

Assessment of QoS in mobile networks

The drive-test campaigns in Italy



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OUTLINE

- ❑ Project cornerstones

- ❑ Project overview (2012-2014)

- ❑ Measurement Methodology:
 - Key Performance Indicators
 - Measurement System Architecture
 - Measurement Campaign Settings

- ❑ Example of results

- ❑ Project evolution (2015-2017)

PROJECT CORNERSTONES

❑ Regulatory reference:

- AGCOM Deliberation n. 154/12/CONS [2012 -> 2015]
- AGCOM Deliberation n. 580/15/CONS [2015 -> 2017]

❑ Main goal:

- Monitoring the QoS performance provided by mobile networks

❑ Methodology:

- The QoS is evaluated through measurement campaigns based on **outdoor nomadic drive-tests** carried out across the country

❑ Main technical reference:

- ETSI Standard: ETSI TS 102-250 & TS 202-057

PROJECT OVERVIEW (2012-2014)

AGCOM DELIBERATION 154/12/CONS (MARCH 29TH, 2012)

- ❑ AGCOM, the Italian National Regulatory Authority (NRA) issued a deliberation on **Quality of Service (QoS) in mobile networks**

- ❑ Broadband Internet Access performance of all four Italian mobile networks (H3G, Telecom Italia, Vodafone and Wind) is evaluated by means of **nomadic test drives**
 - Static measurements for evaluation of mobile network performance
 - *official campaign aimed at publication of results*
 - Dynamical measurements while travelling between static points
 - *experimental campaign for further studies*

MISURAINTERNETMOBILE: AGCOM N. 154/12/CONS DELIBERATION

- ❑ The MisuraInternetMobile project gives users the ability to **verify and compare** the quality of Internet access from mobile terminals

<http://www.misurainternetmobile.it>

The results of the test campaigns can be found here



- ❑ Activity funded by and conducted with the support of Italian mobile network operators, coordinated and monitored by a **Technical Board**
 - AGCOM, FUB, MNOs
- ❑ **Two campaigns per year (four months each)**
 - ≈ 6000km covered (per campaign)
 - 20/40 big cities covering all geographic regions of the Country

THE ROLE OF FONDAZIONE UGO BORDONI

- ❑ Deliberation n. 154/12/CONS commits to **Fondazione Ugo Bordoni** the design and management of the measurement campaign, including:
 - Devising the **measurement system architecture**
 - **Planning** of activities to be carried out as indicated by AGCOM,
 - Supplying **resources and technical equipment**,
 - Performing the **measurements**,
 - Acquiring **results** and making them available to MNOs and AGCOM,
 - Managing the process of technical **validation** of the results,
 - Carrying out the **statistical analysis and aggregation** of the data,
 - Arranging the **final results** for the Technical Board and the public.

MEASUREMENT METHODOLOGY

KEY PERFORMANCE INDICATORS

- ❑ According to ETSI TS-102-250 & TS-202-057 some KPI have been chosen for evaluation of network performance and quality of mobile broadband service, in terms of:
 - Data transmission (DL/UL) throughput
 - Data transmission (DL/UL) unsuccessful rate

 - Web page download time (HTTP/HTTPS)
 - Web page download unsuccessful rate (HTTP/HTTPS)

