Testing is our Competence

LTE: The Need for Speed!

(from a QoE perspective)

Patrick TANG

Vice President, AsiaPacific

Date: 27 July 2017

App Experience

Roaming and Interconnection

Professional Services

Quality of Service & Quality of Experience

Revenue Assurance

Interconnect Fraud Detection

SIGOS

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Agenda

- **SIGOS – An Introduction**
- Global LTE Statistics
- LTE: The Need for Testing
- LTE Reports
- LTE Roaming
  - LTE: IR.38 Testing
  - GSMA LTE GRQ
- LTE Test Scenarios
- LTE: SIGOS Customer Case Studies

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SIGOS in Numbers

27+ years Experience

350+ Employees

Over 470 Mobile Network Operators as Customers

Partners & Representations in 60+ locations

Customers in 157 countries

Cooperation with / Member of:

GSMA Associate Member

GSMA Open Connectivity Solution Provider – SMS HUB ROAMING HUB GLOBAL ROAMING QUALITY

ITU

3GPP A GLOBAL INITIATIVE

LGA InterCert Certified Quality System ISO 9001:2008

TÜV SÜD

BABT

ETSI MEMBER

one M2M

LTE Advanced Pro

SIGOS is accredited, in cooperation and / or certified by

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SIGOS: Your Use Cases and Your Benefits

Testing is our Competence

End-to-End QoS & QoE Testing

- Underlying platform for all SIGOS products
- Most QoS & QoE solution used worldwide
- All technologies, all services, from core to radio

Advanced Roaming Services

- World's largest roaming test system
- GSMA 4G reference system
- #1 roaming rollout and services

Billing & Tariff Verification

- Most comprehensive active RA
- Any stage, any tariff, any promo
- National and roaming RA

Fraud & SIM Box Detection

- #1 fraud detection solution used
- Most innovative & certified solution
- Fastest fraud detection available

App Experience

- Market leader in mobile app testing
- Largest global device bank
- Used by over 400 enterprises

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Representations & Authorized Partners

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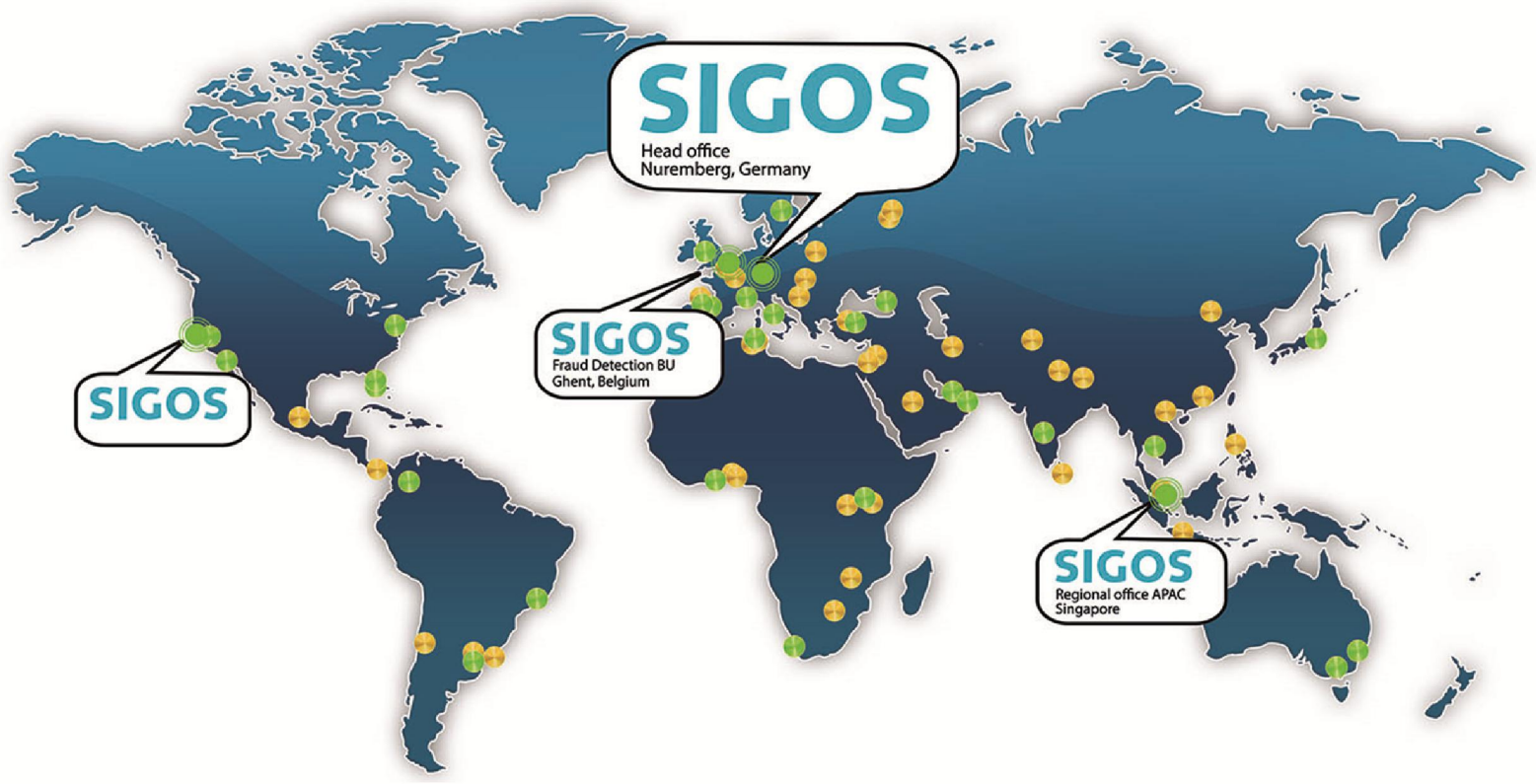

- SIGOS representative
- SIGOS authorized business partner

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Use Case Overview

Network Testing

Radio (2G/3G/**LTE**), Fixed & IP Network; **Core Network**

Quality of Service Testing (QoS)

Periodic QoS & QoE; On Demand;
Network Diagnosis; Benchmarking; **LTE, LTE-Advanced & IMS Testing**; M2M Service Assurance

Quality of Experience Testing (QoE)

Test, Monitor and Benchmark Services on Real Devices; Test and Monitor Mobile Apps on Real Devices; VoLTE; VoWIFI

App & Real Device Testing and Monitoring

Live Monitoring; Performance Testing

Roaming Testing

Inbound Roaming; Outbound Roaming;
Global Roaming Quality (GRQ); Roaming Hubbing;
Steering of Roaming (SoR); Roaming Radar
LTE, CSFB & VoLTE Roaming TestingL

International Carrier Quality Testing (ICQT)

