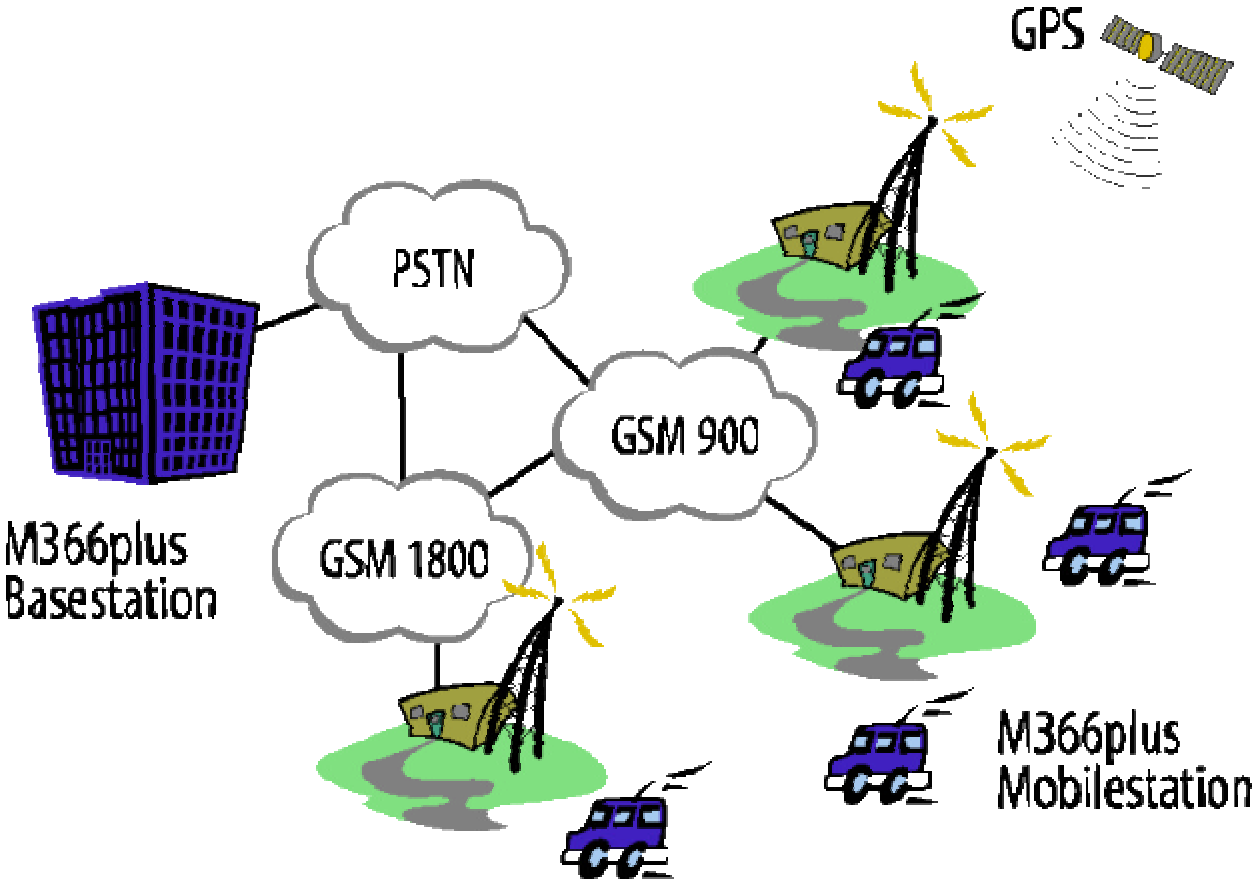
QoS – GSM

Survey on the Quality of Service of Mobile Networks

May / 2000



Contents

I EXECUTIVE SUMMARY

I.I BACKGROUND

The objective of this survey was to assess QoS of GSM mobile networks as perceived by consumers under everyday conditions of use.

The survey was carefully prepared, with the target operators and the consumer defence bureau DECO involved in the definition of methodology. The comments and suggestions made by them were duly taken into account.

According to recent statistics, nearly 5 million people, or 1 person in every 2, regularly use the mobile networks in Portugal. If we add to this the diversity of terminal equipment available on the market and the particular needs of each and every user, it is impossible to gain an extremely precise picture of how the consumer interacts with the mobile network.

This survey must therefore be seen as a general description of behaviour on the mobile networks as a whole, and great care should be taken in applying it to specific situations.

Though expensive and time-consuming, automatic end-to-end testing does provide exact information on the quality of service (**QoS**) provided by a given telecommunications operator. The methodology followed allowed us to assess quality of service on the spot, giving us as realistic a picture as possible of network performance from the user's point of view.

With this approach in mind, we planned and conducted QoS assessment testing on the GSM mobile networks of OPTIMUS, TELECEL and TMN. The results of these tests are reported below.

Measurements were taken in the period from 31/01/2000 to 05/05/2000. A total of 23 446 test calls were made in 23 cities and 10 major road arteries during a total of 250 hours and over a mileage exceeding 10000 km.