 - Packet delay
 - Packet loss
 - Jitter

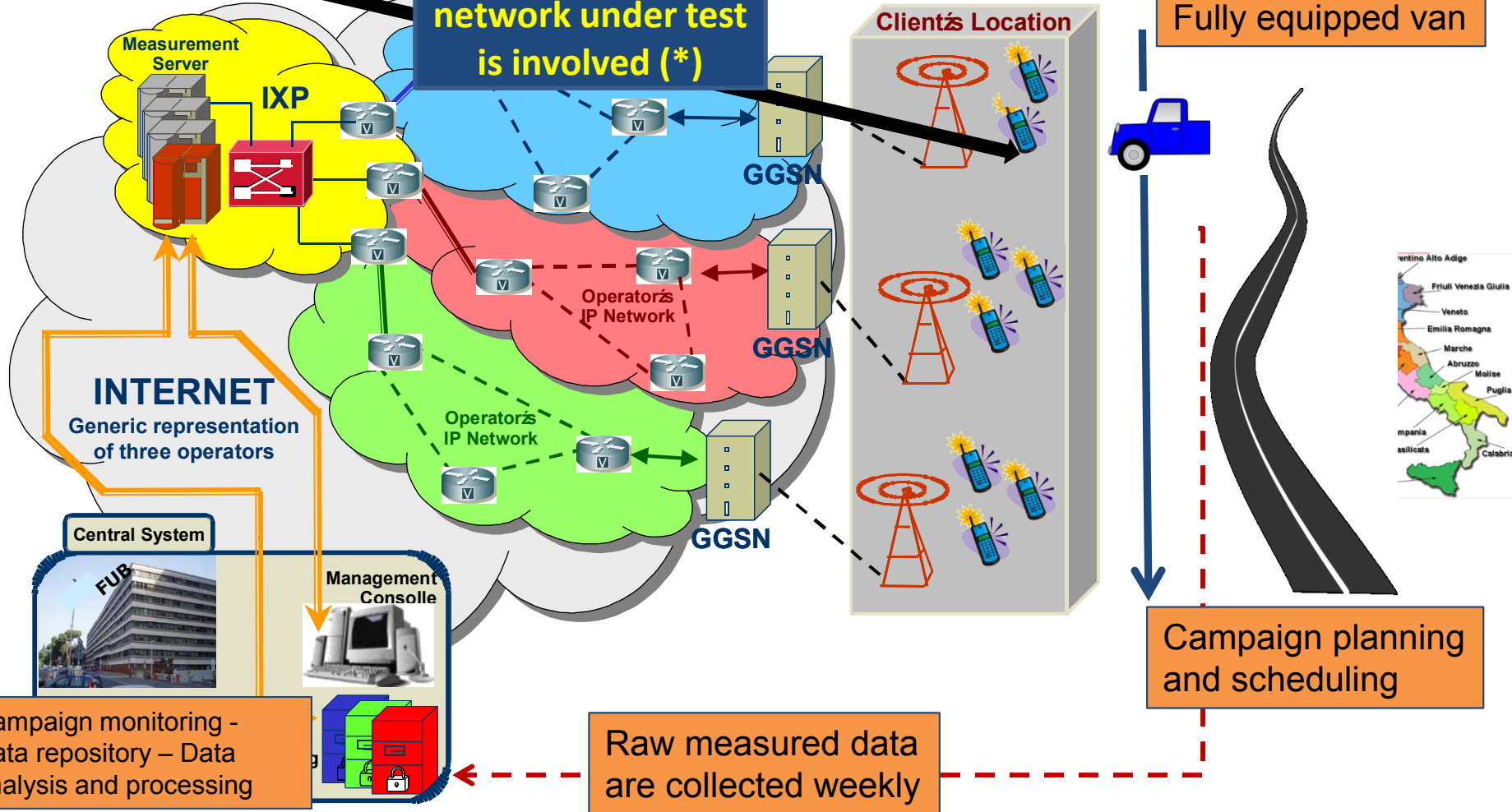
MEASUREMENT SYSTEM ARCHITECTURE

Test server at MIX - Milano

Only the mobile network under test is involved (*)

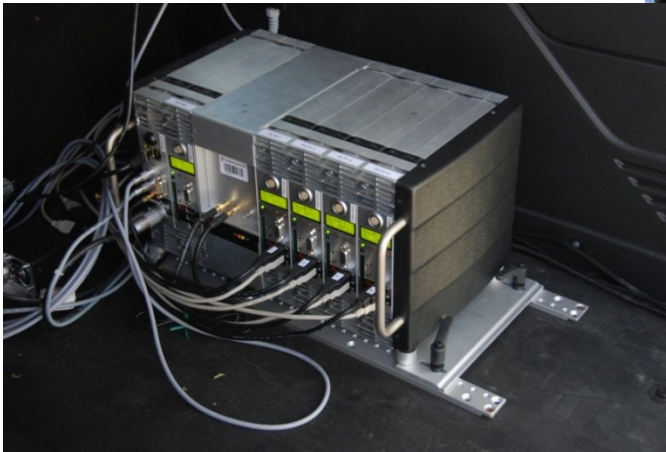
(*) exception: NEW Youtube tests

Fully equipped van



THE MOBILE LAB AND THE MEASUREMENT TOOL

- ❑ The Technical Board selected the Diversity Benchmarking I as the measurement tool for the drive test campaigns
 - N+1 independent CPUs (N devices + 1 scanner) manage the measurement activity
 - Deep insight into the behaviour of devices and networks



THE MOBILE LAB

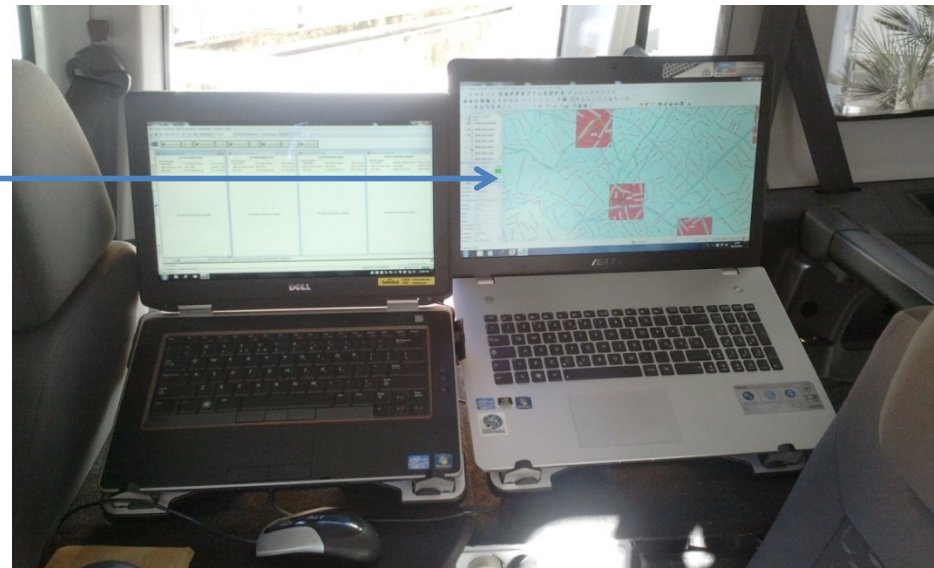
MEASUREMENT CAMPAIGN FIRST IMPLEMENTATION



Drive-test: the four terminal devices

Drive-test: the path management console

Drive-test: the test management console



ACTIVITY SCHEDULE

❑ Closed measurement campaigns

Campaign	Period	Nr of cities	
2012_1	June-October 2012	20	<u>experimental</u>
2013_1	January-May 2013	20	<u>published</u>
2013_2	November 2013-March 2014	20	<u>published</u>
2014_1	May-September 2014	40	<u>to be published</u>