Periodic QoS; A2P SMS; Incoming CLI Verification

Fraud & SIM Box Detection

Enhanced SIM Box Detection; Interconnect Assurance; OTT Bypass Detection; SMS Bypass; EU Refiling Detection; Leaky PBX Detection; SIM Box Terminator

Revenue Assurance

CDR Comparison and Testing; Billing Verification; Roaming RA; RA for Mobile Regulators; Prepaid SIM Recharging; Test Call / Event Generation

Boundary Free Testing

QoS Testing on the Move; Nomadic, Venue or Large Scale Testing; SITE 360

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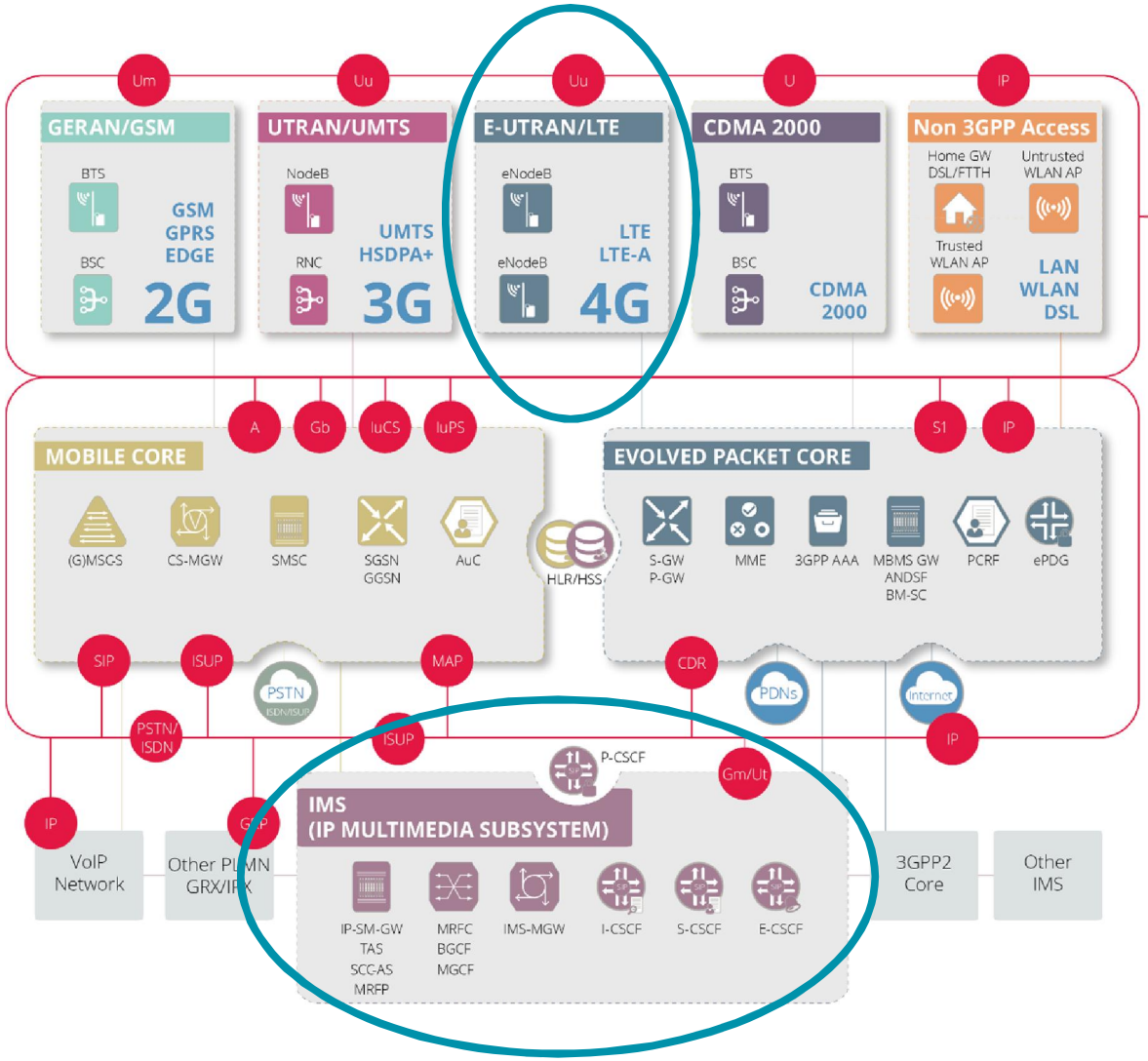
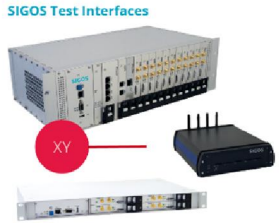
LTE and IMS Testing Concept





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GlobalRoamer – World's Largest test probe coverage

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210+ countries

780+ networks

330+ locations

Germany + Belgium
Central Unit + SIM
Multiplexer + 420 Pool
SIM Cards

- GlobalRoamer Country
- GlobalRoamer Location
- LTE / CSFB Location

*Map includes GlobalRoamer Q1 rollout plan

March 2017

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Worldwide Customers Footprint

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470 Network Operators and over **670 Enterprise Customers** in 157 countries worldwide use products of the SIGOS portfolio for QoS & QoE testing, fraud detection, roaming testing, app & device testing and revenue assurance

Country with SIGOS Customers

Country without SIGOS Customer

January 2017

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Worldwide Customers: Leading Mobile Operators

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North America

Aruba
Bahamas
Canada
Curaçao
Dominican Republic
El Salvador
Guatemala
Haiti
Honduras
Jamaica
Mexico
Panama
USA

South America

Argentina
Bolivia
Brazil
Chile
Colombia
Ecuador
Paraguay
Peru
Suriname
Uruguay
Venezuela

Europe

Albania
Austria
Belarus
Belgium
Bosnia
Bulgaria
Croatia
Cyprus
Czech Rep.
Denmark
Estonia
Finland
France
Georgia
Germany
Greece
Hungary
Iceland
Ireland
Isle of Man
Italy
Kosovo
Latvia
Liechtenstein
Lithuania
Luxemburg
Macedonia
Malta
Moldova
Monaco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
UK
Ukraine

Africa / Middle East

Algeria
Angola
Bahrain
Benin
Burkina Faso
Burundi
Cameroon
Cape Verde
Chad
Congo Brazzaville
Democratic Rep. of Congo
Djibouti
Egypt
Ethiopia
Gabon
Ghana
Guinea
Guinea-Bissau
Iraq
Israel
Ivory Coast
Jordan
Kenya
Kuwait
Lebanon
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Niger
Nigeria
Oman
Palestine
Qatar
Réunion Island
Rwanda
Saudi Arabia
Senegal
Sierra Leone
Somalia
South Africa
South Sudan
Tanzania
Togo
Tunisia
UAE
Uganda
Yemen
Zambia
Zimbabwe