The technical and methodological options taken on this survey had a direct influence in the results, and therefore should be taken into account when it comes to analysing the results. The following aspects are

particularly important:

- The terminal equipment used was dual band with EFR. Users whose terminal equipment does not have these characteristics can reasonably be expected to obtain network performance which is poorer than the results of the survey suggest;

- The testing equipment used was automatic, eliminating the subjectivity inherent to the human user and ensuring equality of assessment conditions for all 3 network operators targeted by the survey;

- Tests were carried out from moving vehicles with roof mounted antennas;

- For simultaneous analysis of accessibility and audio quality we set a standard conversation time of 75 seconds, which was the average duration of calls made on the networks in question in 1999. Our results do not permit us to extend conclusions for calls of longer duration. The ability of the networks to sustain uninterrupted conversation for longer calls will be assessed in a future survey.

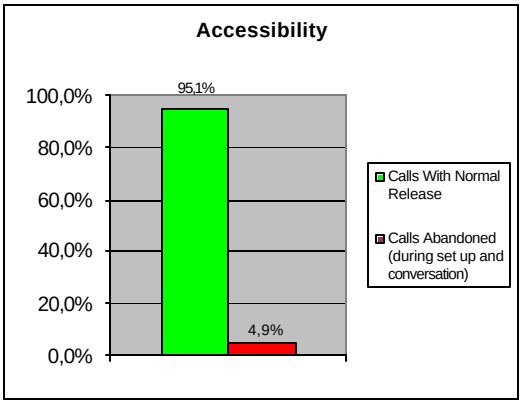
- The results of the survey reflect only the behaviour of the networks at the place and the time measurements were taken.

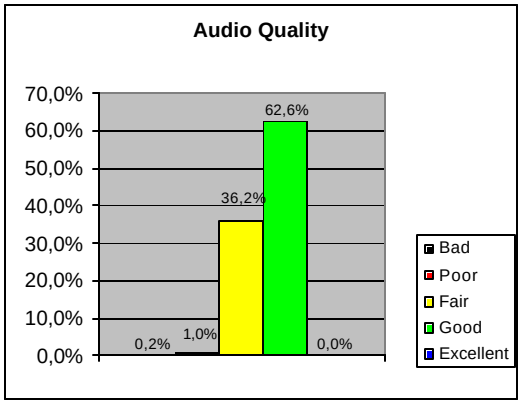
- Operators are continually improving their networks in terms both of coverage and audio quality. The operations necessary for these improvements may cause momentary disruption to the service in the geographical areas affected.

I.II MAJOR CONCLUSIONS

All in all, the results of our survey show that the performance of the GSM mobile networks in Portugal is good.

There is no significant difference in audio quality between calls made in cities and the major road arteries in which testing was carried out.





Around 60% of the calls made via the networks of TMN and TELECEL have good audio quality. This figure comes near to 75% for the third operator, OPTIMUS, which, as the last to enter the market, has the benefit of technology that was not available when the other two operators began their activity.

The ability of the networks to set up and hold voice calls (accessibility) is generally good and on a par with quality levels in the UK and France, as we can figure out by comparing the present results with those of the most recent studies by the British and French regulators.[1]

However, call failure rates give cause for concern in certain areas of the country, especially Lisboa and Porto, where network overload is an obvious problem.

All networks have good coverage. There are still some "shadow zones", however, due either to local topography or artificial obstructions which hinder the normal radio propagation.

[1] http://www.oftel.gov.uk/feedback/mble0500.htm - http://www.art-telecom.fr/

1 SURVEY TECHNICAL DETAILS

1.1 QUALITY OF SERVICE INDICATORS

This survey assessed three quality aspects of a mobile network, which are fundamentally important from the user's point of view:

a) Accessibility: The ability of a mobile network to set up and hold calls.

More specifically, the ability to successfully establish calls between two terminals on the same network or between a terminal on a mobile network and a terminal on the PSTN (Public Switched Telephone Network).

In the cases where the call was not established or where it was interrupted during conversation, the cause of the failure or interruption is indicated.

b) Coverage: Signal levels.

The test equipment used allowed us to measure the strength of the signal received by the mobile terminal. Measurements were taken on the BCCH[2] control channel and therefore were not affected by frequency hopping and downlink power control algorithms.

All measurements are geo-referenced to allow their subsequent mapping for easy visualization of the coverage levels of each operator.

Table 1 – Signal strength on the control channel

Signal strength (dBm)	
> -77	Good
-86 a -77	Fair
-110 to -87	Bad

c) Audio quality: These tests measured conversation perception for successful set up calls over a pre-determined period of time.

[2] ***B****roadcast* ***C****ontrol* ***Ch****annel* – Transports information to all mobile stations (MS's) served by a specified BTS (*Base Transceiver Station*). Transmission occurs in downlink mode and carries a number of different control parameters, such as : CI (*Cell Identity*), LAC (*Local Area Code*), MCC (*Mobile Country Code*), MNC (*Mobile Network Code*) and FH algorithm (*Frequency Hopping*).

To measure audio quality, the test system simulates a telephone conversation between two users.

The assessment method for perceived audio quality is based on the "E-Model" recommended by the ETSI[3] (ETR 250) and the ITU[4] (ITU-T *Recommendation* G.107). This model serves as the basis for calculation of the MOS (*Mean Opinion Score*).