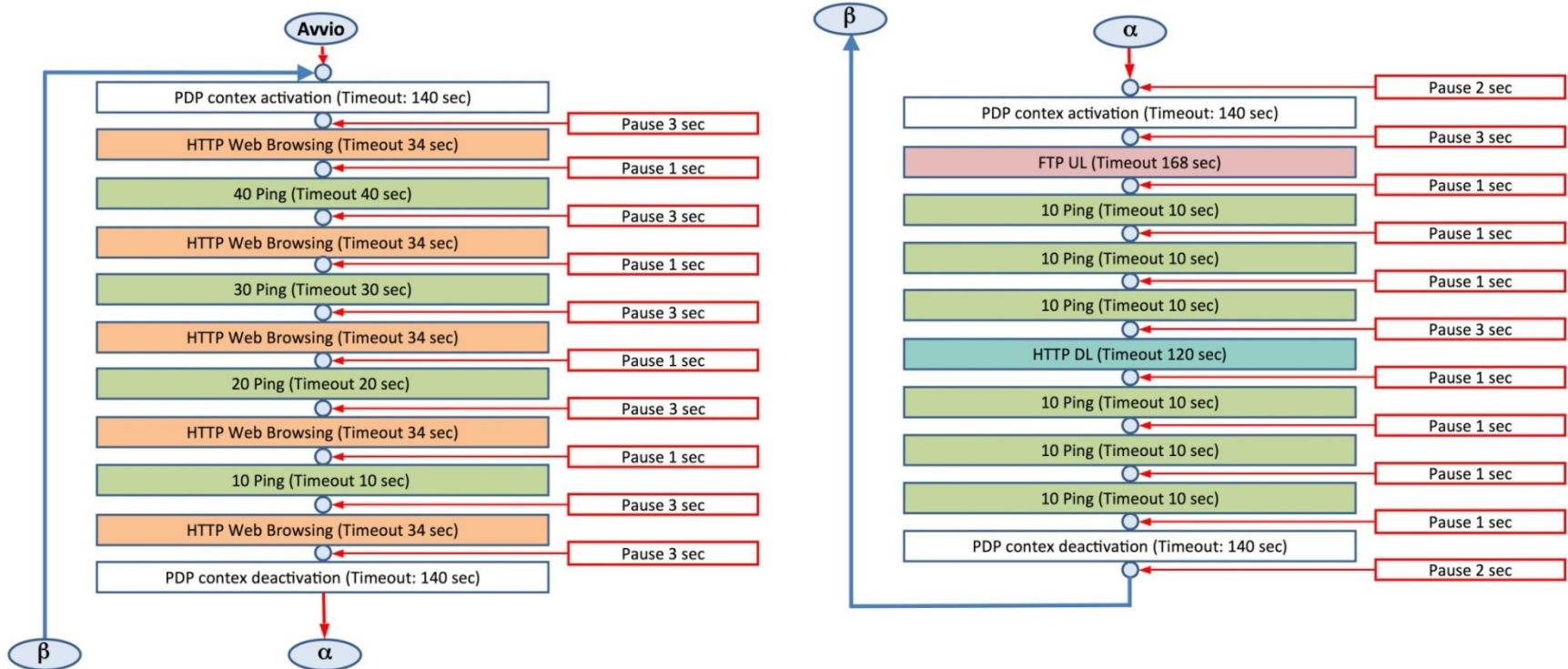
❑ Measurements are performed only

➤ Monday-Friday 8:00-20:00

MEASUREMENT SUITE DEFINITION (2012-2014)

- ❑ During every test suite, a test cycle composed of atomic tests is performed
 - FTP upload data transmission: an MP3 test file is uploaded, the file size is **1 Mbyte**;
 - HTTP download data transmission: an MP3 test file is downloaded, the file size is **3 Mbyte**;
 - HTTP/HTTPS web page browsing: a web page defined by ETSI is downloaded. The web reference page size is **800 kbyte**;
 - Ping: to measure the packet transmission delay. Measurements are carried out by ICMP packets (Internet Control Message Protocol) having a size of **32 bytes**.

MEASUREMENT LOOP EXAMPLE

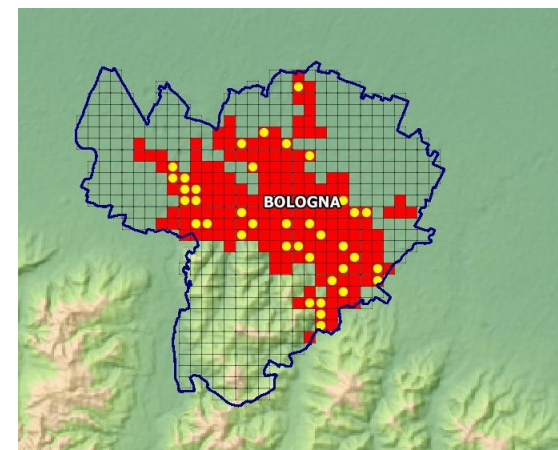


In each static point the test suite is repeated along a predefined time interval

- 20 min (1013 test points, 20 cities)
- 15 min (1202 test points, 40 cities)

DRIVE TEST: SELECTION CRITERIA OF MEASUREMENT PIXELS

- ❑ The municipal area of the selected cities is divided in elementary square areas (pixels) of side equal to 500meters
- ❑ A basic subset among the total pixel of a city was identified based on a function of population density
 - Corine Database from EEA
- ❑ The number of tested pixels
 - is predetermined for each city
 - depends both on the size of the subset and on the population of the region
- ❑ Pixels are randomly chosen from those belonging to the basic subset