Oceania

Australia
Fiji
Guam & Northern Mariana Islands
New Zealand
Timor-Leste

Asia Pacific

Afghanistan
Armenia
Azerbaijan
Bangladesh
Brunei
Cambodia
China
Hongkong
India
Indonesia
Japan
Kazakhstan
Kyrgyzstan
Laos
Macau
Malaysia
Maldives
Mongolia
Nepal
Pakistan
Philippines
Singapore
South Korea
Sri Lanka
Taiwan
Tajikistan
Thailand
Uzbekistan
Vietnam

January 2017

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List of countries by 4G LTE penetration

2016 November rankings

Rank	Country/Territory	Penetration
1	South Korea	96%
2	Japan	92%
3	Lithuania	85%
4	Hong Kong	84%
5	Netherlands	84%
6	Singapore	83%
7	Norway	82%
8	Kuwait	82%
9	Sweden	81%
10	United States	81%
11	Qatar	81%
12	Hungary	80%
13	Australia	79%
14	Taiwan	78%
15	Finland	76%
16	United Arab Emirates	76%
17	Canada	75%
18	Estonia	75%
19	China	74%
20	Bahrain	74%
21	Slovenia	74%
22	Czech Republic	73%
23	Latvia	73%
24	India	72%
25	Switzerland	71%
26	Denmark	71%
27	Belgium	70%
28	Thailand	70%
29	Spain	67%
30	Peru	67%
31	Austria	66%
32	Portugal	66%
33	Georgia	65%
34	Luxembourg	65%
35	Brunei	64%
36	Mexico	64%
37	Slovakia	64%
38	Saudi Arabia	63%
39	Argentina	63%
40	South Africa	63%
41	Bulgaria	63%
42	Malaysia	63%
43	Croatia	62%
44	Oman	62%
45	Panama	62%
46	Albania	61%
47	Iceland	61%
48	Morocco	60%
49	Colombia	60%
50	Greece	60%
51	Indonesia	59%
52	Jordan	58%
53	Romania	58%
54	United Kingdom	58%
55	New Zealand	58%
56	Chile	58%
57	Israel	58%
58	Germany	57%
59	Poland	57%
60	Guatemala	57%
61	Cambodia	55%
62	Italy	54%
63	Brazil	54%
64	Tunisia	54%
65	Venezuela	53%
66	Costa Rica	53%
67	Turkey	53%
68	Pakistan	53%
69	Dominican Republic	52%
70	Kazakhstan	52%
71	France	49%
72	Russia	49%
73	Iran	48%
74	Philippines	45%
75	Ireland	43%
76	Ecuador	42%
77	Lebanon	41%
78	Sri Lanka	40%

WIKIPEDIA
The Free Encyclopedia

The fast keep getting faster

The best performers in our speed rankings continue to push LTE to its technological limits. 15 countries now deliver typical downloads in excess of 30 Mbps. OpenSignal's average measured LTE speed globally, however, is dropping as more countries bring lower capacity networks online.

https://en.wikipedia.org/wiki/List_of_countries_by_4G_LTE_penetration

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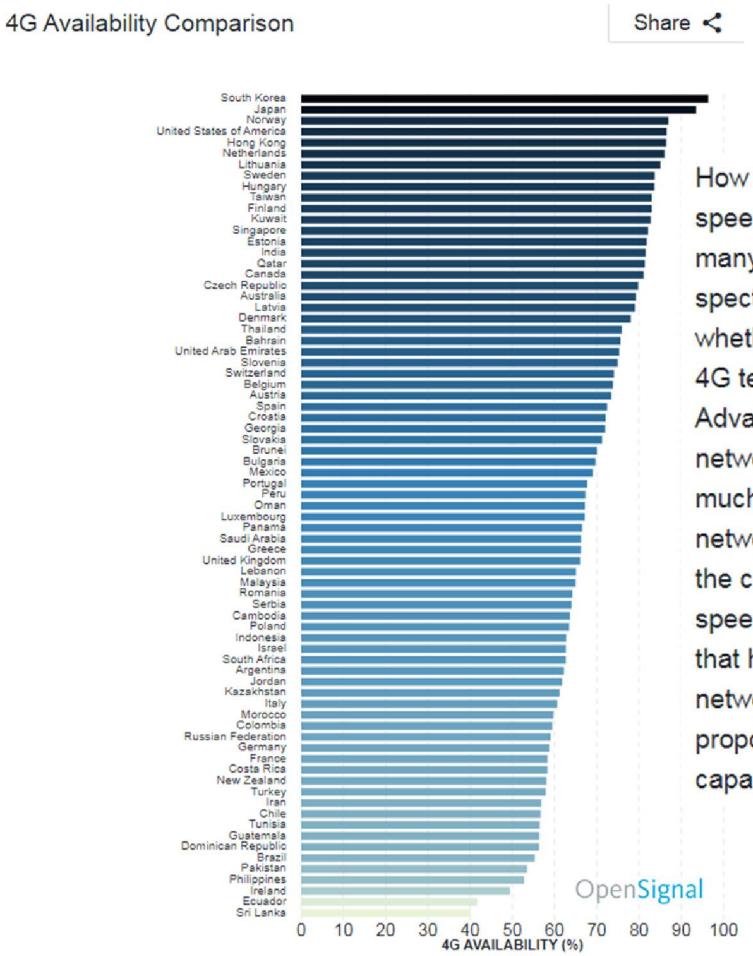
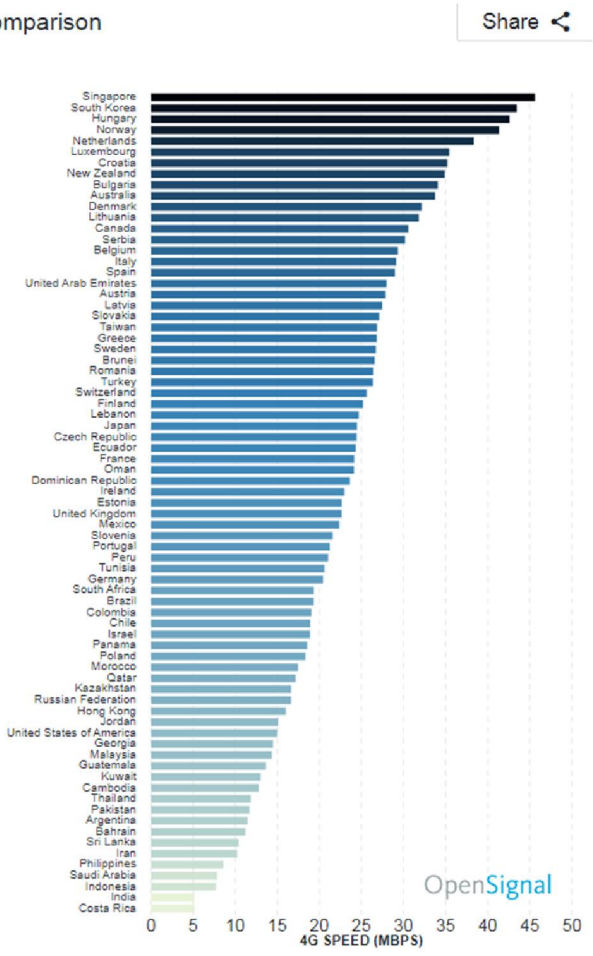
Global LTE Statistics



How fast a country's 4G speed is can depend on many factors: how much spectrum is devoted to LTE, whether it has adopted new 4G technologies like LTE Advanced, how densely networks are built and how much congestion is on those networks. In general, though, the countries with the fastest speeds tend to be the ones that have built LTE-Advanced networks and have a large proportion of LTE-Advanced capable devices.