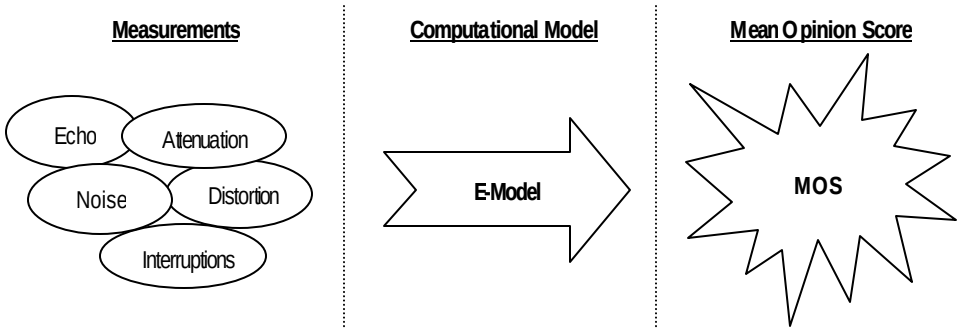


Figure 1 – Methodology for measuring audio quality.

The MOS scale quantifies the effort necessary for conversation to be perceptible. Where perception is nil, the MOS value is 0; perfect perception has a MOS value of 5. These values are merely theoretical extremes and are never recorded in real measurements.

Table 2 – The MOS Scale

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

1.2 METHODOLOGY

The methodology followed by this survey was based on 3 fundamental aspects:

a) **End-to-end measurement:** measurements are made between two terminal points on the mobile network or between one mobile terminal and one PSTN terminal.

[3] European Telecommunications Standards Institute.

[4] International Telecommunications Union.

End-to-end testing has a number of advantages:

- Same point of view than the real consumers;
- Reflects connection problems as experienced by consumers;
- Allows to pick a sample in such a way that results reflect realities as perceived by the consumer in general (selection of routes, number and duration of calls, time of day when measurements are made, etc.);
- Reveals the problems affecting networks and allows them to be located;
- Allows comparison between the performances of different networks.

b) Impartiality: Measurements on the networks of the three operators (OPTIMUS, TELECEL and TMN) were carried out simultaneously to ensure equality of test conditions.

c) Objectivity: testing was fully automatic, thus eliminating the subjectivity inherent to human intervention or decision.

Tests consisted in the set up and hold of voice calls in the conditions listed below:

1. Tests between mobile and PSTN terminals are denominated type-A, or mobile-fixed, measurements; tests between terminals on the same mobile network are designated type-B, or mobile-mobile, measurements.

2. In mobile-mobile measurements, one terminal remained stationary, at a place with good coverage, while the other terminal was in continuous movement throughout the city or road under test.

Table 3 – Origin and destination of test calls.

		Destination			
		TMN	**TELECEL**	**OPTIMUS**	**PSTN**
Origin	**TMN**	✓	---	---	✓
	TELECEL	---	✓	---	✓
	OPTIMUS	---	---	✓	✓
	PSTN	✓	✓	✓	---

3. Calls were initiated alternately by one terminal then the other; regardless of which terminal made the call, audio quality (MOS) measurements were taken in both directions during a simulated conversation.

4. Where the first call attempt failed, a second attempt was made immediately afterwards.

5. After the call was successfully established, a simulated conversation with a maximum duration of 75 seconds was held (this duration is shorter in cases where the call was abandoned or where the call set up time was long).

6. Calls were initiated (one for each operator) at 2-minute intervals.

1.3 TESTED AREAS

Since the aim of the survey was to assess the quality of the service provided by mobile operators as perceived by the user, we selected areas where these services are most used, i.e. urban areas and major road arteries. We also took care to spread the survey around all regions of mainland Portugal.

For the major road arteries, we selected motorways and principal A-grade roads.

The urban areas covered by the survey represent around one third of the population of Portugal, according to latest Census figures.