❑ Selected pixels, campaign scheduling and paths are kept secret

DRIVE TEST: VISITED CITIES AND MEASURING POINTS (2012-2013)



Region	City	Pixels
Abruzzo	Pescara	19
Basilicata	Potenza	10
Calabria	Reggio Calabria	28
Campania	Napoli	82
Emilia-Romagna	Bologna	57
Friuli-Venezia Giulia	Trieste	23
Lazio	Roma	198
Liguria	Genova	44
Lombardia	Milano	134
Marche	Ancona	19
Molise	Campobasso	10
Piemonte	Torino	73
Puglia	Bari	56
Sardegna	Cagliari	23
Sicilia	Palermo	80
Toscana	Firenze	51
Trentino-Alto	Trento	18
Umbria	Perugia	19
Valle d'Aosta	Aosta	10
Veneto	Verona	59
TOTAL		1013

PIXEL SELECTION CRITERIA UP TO 2013 (BEFORE ADDITION OF 20 NEW CITIES IN 2014)

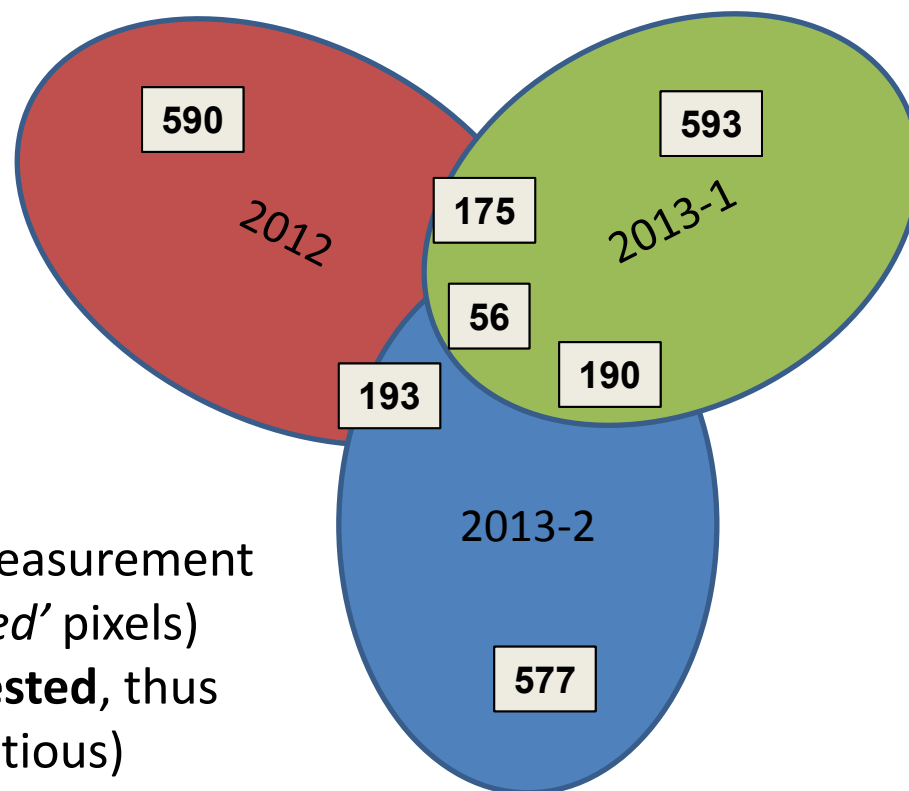
REGIONE	Popolazione nelle 20 regioni (%)	COMUNE	Superficie territoriale totale (%)	Popolazione nelle 20 città (%)	Numero pixel comuni	Numero pixel SUBSET (30%; Dens media > 1875)	Numero pixel 1 (20% - min. 10)	Numero pixel 2 (popolazione regionale - min. 10)	Numero pixel SELEZIONE
LAZIO	9.4%	ROMA	31.7%	28.3%	5,154	1,504	301	94	198
LOMBARDIA	16.4%	MILANO	4.4%	13.6%	728	515	103	164	134
CAMPANIA	9.6%	NAPOLI	2.8%	9.8%	497	340	68	96	82
PIEMONTE	7.4%	TORINO	3.2%	9.3%	518	360	72	74	73
SICILIA	8.3%	PALERMO	3.8%	6.7%	646	382	76	83	80
LIGURIA	2.7%	GENOVA	5.9%	6.2%	996	299	60	27	44
EMILIA-ROMAGNA	7.3%	BOLOGNA	3.4%	3.9%	567	198	40	73	57
TOSCANA	6.2%	FIRENZE	2.5%	3.8%	410	198	40	62	51
PUGLIA	6.7%	BARI	2.8%	3.3%	478	220	44	67	56
VENETO	8.1%	VERONA	5.0%	2.7%	799	184	37	81	59
FRIULI-VENEZIA GIULIA	2.0%	TRIESTE	2.0%	2.1%	368	132	26	20	23
CALABRIA	3.3%	REGGIO DI CALABRIA	5.7%	1.9%	985	108	22	33	28
UMBRIA	1.5%	PERUGIA	10.9%	1.7%	1,786	110	22	15	19
SARDEGNA	2.8%	CAGLIARI	2.1%	1.6%	354	91	18	28	23
ABRUZZO	2.2%	PESCARA	0.8%	1.3%	138	79	16	22	19
TRENTINO-ALTO ADIGE	1.7%	TRENTO	3.8%	1.2%	628	97	19	17	18
MARCHE	2.6%	ANCONA	3.0%	1.1%	504	59	12	26	19
BASILICATA	1.0%	POTENZA	4.2%	0.7%	698	42	10	10	10
MOLISE	0.5%	CAMPOBASSO	1.3%	0.5%	223	27	10	10	10
VALLE D'AOSTA	0.2%	AOSTA	0.5%	0.4%	85	24	10	10	10
100.0%		TOTALE	100.0%	100.0%	16,562	4,969	1,006	1,012	1,013