Source: OpenSignal

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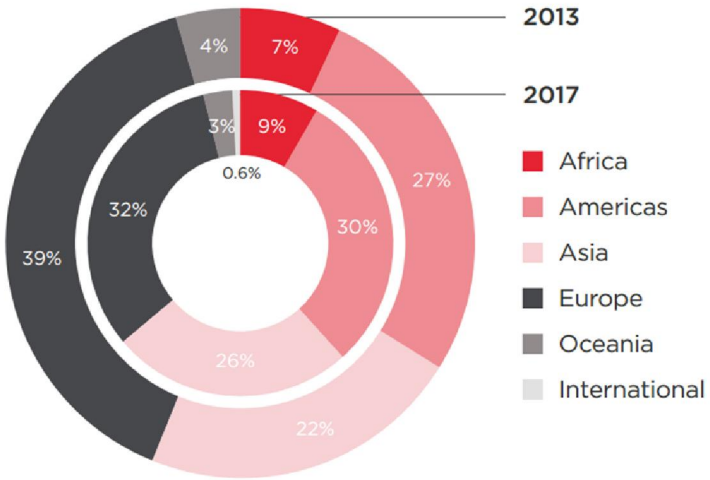
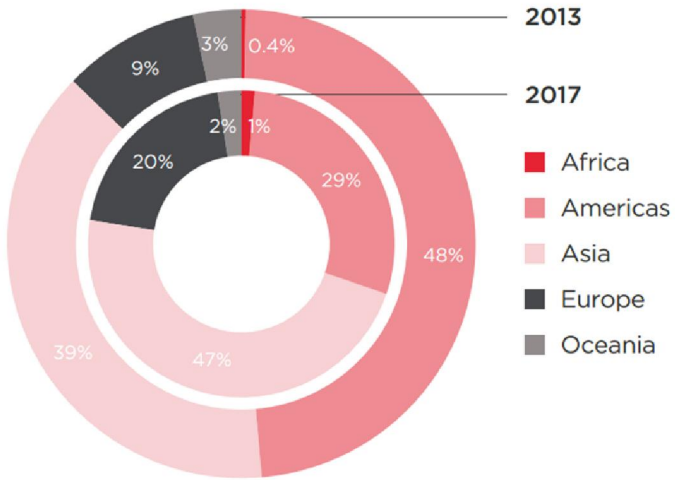
Regional LTE Deployments/Connections and Forecast



LTE Deployments by Region 2013/2017



LTE Connections by Region 2013/2017

Source: GSMA Intelligence 2014

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LTE Challenges

New complexity in the network structure requires sophisticated solutions for network optimization

- **Fast trouble shooting**
- **Detailed network diagnoses**

The new service platforms will interact intensely with the network components and will require frequent network updates

- **Root cause analyses will be more important**
- **Automated regression tests will be essential**

QoS/QoE will also depend on smartphone and app interaction

- Need for **parallel channel of testing with smart phones/real devices**

Voice based services in LTE require new solutions

- Solutions like **CSFB and VoLTE** to be tested specifically

LTE Testing

Air and Core Network Interfaces Test Concept

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CLU/WLU or Nomadic with MC77xx Interface (LTE FDD)

or

E392-U32 Data Stick Module (LTE TDD)

SITE Central Unit (CU)

Air Interface Testing

IP connection (fixed/wireless)

LAN

LTE Network

IP connection (fixed)

Core Network Interface Testing

LU with Ethernet IP Interface Board

SIM Multiplexer

SITE GUI

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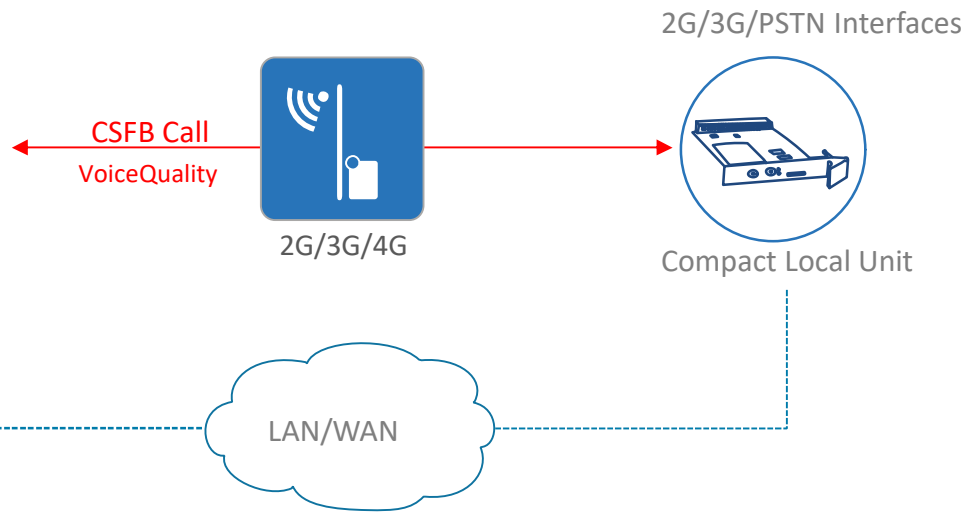
CSFB Smartphone



Relevant CSFB KPIs:

- Overall_Call_Establishment_Duration
- Overall_Time_To_Ring_Duration
- Return_to_LTE_duration
- IP_Timeout_Duration
- POLQA_MOS

Troubleshooting EPC via:

- L3 tracing (NAS and RRC)