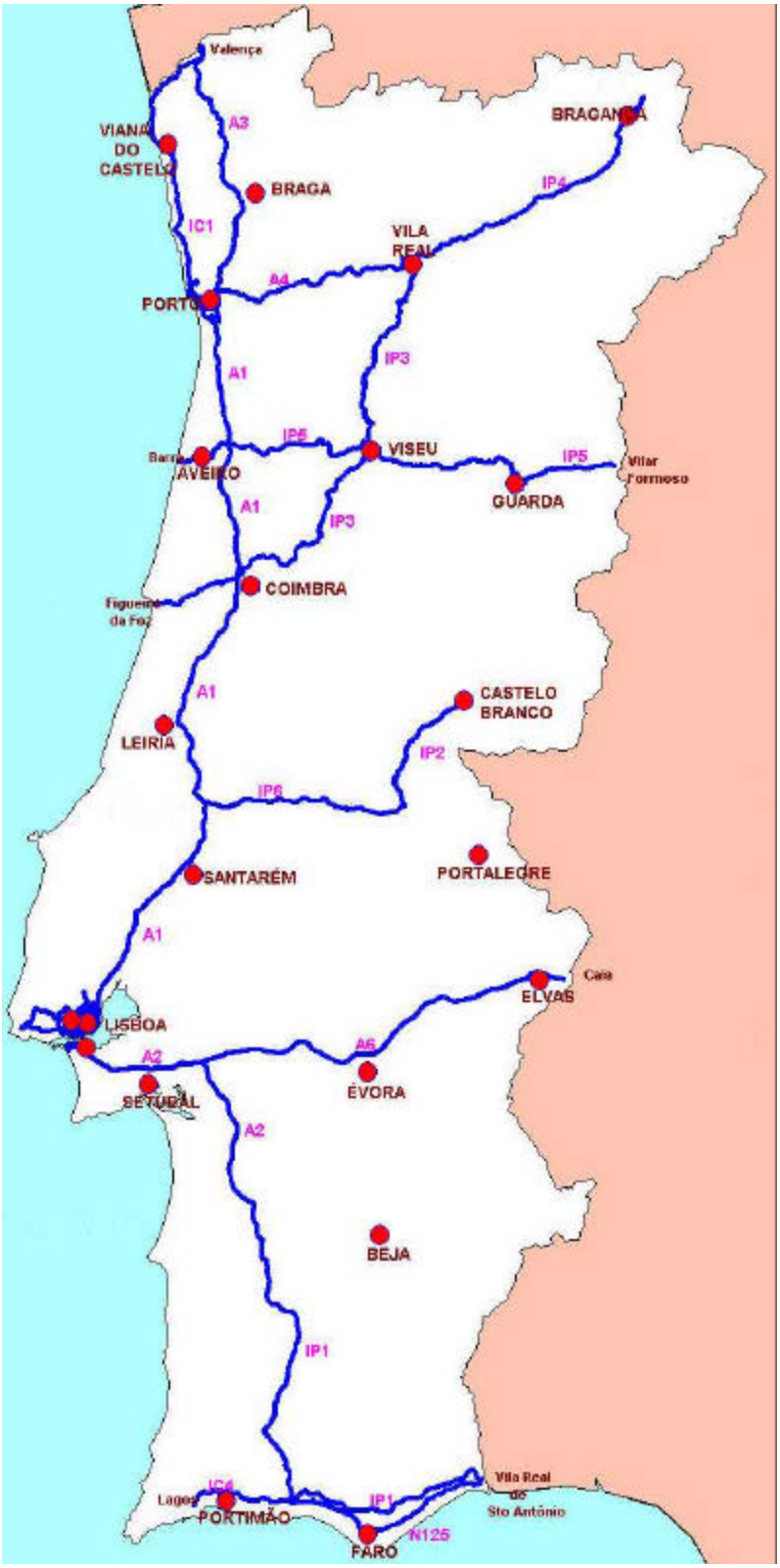


Figure 2 – Urban areas and major road arteries covered by the survey.

Table 4 – Urban areas and population (91 Census)

City	No. of inhabitants
Viana do Castelo	83 095
Bragança	33 055
Braga	141 256
Vila Real	46 300
Porto	302 472
Vila Nova de Gaia	248 565
Viseu	83 601
Guarda	38 765
Aveiro	66 444
Coimbra	139 052
Castelo Branco	54 310
Leiria	96 517
Santarém	62 621
Lisboa	663 394
Amadora	181 774
Almada	151 783
Setúbal	103 634
Portalegre	26 111
Elvas	24 474
Évora	53 754
Beja	35 827
Portimão	50 761
Faro	38 833
Total	2 726 398

Table 5 – Road arteries

Road artery	Approximate distance (km)
Lisboa-Sintra-Cascais-Lisboa (A5 + IC19)	60[5]
Lisboa-Porto (A1)	300[6]
Lisboa-Torres Novas -Castelo Branco (A1 + IP6 + IP2)	240[6]
Lisboa-Vila Real de Stº. António (A2 + IP1)	330[6]
Vila Real de Stº. António-Lagos (EN 125)	135[6]
Lisboa-Évora-Elvas (A2 + A6)	210[6]
Porto-Braga-Valença-Viana do Castelo-Porto (A3 + IC1)	240[6]
Porto-Bragança (A4 + IP4)	220[6]
Aveiro-Vilar Formoso (IP5)	200[6]
Vila Real-Figueira da Foz (IP3)	230[6]
Total	2 165

[5] These roads were travelled 6 times during measurement campaigns.

[6] These roads were travelled 3 times during measurements campaigns.

1.4 MEASUREMENT CONDITIONS

Given the population density of the Lisboa and Porto areas, and to make the survey as representative as possible, test campaigns in these areas were carried out over several days. We also spread testing to cover the morning and evening rush hours, and therefore the whole daily test period lasted from 8am to 8pm.

In the other urban areas, test campaigns were carried out in a single day.

For the road arteries, to make the survey as representative as possible, we made 3 journeys for each artery: 2 for mobile-fixed measurements and 1 for mobile-mobile measurements.

1.5 TESTING AND MEASUREMENT EQUIPMENT

The equipment used for testing was the *TEKTRONIX M366plus*, a QoS analyser for GSM networks.

Major Features:

- Supports measurement on GSM 900, DCS 1800 and dual-band;
- Supports simultaneous measurement of 3 operators/networks;
- Supports geo-referencing of all measurements;
- Data obtained can be post-processed with special tools, developed by the manufacturer, enabling the compilation of full reports.
- Testing equipment can be configured for call duration, number dialled and time between calls.

The equipment comprises two measurement units:

a) ***Base Station*:** the fixed node of the M366plus system. It incorporates 3 PSTN interfaces and DSP[7] measurement boards. The base station is connected to a PC via which configuration and maintenance can be performed.