«enabled» pixels

RANDOM SELECTION OF TEST PIXELS – REPEATED TESTS

□ 20-cities campaigns

□ Due to the random selection of measurement point (within the subset of 'enabled' pixels) **some pixels may be repeatedly tested**, thus possibly allowing subsequent (cautious) comparisons of results



EXAMPLE

SYNTHESIS OF THE ACTIVITY DURING ONE CAMPAIGN (2013-1)

City	N_Pixel (planned)	Pixel H3G	N_test H3G	Pixel TIM	N_test TIM	Pixel Vodafone	N_test Vodafone	Pixel Wind	N_test Wind	Pixel (Total)	N_test (Total)
Ancona	19	19	1 918	19	2 992	19	2 324	19	2 095	19	9 329
Aosta	10	10	1 004	10	1 507	10	1 201	10	1 179	10	4 891
Bari	56	50	5 081	56	8 417	56	7 743	55	6 083	56	27 324
Bologna	57	57	6 328	57	9 239	57	7 903	57	6 050	57	29 520
Cagliari	23	23	2 188	23	3 483	23	2 681	23	1 710	23	10 062
Campobasso	10	8	852	10	1 608	10	1 481	10	834	10	4 775
Firenze	51	51	5 289	51	7 998	51	5 997	51	4 254	51	23 538
Genova	44	44	5 205	44	6 146	44	5 337	44	5 594	44	22 282
Milano	134	134	15 271	134	21 328	134	19 266	134	16 837	134	72 702
Napoli	82	74	9 521	82	10 810	82	10 987	82	8 993	82	40 311
Palermo	80	79	10 726	80	11 007	80	11 025	80	7 734	80	40 492
Perugia	19	19	1 866	19	2 897	19	2 302	19	1 477	19	8 542
Pescara	19	19	2 227	19	2 815	19	2 392	19	1 568	19	9 002
Potenza	10	10	962	10	1 349	10	1 378	10	1 154	10	4 843
Reggio Calabria	28	28	3 137	28	4 298	28	3 597	28	3 233	28	14 265
Roma	198	190	19 115	198	22 085	198	20 279	198	16 176	198	77 655
Torino	73	73	8 207	73	11 378	73	10 245	73	9 455	73	39 285
Trento	18	17	1 724	18	2 479	18	2 190	18	1 856	18	8 249
Trieste	23	22	2 412	22	3 572	22	2 641	22	2 229	22	10 854
Verona	59	58	7 226	58	9 945	57	8 688	58	6 701	58	32 560
TOTAL	1 013	985	110 259	1 011	145 353	1 010	129 657	1 010	105 212	1 011	490 481

DATA PROCESSING

- ❑ The obtained data are **validated** and processed

- ❑ Aggregation for performance-related KPIs
 - for each city, for each operator, for each test and KPI, the upper and lower values (below 5° and above 95° percentile) are discarded
 - the remaining 90% of the data are **first averaged at pixel level**
 - the results are then aggregated at city level and on national basis

- ❑ Aggregation for failure-related KPIs
 - **direct aggregation** from 'atomic' test level to city or campaign level

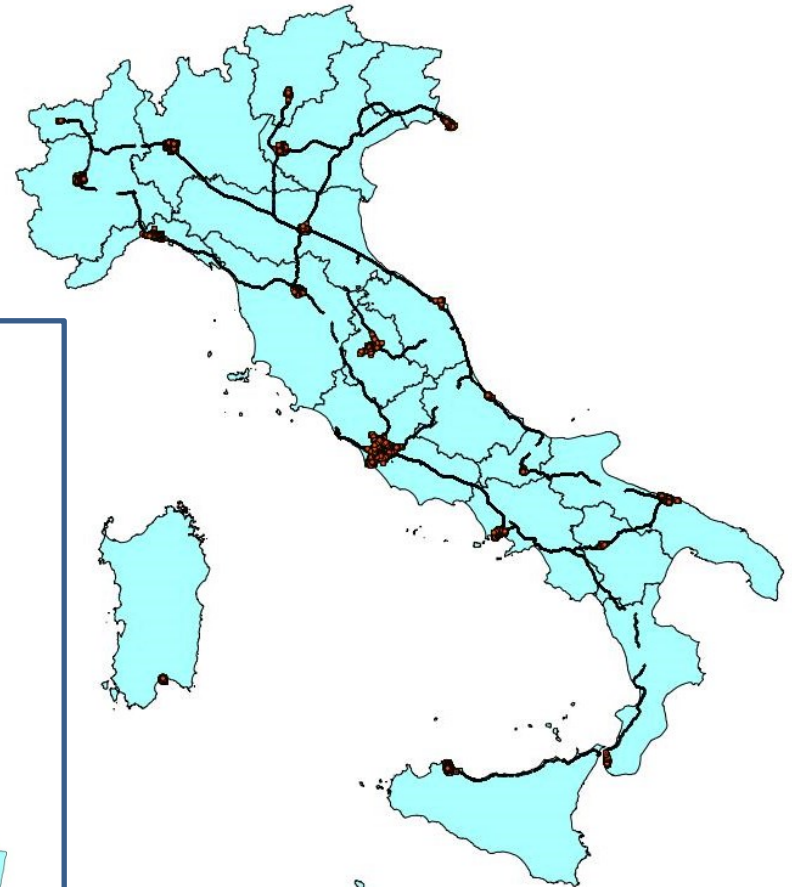
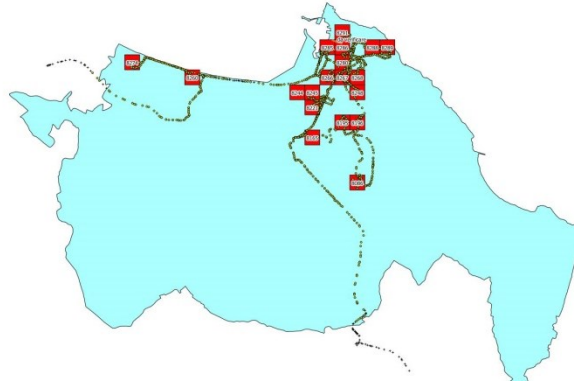
- ❑ The results were distinguished between **static** (for official/public use) and **dynamic** measurements (for internal/research purpose)