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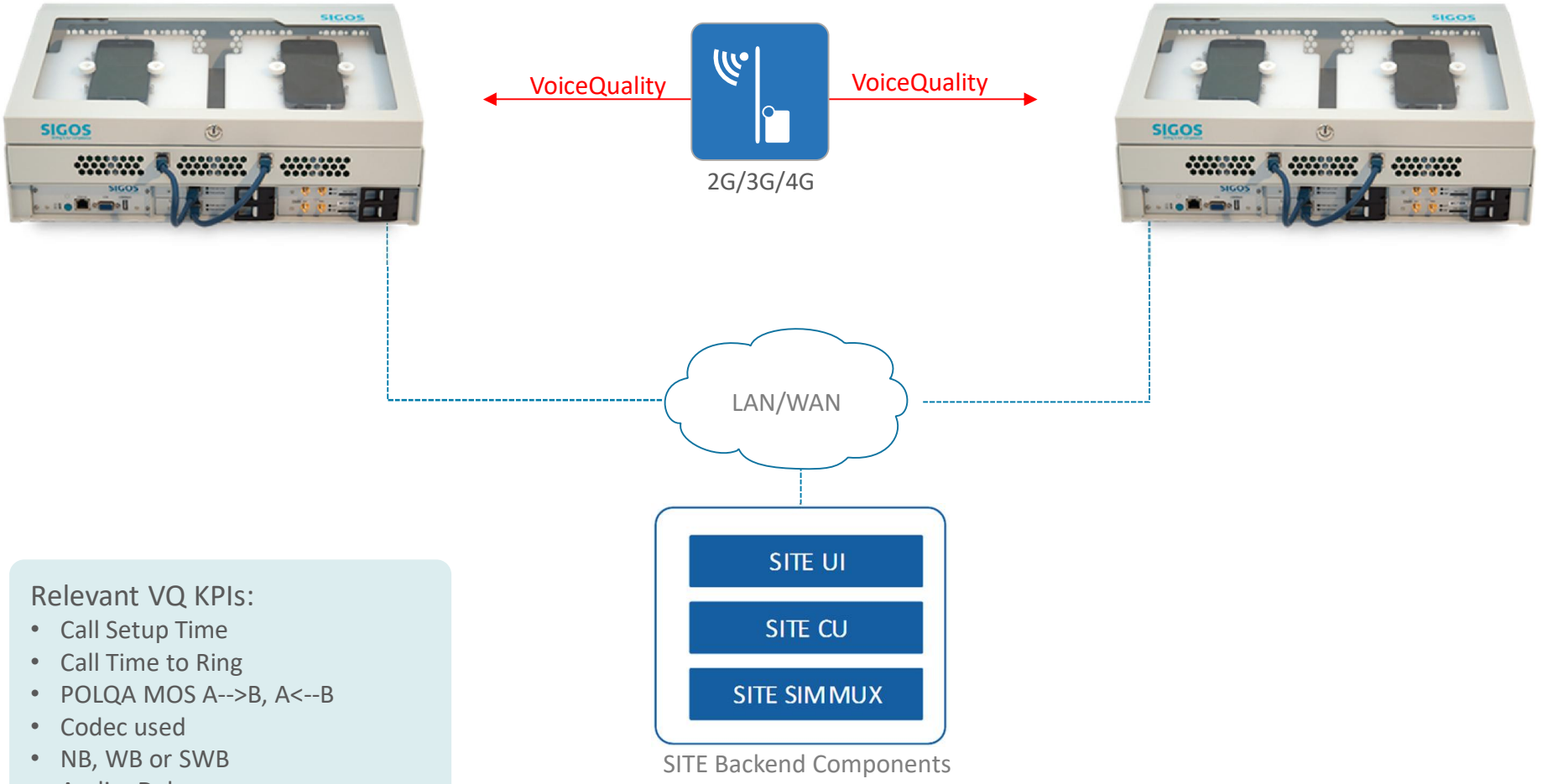
Voice Quality (incl. HD) on Smartphone



Relevant VQ KPIs:

- Call Setup Time
- Call Time to Ring
- POLQA MOS A-->B, A<--B
- Codec used
- NB, WB or SWB
- Audio_Delay

Note: For HD Quality Check, dedicated AMR-WB capable smartphone needs to be connected in the Hybrid CLU

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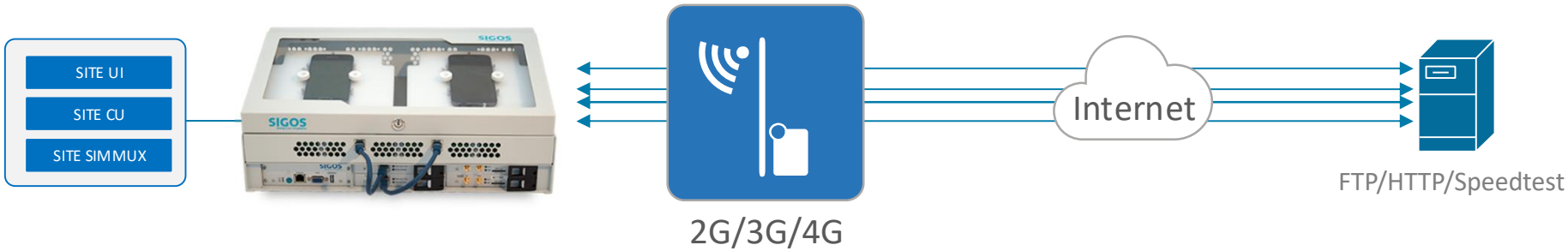
Smartphone Data Speed Testing



Test Cases

DG_FTP/HTTP_DL/UL	This test case initiates an FTP/HTTP UL/DL session
DG_SpeedTest	This test case initiates a speedtest session
KPIs: HTTP/FTP/Speedtest throughput in DL/UL **Data Speed Troubleshooting:** available via L3 (NAS and RRC) **Supported Network Types:** GSM, UMTS, LTE	

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Multi RAB and E-RAB Testing on Smartphone