[7] Digital Signal Processor

This unit makes and receives voice calls, performs quality measurements and stores data.

b) ***Mobile Station*:** This unit includes 3 mobile terminal interface boards with incorporated DSP, each of which is linked to 3 SAGEM OT75-M dual-band mobile telephones with EFR.[8] It also includes a board for processing GPS signals. The antennas for the GPS and the 3 mobile telephones were placed on the roof of the vehicle (when the unit was mounted in a vehicle).

The mobile station is connected to a portable PC for purposes of configuration and maintenance.

The operations performed by this unit are identical to those performed by the Base Station: it makes and receives calls, carries out quality measurements and stores data.

As its name indicates, the mobile station is designed to take measurements while in motion – mounted in a vehicle, for example. Nothing however prevents it from being used while stationary.

1.6 POST-PROCESSING TOOLS

The M366plus analyser comes with a software tool, "Report", which supports the storage and organization of information, plus the generation of statistics on the data obtained by the measuring units.

The files generated by the measurement units are organized into a database structure. "Report" can therefore use MS ACCESS or ORACLE to perform this action.

This software tool makes it possible to generate different reports on single or multiple sessions, to greater or lesser degrees of detail.

The M366plus incorporates a GPS receiver which makes it possible to geo-reference all measurements. This information is processed by the "GeoReport" tool which, in conjunction with a third tool, "MAPINFO", makes possible visualization of statistics in the form of a digitally-generated geographic map.

[8] Enhanced Full Rate – Voice encoder/decoder enabling audio quality comparable to that of the PSTN line.

2 RESULTS

2.1 DEFINITIONS

MOS: ***M****ean* ***O****pinion* ***S****core* – Audio quality index for end-to-end communication. Has value 0 when no communication exists and value 5 when communication is perfect. Values 0 and 5 are merely theoretical and therefore never appear in real measurements.

Routed calls: Calls successfully established by the network between the two ends (i.e. the call reaches the called terminal).

- **Abandoned during conversation:** Calls which are successfully established but which are then abandoned during conversation.
- **Normal release:** Calls that are successfully established and successfully completed.

Calls not routed: Calls which fail to connect the two terminals (i.e. the call fails to reach the called terminal).

Abandoned calls: Calls that are abandoned either in the call set up phase or during conversation.

- **Call ending cause:** The reason for the abandonment of calls.
  - **No service:** Service unavailable (no network coverage).
  - **Congestion:** Network overload.
  - **Radio link failure:** Failure in the radioelectric channel between the mobile terminal and the base station. This may occur when the mobile terminal enters a network shadow zone.
  - **Other:** Other call abandonment causes.

RSSI (dBm): ***R****eceived* ***S****ignal* ***S****trength* ***I****ndication* – Indicates the strength of the signal received by the mobile terminal. The RSSI is measured on the control channel (BCCH) and therefore is not affected by frequency hopping or downlink power control algorithms.

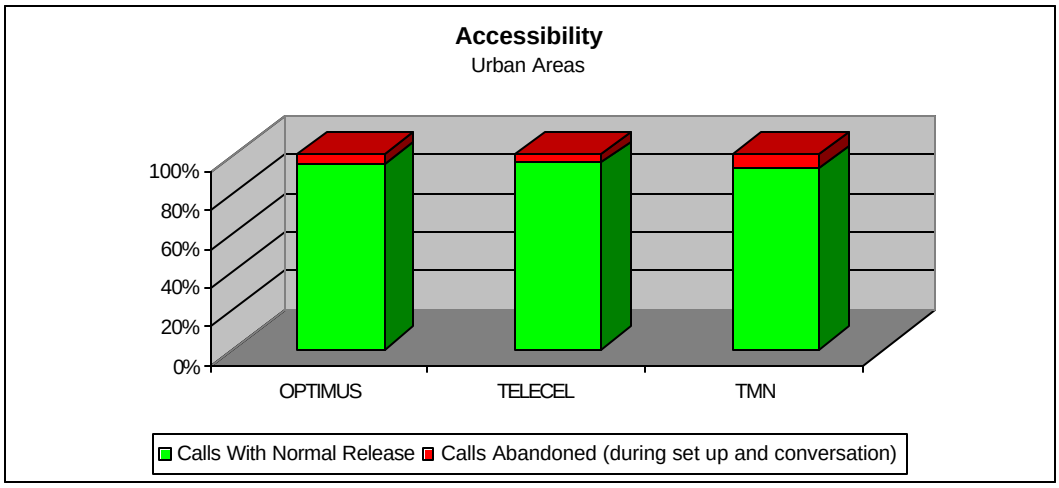
BCCH ***B****roadcast* ***C****ontrol* ***Ch****annel* – Sends information to all mobile terminals (MS's) served by a given BTS (*Base Transceiver Station*). Information is sent in downlink mode and includes a range of control parameters such as: CI (Cell Identity), LAC (Local Area Code), MCC (Mobile Country Code), MNC (Mobile Network Code) and FH (Frequency Hopping) algorithm.

PSTN: **P**ublic **S**witched **T**elephone **N**etwork.