EXTRA-URBAN/URBAN DYNAMIC MEASUREMENTS

☐ Transfer between test cities

☐ Transfer between pixels within the municipal area

☐ Transfer from and toward other cities

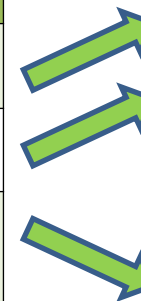


EXAMPLE OF RESULTS

EXAMPLE OF OVERALL RESULTS FOR COMMUNICATION TO THE PUBLIC

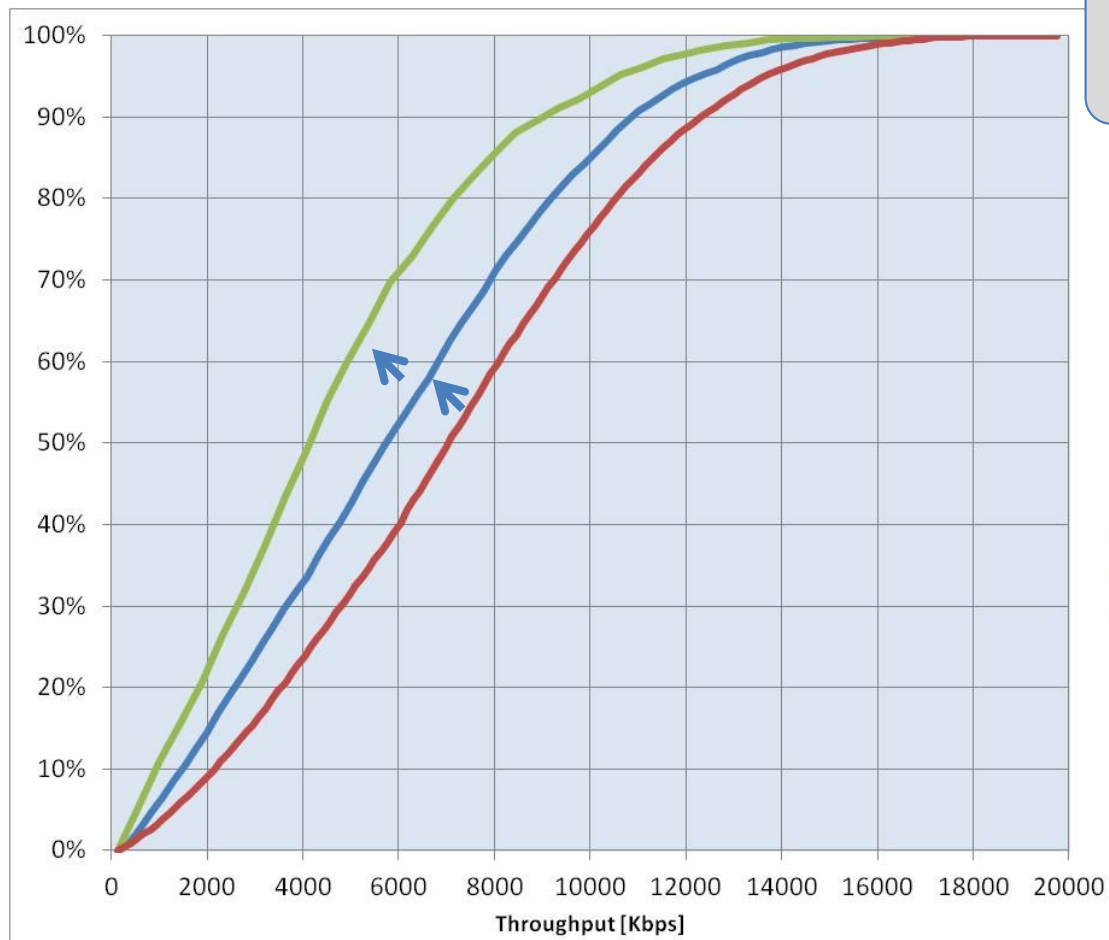
- ❑ A positive trend can be observed in the overall average performance of the 4 national mobile networks
- ❑ 3G tests with USB dongles

KPI	2013_1	2013_2
FTP Upload <u>throughput</u> (kbps)	1573	1707
HTTP Download <u>throughput</u> (kbps)	6268	6738
Web page download <u>time</u> HTTP (sec)	3.58	2.90
Web page download <u>time</u> HTTPS (sec)		3.17
Round Trip <u>Time</u> (ms)	54.51	55.37