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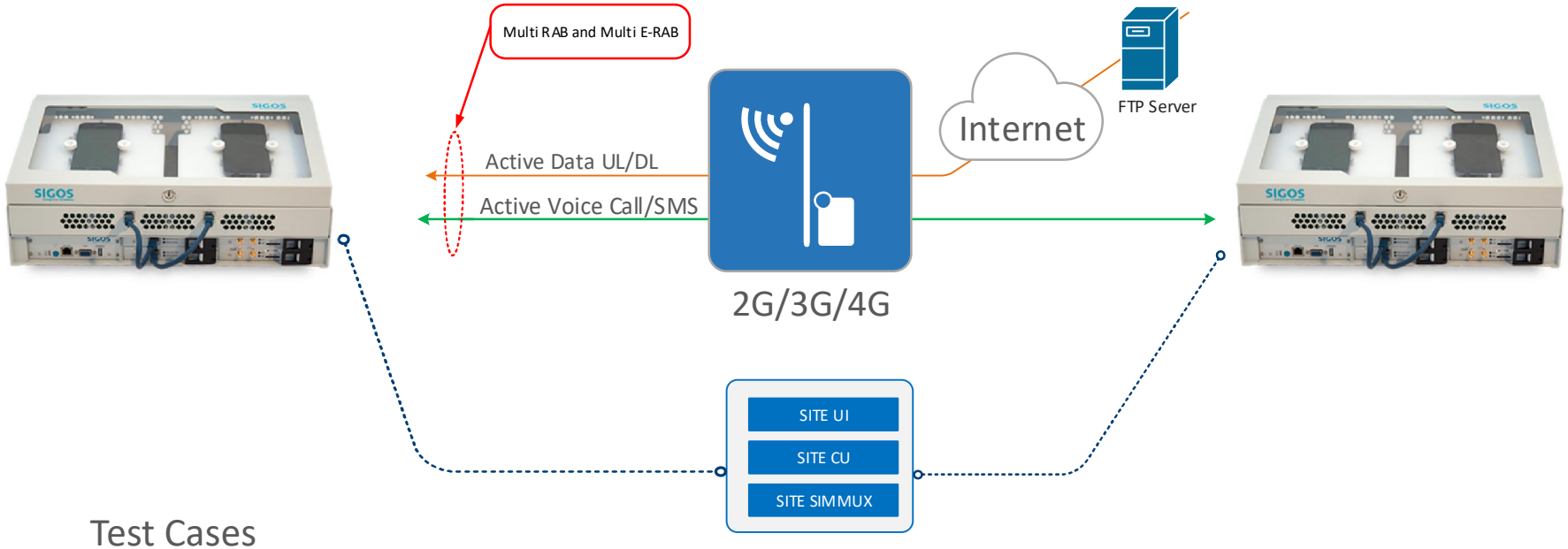

Test Cases

DG_MutiRAB_Voice_MX_w_backgrd_FTP	This test case initiates an FTP UL/DL session, once established, it Originates/Terminates a Voice Call.
DG_MutiRAB_SMS_MX_w_backgrd_FTP	This test case initiates an FTP UL/DL session, once established, it Originates/Terminates an SMS.
KPIs: POLQA MOS (optional), FTP DL/UL Throughput, VoiceCall establishments durations, E2E_SMS_Durations **Multi (E) RAB troubleshooting:** available via L3 (NAS and RRC) **Supported Network Types:** GSM, UMTS, LTE	

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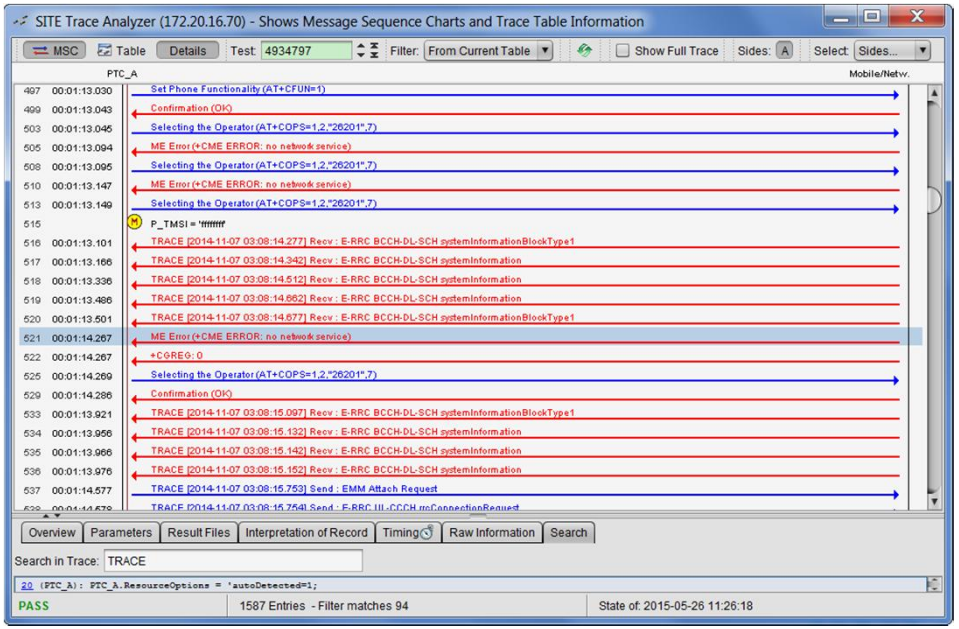
Layer 3 Traces from Smartphones

- Layer 3 messages from UEs (NAS and RRC) are an important tool for troubleshooting and extracting KPIs

- With SITE 2.10, L3 messages are available for the Samsung Galaxy Family with Qualcomm Chipsets:
  - Standard device firmware
  - Root-access device firmware



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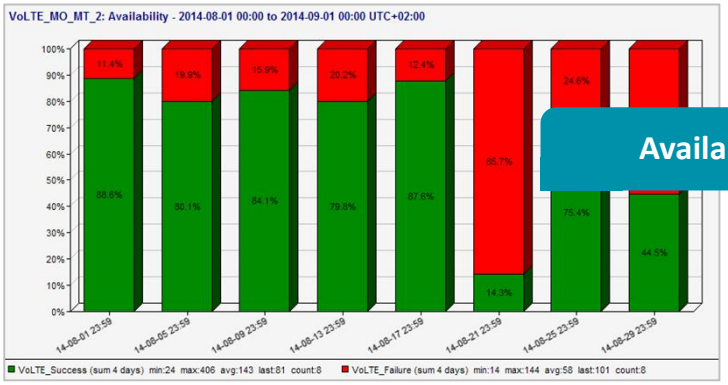
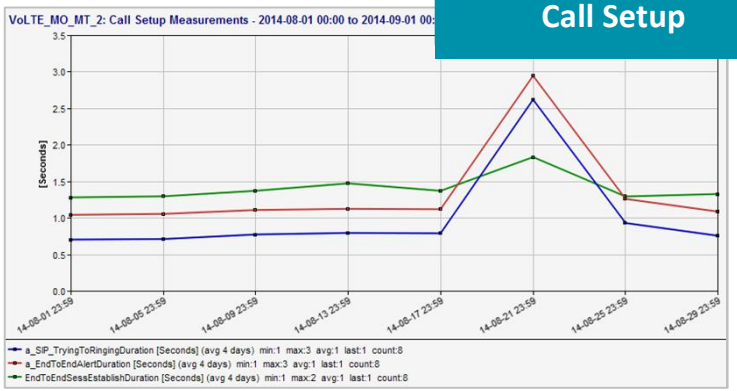
LTE Report Templates – VoLTE Example