2.2 URBAN AREAS

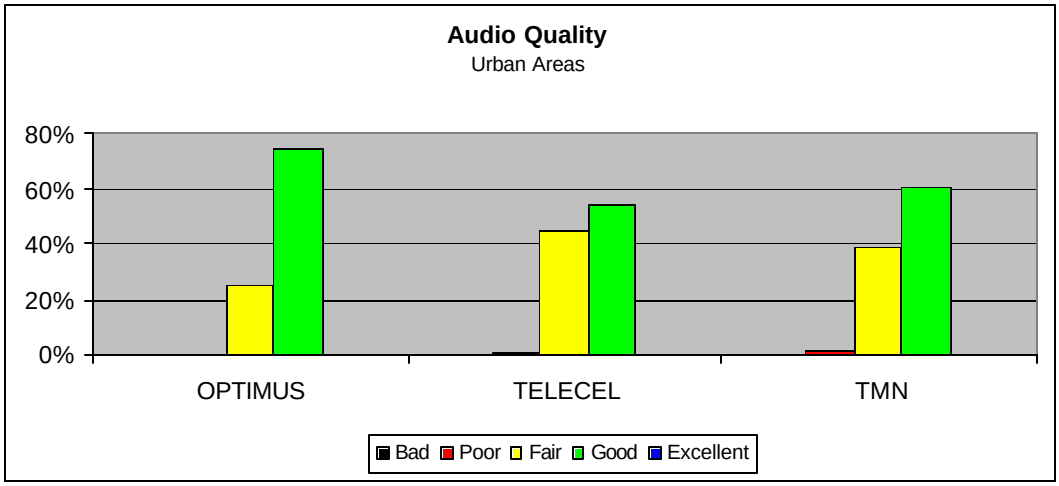
2.2.1 ACCESSIBILITY

		Operator	OPTIMUS			TELECEL			TMN		
		Call Type	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
Performed Calls		Total	1910 100%	3089 100%	4999 100%	1920 100%	3093 100%	5013 100%	1953 100%	3132 100%	5085 100%
Routed Calls		Total	1851 96,91%	2972 96,21%	4823 96,48%	1854 96,56%	2993 96,77%	4847 96,69%	1839 94,16%	2979 95,11%	4818 94,75%
		Abandoned During Conversation	13 0,68%	29 0,94%	42 0,84%	18 0,94%	35 1,13%	53 1,06%	26 1,33%	37 1,18%	63 1,24%
		Normal Release	1838 96,23%	2943 95,27%	4781 95,64%	1836 95,63%	2958 95,64%	4794 95,63%	1813 92,83%	2942 93,93%	4755 93,51%
Calls Not Routed			59 3,09%	123 3,98%	182 3,64%	66 3,44%	100 3,23%	166 3,31%	114 5,84%	153 4,89%	267 5,25%
Abandoned Calls		Total	72 3,77%	152 4,92%	224 4,48%	84 4,38%	135 4,36%	219 4,37%	140 7,17%	190 6,07%	330 6,49%
	Call Ending Causes	No Service	2 0,10%	10 0,32%	12 0,24%	1 0,05%	8 0,26%	9 0,18%	1 0,05%	15 0,48%	16 0,31%
		Congestion	0 0,00%	58 1,88%	58 1,16%	0 0,00%	54 1,75%	54 1,08%	0 0,00%	93 2,97%	93 1,83%
		Radio Link Failure	18 0,94%	14 0,45%	32 0,64%	11 0,57%	17 0,55%	28 0,56%	26 1,33%	20 0,64%	46 0,90%
		Other	52 2,72%	70 2,27%	122 2,44%	72 3,75%	56 1,81%	128 2,55%	113 5,79%	62 1,98%	175 3,44%



2.2.2 AUDIO QUALITY

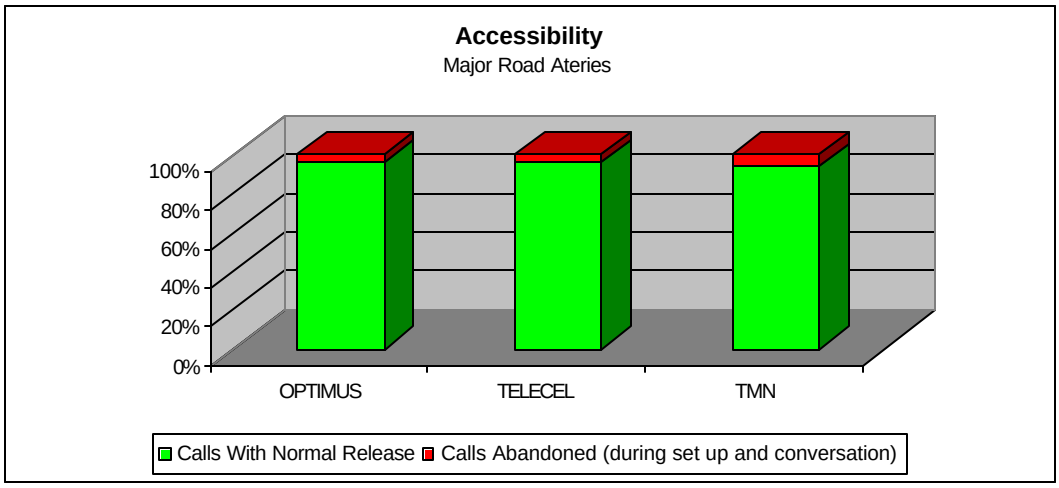
Performed Calls	Operator		OPTIMUS			TELECEL			TMN		
	Call Type		Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
	Total		3693 100%	5910 100%	9603 100%	3637 100%	5948 100%	9585 100%	3663 100%	5907 100%	9570 100%
MOS	1	Bad	4 0.11%	9 0.15%	13 0.14%	9 0.25%	12 0.20%	21 0.22%	4 0.11%	7 0.12%	11 0.11%
	2	Poor	14 0.38%	14 0.24%	28 0.29%	55 1.51%	30 0.50%	85 0.89%	70 1.91%	33 0.56%	103 1.08%
	3	Fair	902 24.42%	1501 25.40%	2403 25.02%	2440 67.09%	1848 31.07%	4288 44.74%	1341 36.61%	2334 39.51%	3675 38.40%
	4	Good	2773 75.09%	4386 74.21%	7159 74.55%	1133 31.15%	4058 68.22%	5191 54.16%	2248 61.37%	3533 59.81%	5781 60.41%
	5	Excellent	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%