EXAMPLE OF RESULTS FOR STUDY PURPOSE

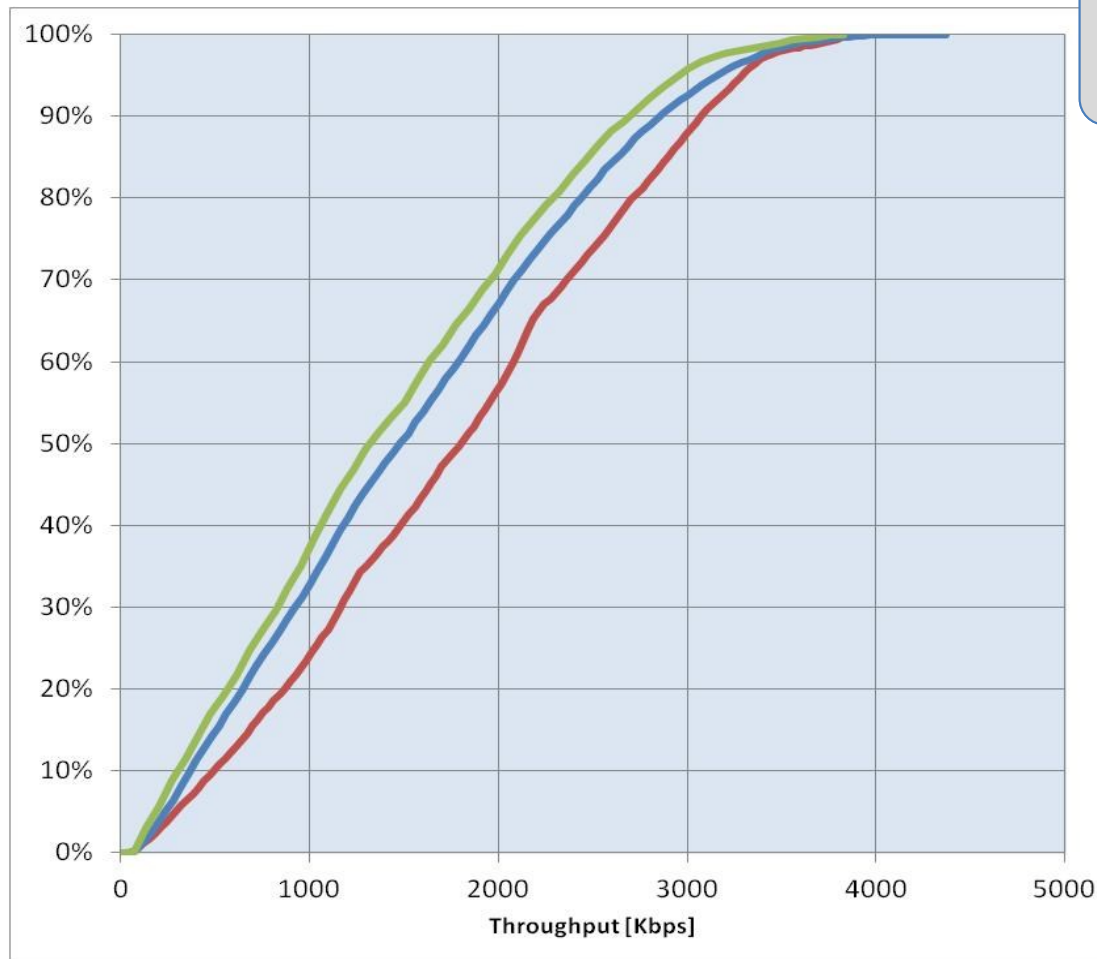
CUMULATIVE CURVES: HTTP DL THROUGHPUT DISTRIBUTION



29355 http dl test
between static and dynamic
measurements

Dynamic_URBAN
Dynamic_EXTRA-URBAN
Static_URBAN

CUMULATIVE CURVES: FTP UL THROUGHPUT DISTRIBUTION



37145 ftp ul test
between static and dynamic
measurements

Static_URBAN
Dynamic_URBAN
Dynamic_EXTRA-URBAN

PROJECT EVOLUTION (2015-2017)

AGCOM DELIBERATION 580/15/CONS (NOVEMBER XXTH, 2015)

- ❑ AGCOM, the Italian National Regulatory Authority (NRA) issued a **NEW** deliberation on **Quality of Service (QoS) in mobile networks**

- ❑ Broadband Internet Access performance of all four Italian mobile networks (H3G, Telecom Italia, Vodafone and Wind) is evaluated by means of **nomadic test drives**
 - **STATIC & DYNAMICAL** measurements for evaluation of mobile network performance
 - The test devices are **SMARTPHONES** (Samsung S5 cat. 4)
 - **4G TECHNOLOGY** is tested
 - **YOUTUBE** videostreaming tests
 - New **FIXED DURATION** approach for DL/UL data transfer tests

 - New **graphic interactive access** to the measured data

THE NEWLY EQUIPPED MOBILE LAB

- ❑ The measurement tool has been upgraded (Diversity Benchmarking II)
 - 4 smartphones (Samsung S5) are hosted in the new equipment
 - The tests are performed by the Android OS
 - LTE test capabilities



6 antennas (+2 GPS)
in the rooftop box

(without RF combiners
=> 18 + 2 antennas)



FIXED DURATION TESTS

❑ ETSI TR 102 678 V1.2.1 (2011-05)

- Speech and multimedia Transmission Quality (STQ);
QoS Parameter Measurements based on fixed Data Transfer Times

➤ *“Due to the wide range of uplink and downlink throughput in modern mobile communication networks, limited and regular run times cannot be provided when having e.g. fixed object (file) sizes for the measurements.”*