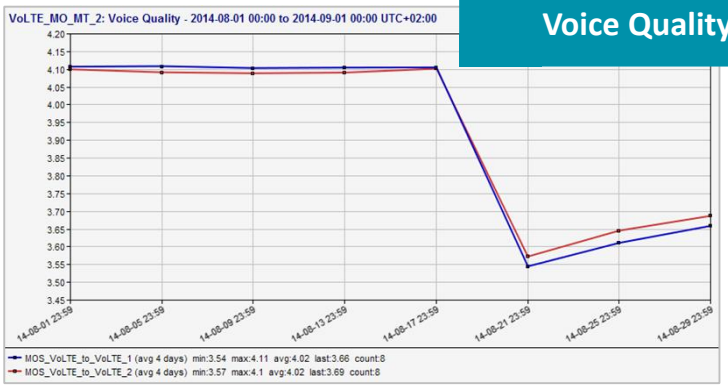
VoLTE MO MT Service Performance



Availability



Call Setup



Voice Quality

VoLTE_MO_MT_2: Overview - 2014-08-01 00:00 to 2014-09-01 00:00 UTC+02:00

KPI ↓	14-08-01 23:59	14-08-05 23:59	14-08-09 23:59	14-08-13 23:59	14-08-17 23:59	14-08-21 23:59	14-08-25 23:59	14-08-29 23:59	avg
a_IMS_RegistrationDuration [Seconds]	1.92	1.95	1.95	1.67	1.73	1.17	2.28	2.05	1.86
a_SIP_TotalRegistrationDuration [Seconds]	6.01	6.08	6.17	7.15	6.79	6.56	5.74	4.86	6.11
EndToEndSessEstablishDuration [Seconds]	1.28	1.29	1.37	1.47	1.37	1.83	1.29	1.32	1.35
a_SIP_DeregistrationDuration [Seconds]	4.06	4.03	4.03	4.04	4.03	4.03	3.28	3.4	3.93
a_RTP_AvgIpdvRx [Milliseconds]	0	-0.7	-64.23	-46.13	-39.94	-14.5	-47.85	-51.17	-26.51
a_RTP_AvgJitterRx [Milliseconds]	0.87	1.06	0.97	0.91	0.96	1.1	1.93	1.91	1.13
a_RTP_NumPacketsLostRx	-840.21	0	0.02	0	0.11	0	0.1	0	-118.17
a_RTP_NumPacketsLostTx	-840.21	0	0	0	0	0	0	0	-118.19
ActiveSpeechLevelDegraded_1 [dBov]	-27.78	-27.78	-27.78	-27.78	-27.78	-27.82	-27.37	-27.36	-27.72
ActiveSpeechLevelDegraded_2 [dBov]	-27.78	-27.78	-27.78	-27.78	-27.78	-27.79	-27.35	-27.35	-27.72
ActiveSpeechLevelReference_1 [dBov]	-27.72	-27.73	-27.73	-27.73	-27.73	-27.59	-27.24	-27.24	-27.65
ActiveSpeechLevelReference_2 [dBov]	-27.72	-27.73	-27.73	-27.73					-27.65
ActiveSpeechRatioDegraded_1	0.41	0.41	0.41	0.41					0.42
ActiveSpeechRatioDegraded_2	0.44	0.44	0.44	0.44					0.45
ActiveSpeechRatioReference_1	0.55	0.55	0.55	0.55					0.56

Service Overview

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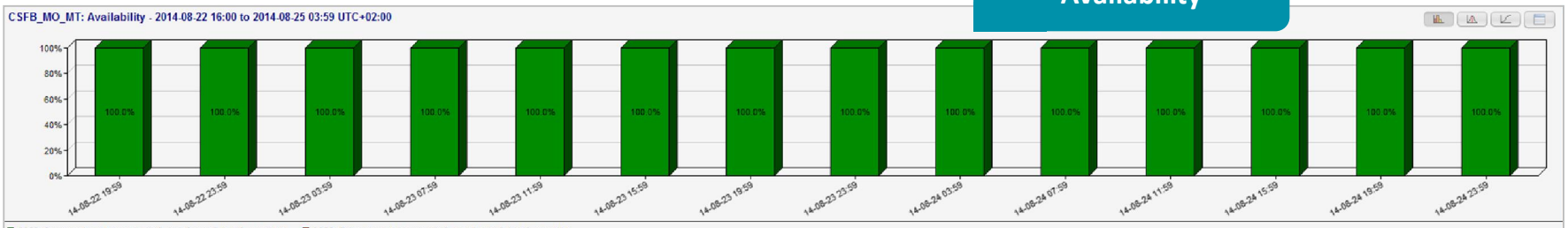
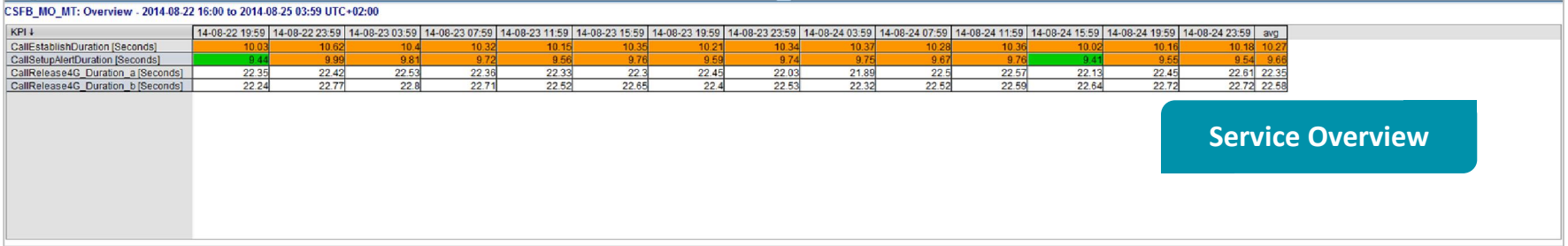
LTE Report Templates – CSFB Example