2.3 MAJOR ROAD ARTERIES

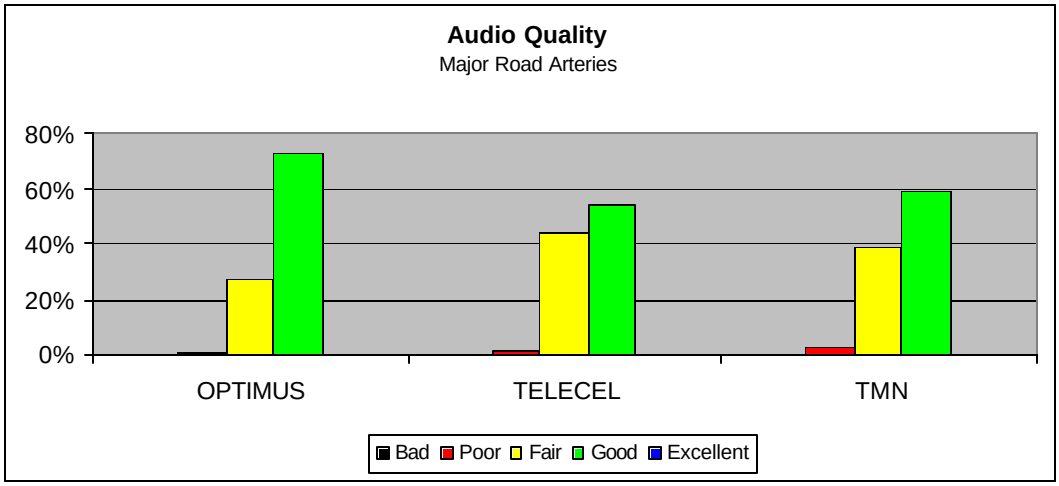
2.3.1 ACCESSIBILITY

		Operator	OPTIMUS			TELECEL			TMN		
		Call Type	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
Performed Calls		Total	950 100%	1808 100%	2758 100%	971 100%	1813 100%	2784 100%	975 100%	1832 100%	2807 100%
Routed Calls		Total	932 98,11%	1752 96,90%	2684 97,32%	934 96,19%	1754 96,75%	2688 96,55%	934 95,79%	1754 95,74%	2688 95,76%
		Abandoned During Conversation	6 0,63%	23 1,27%	29 1,05%	4 0,41%	18 0,99%	22 0,79%	12 1,23%	29 1,58%	41 1,46%
		Normal Release	926 97,47%	1729 95,63%	2655 96,27%	930 95,78%	1736 95,75%	2666 95,76%	922 94,56%	1725 94,16%	2647 94,30%
Calls Not Routed			18 1,89%	55 3,04%	73 2,65%	37 3,81%	59 3,25%	96 3,45%	41 4,21%	78 4,26%	119 4,24%
Abandoned Calls		Total	24 2.53%	78 4.31%	102 3.70%	41 4.22%	77 4.25%	118 4.24%	53 5.44%	107 5.84%	160 5.70%
	Call Ending Causes	No Service	3 0,32%	6 0,33%	9 0,33%	1 0,10%	0 0,00%	1 0,04%	3 0,31%	4 0,22%	7 0,25%
		Congestion	0 0.00%	31 1.71%	31 1.12%	0 0.00%	26 1.43%	26 0.93%	0 0.00%	51 2.78%	51 1.82%
		Radio Link Failure	4 0.42%	13 0.72%	17 0.62%	3 0.31%	10 0.55%	13 0.47%	13 1.33%	16 0.87%	29 1.03%
		Other	17 1,79%	28 1,55%	45 1,63%	37 3,81%	41 2,26%	78 2,80%	37 3,79%	36 1,97%	73 2,60%