❑ Fixed duration tests available in Diversity Benchmarker

- DL/UL transfer tests of very large files (e.g. **2 Gbyte**), limited to **30 sec**

VIDEOSTREAMING TEST

- ❑ A streaming service could be developed and located at the NAP
 - 👎 Advanced real-world streaming techniques can hardly be replicated
 - 👍 The test activity is kept within the mobile network under test

- ❑ One of the most diffused videostreaming service (YouTube) can be used by the measurement equipment ✓
 - 👍 Advanced streaming techniques, as experienced by the users, can be taken into account
 - 👎 The tests involve sections of external networks

VIDEOSTREAMING TEST

❑ ETSI TR 101 578 V1.2.1 (2015-07)

- Speech and multimedia Transmission Quality (STQ);
- QoS aspects of TCP-based video services like YouTube™

❑ Fixed duration test

- Download & playout of a long video (300 sec), limited to 30 sec

- This prevents the test from being performed mostly after completion of the file transfer

COMPARISON TABLE FOR THE CAMPAIGNS

AGCOM Deliberation

154/12/CONS	580/15/CONS
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Drive Test Campaigns

2012	2013 - 1	2013 - 2	2014	2015	2016 - 1	2016 - 2	2017
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Type of tests

Data download	HTTP	FIXED FILE	E	x	x	x	x		
		FIXED DURATION					x	x	
Data upload	FTP	FIXED FILE	E	x	x	x			
	HTTP	FIXED DURATION					x	x	
Web page download	HTTP		E	x	x	x	x	x	
	HTTPS			E	x	x	x	x	
Packet TX/RX			E	x	x	x	x	x	
Videostreaming							x	x	

x
E
R

x Official tests for publication
E Experimental test/campaign
R Reserved to AGCOM/FUB

In 3G sub-campaign the fixed-file DL test is carried out for comparison with previous campaigns (historical series)

FTP UL tests are replaced with HTTP UL tests (ref. ETSI ES 202 765-4 V1.2.1)

3G-limited and 4G sub-campaigns (in selected cities) are carried out

Test devices

USB dongle	E	x	x	x				
Smartphone					x	x		

Technology

3G-2G	E	x	x	x	x	x		
4G-3G-2G					x	x		

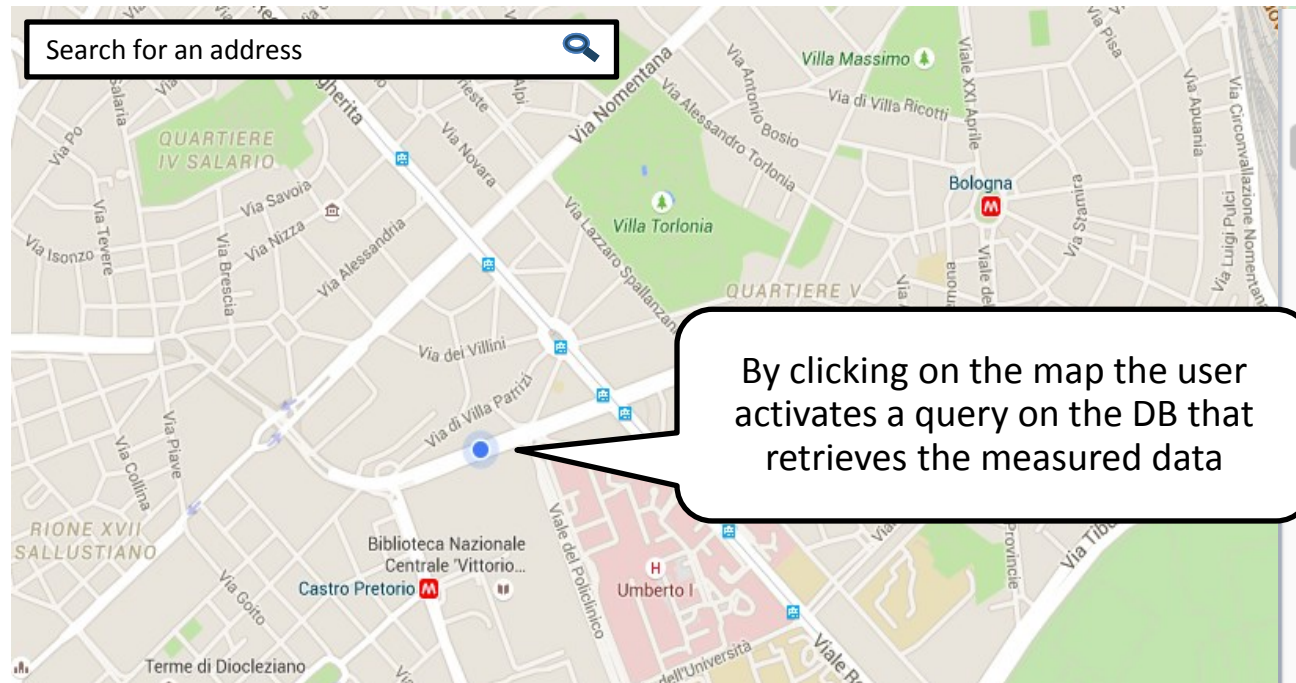
Test scenario

Static	E	x	x	x	x	x		
Dynamic	R	R	R	R	x	x		
N. of cities	20	20	20	40	40	40		
N. of static points	1013	1013	1013	1202	1202	1202		

INTERACTIVE ACCESS TO THE RESULTS

GRAPHIC INTERFACE

- A new approach to the presentation of the results will allow the users to access **specific data, related to the closest measurement point wrt a selected address (home, office...) or geographical point.**



Thank you for your attention

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