2.3.2 AUDIO QUALITY

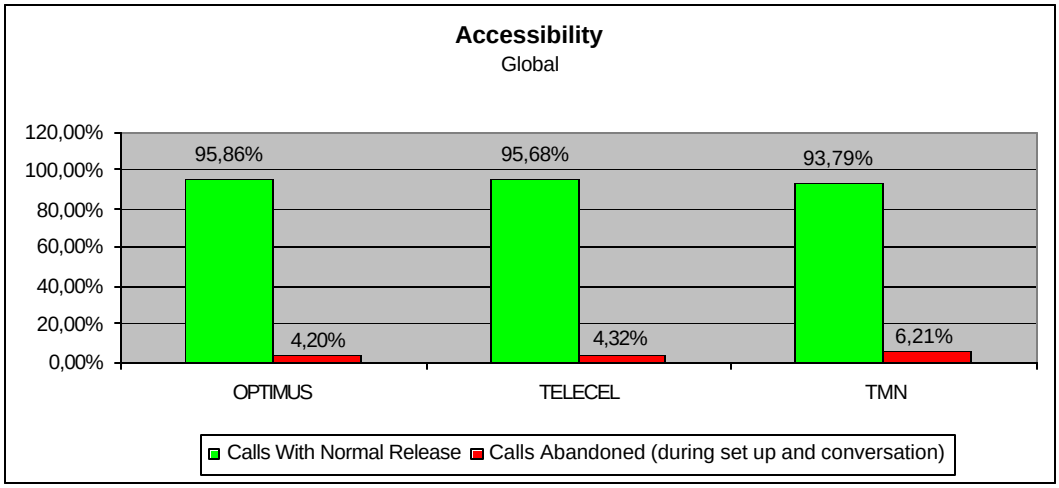
Performed Calls	Operator		OPTIMUS			TELECEL			TMN		
	Call Type		Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
	Total		1859 100%	3479 100%	5338 100%	1862 100%	3485 100%	5347 100%	1858 100%	3478 100%	5336 100%
MOS	1	Bad	1 0.05%	4 0.11%	5 0.09%	6 0.32%	6 0.17%	12 0.22%	5 0.27%	4 0.12%	9 0.17%
	2	Poor	9 0.48%	13 0.37%	22 0.41%	43 2.31%	28 0.80%	71 1.33%	104 5.60%	32 0.92%	136 2.55%
	3	Fair	464 24.96%	979 28.14%	1443 27.03%	1218 65.41%	1146 32.88%	2364 44.21%	660 35.52%	1396 40.14%	2056 38.53%
	4	Good	1385 74.50%	2483 71.37%	3868 72.46%	595 31.95%	2305 66.14%	2900 54.24%	1089 58.61%	2046 58.83%	3135 58.75%
	5	Excellent	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%



2.4 GLOBAL

2.4.1 ACCESSIBILITY

		Operator	OPTIMUS			TELECEL			TMN		
		Call Type	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
Performed Calls		Total	2860 100%	4897 100%	7757 100%	2891 100%	4906 100%	7797 100%	2928 100%	4964 100%	7892 100%
Routed Calls		Total	2783 97,31%	4724 96,47%	7507 96,78%	2788 96,44%	4747 96,76%	7535 96,64%	2773 94,71%	4733 95,35%	7506 95,11%
		Abandoned During Conversation	19 0,66%	52 1,06%	71 0,92%	22 0,76%	53 1,08%	75 0,96%	38 1,30%	66 1,33%	104 1,32%
		Normal Release	2764 96,64%	4672 95,41%	7436 95,86%	2766 95,68%	4694 95,68%	7460 95,68%	2735 93,41%	4667 94,02%	7402 93,79%
Calls Not Routed			77 2,69%	178 3,63%	255 3,29%	103 3,56%	159 3,24%	262 3,36%	155 5,29%	231 4,65%	386 4,89%
Abandoned Calls		Total	96 3,36%	230 4,70%	326 4,20%	125 4,32%	212 4,32%	337 4,32%	193 6,59%	297 5,98%	490 6,21%
	Call Ending Causes	No Service	5 0,17%	16 0,33%	21 0,27%	2 0,07%	8 0,16%	10 0,13%	4 0,14%	19 0,38%	23 0,29%
		Congestion	0 0,00%	89 1,82%	89 1,15%	0 0,00%	80 1,63%	80 1,03%	0 0,00%	144 2,90%	144 1,82%
		Radio Link Failure	22 0,77%	27 0,55%	49 0,63%	14 0,48%	27 0,55%	41 0,53%	39 1,33%	36 0,73%	75 0,95%
		Other	69 2,41%	98 2,00%	167 2,15%	109 3,77%	97 1,98%	206 2,64%	150 5,12%	98 1,97%	248 3,14%



2.4.2 AUDIO QUALITY

Performed Calls		Operator	OPTIMUS			TELECEL			TMN		
		Call Type	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global	Mobile-Mobile	Mobile-Fixed	Global
		Total	5552 100%	9389 100%	14941 100%	5499 100%	9433 100%	14932 100%	5521 100%	9385 100%	14906 100%
MOS	1	Bad	5 0.09%	13 0.14%	18 0.12%	15 0.27%	18 0.19%	33 0.22%	9 0.16%	11 0.12%	20 0.13%
	2	Poor	23 0.41%	27 0.29%	50 0.33%	98 1.78%	58 0.61%	156 1.04%	174 3.15%	65 0.69%	239 1.60%
	3	Fair	1366 24.60%	2480 26.41%	3846 25.74%	3658 66.52%	2994 31.74%	6652 44.55%	2001 36.24%	3730 39.74%	5731 38.45%
	4	Good	4158 74.89%	6869 73.16%	11027 73.80%	1728 31.42%	6363 67.45%	8091 54.19%	3337 60.44%	5579 59.45%	8916 59.81%
	5	Excellent	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%