CSFB MO MT Service Performance

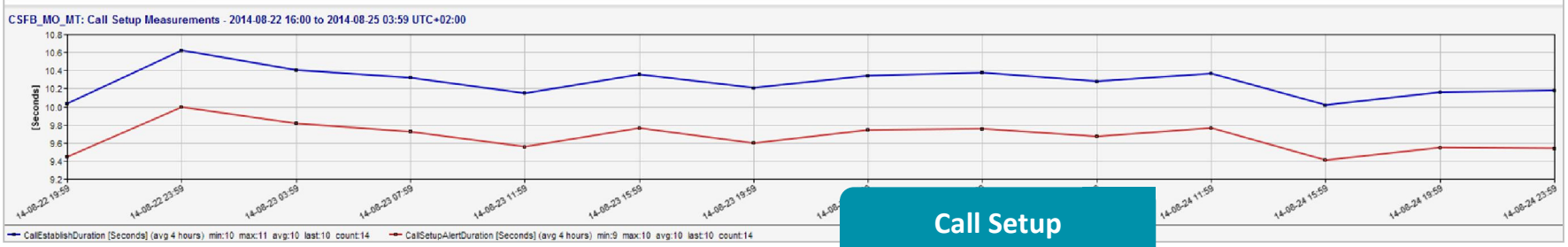
Availability





KPI	14-08-22 19:59	14-08-22 23:59	14-08-23 03:59	14-08-23 07:59	14-08-23 11:59	14-08-23 15:59	14-08-23 19:59	14-08-23 23:59	14-08-24 03:59	14-08-24 07:59	14-08-24 11:59	14-08-24 15:59	14-08-24 19:59	14-08-24 23:59	avg
CallEstablishDuration [Seconds]	10.03	10.62	10.4	10.32	10.15	10.35	10.21	10.34	10.37	10.28	10.36	10.02	10.16	10.18	10.27
CallSetupAlertDuration [Seconds]	9.44	9.99	9.81	9.72	9.56	9.76	9.59	9.74	9.75	9.67	9.76	9.41	9.55	9.54	9.66
CallRelease4G_Duration_a [Seconds]	22.35	22.42	22.53	22.36	22.33	22.3	22.45	22.03	21.89	22.5	22.57	22.13	22.45	22.61	22.35
CallRelease4G_Duration_b [Seconds]	22.24	22.77	22.8	22.71	22.52	22.65	22.4	22.53	22.32	22.52	22.59	22.64	22.72	22.72	22.58

Service Overview



Call Setup

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LTE Roaming

Challenge:

- Verifying the LTE roaming services from the GSMA's Standard International Roaming Agreements: AA.12/ AA.13/ AA.14
- Ensuring QoS for LTE services in roaming scenarios and offering the **same LTE experience** as in the home network

Solution:

- IR.38 Automated Test Case Suite
  - Mandatory pre-defined set of tests used for testing roaming agreements, can be executed ad-hoc or periodically
- LTE Global Roaming Quality (GRQ)
  - Framework developed by SIGOS to test LTE services for roaming subscribers
  - Periodic testing and reporting for the most important KPIs

LTE Roaming

Benefits:

- Verify the LTE roaming services from the GSMA's Standard International Roaming Agreements
- Ensure that your roaming partners respect SLAs
- Determine subscribers to use mobile data when roaming, by offering guaranteed QoS

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SITE IR.38 Test Suite

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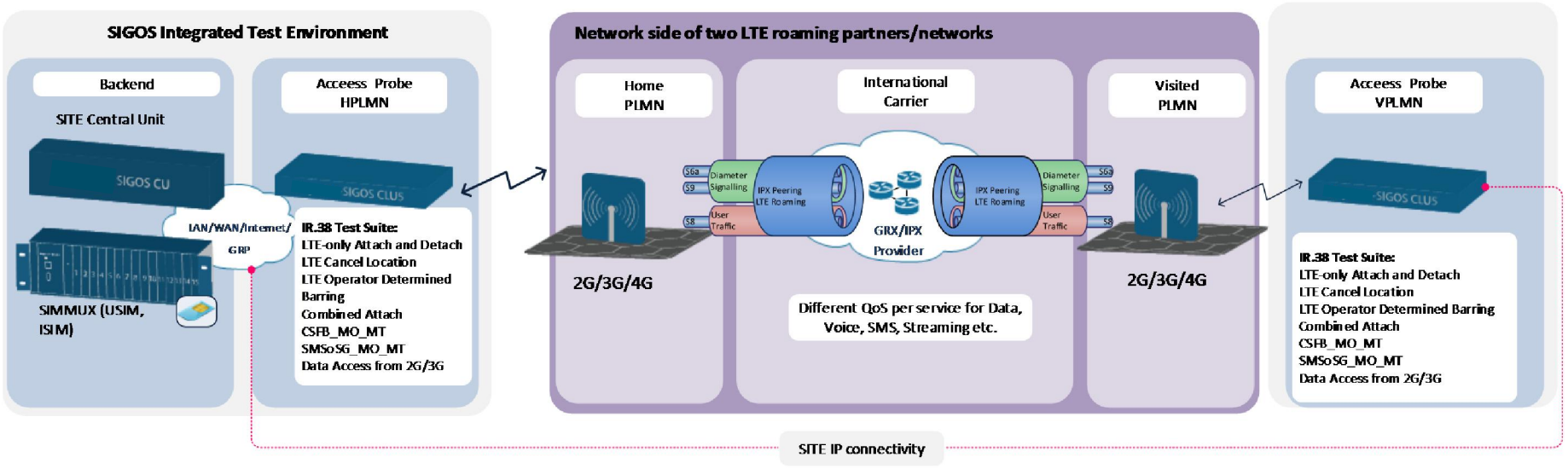

- Provides end-to-end functional capability tests for roaming services over LTE: **LTE data, CSFB voice and SMS over SGs**
- Validation of LTE roaming **interoperability for HPLMN (a) and VPLMN (b)**
- **Automated IR.38 test suite execution**
- **Automated IR.38 GSMA template report creation**
- **Ad-hoc or periodic** execution for each individual test case within the IR.38 suite

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SITE IR.38 Test Case Support

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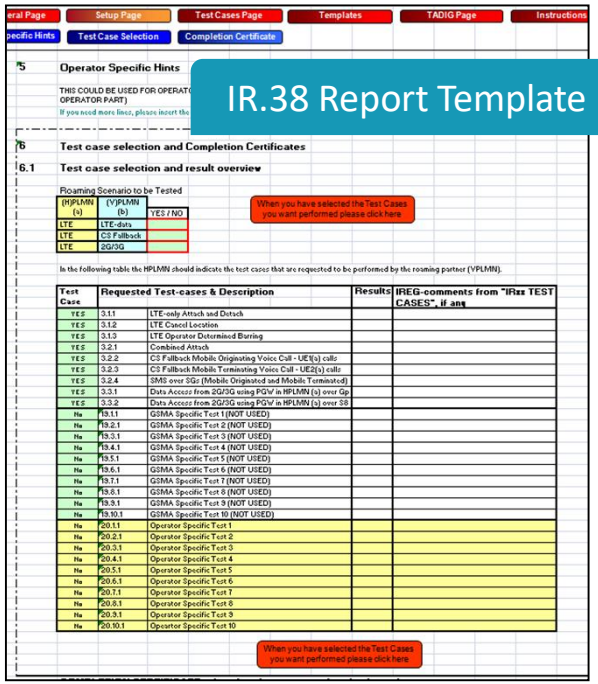
IR.38 Test-cases & Description	SITE support
LTE-only Attach and Detach	Y
LTE Cancel Location	Y
LTE Operator Determined Barring	Y
Combined Attach	Y
CS Fallback Mobile Originating Voice Call - UE1(a) calls UE2(a)	Y
CS Fallback Mobile Terminating Voice Call - UE2(a) calls UE1(a)	Y
SMS over SGs (Mobile Originated and Mobile Terminated)	Y
Data Access from 2G/3G using PGW in HPLMN (a) over Gp Interface	Y
Data Access from 2G/3G using PGW in HPLMN (a) over S8 Interface	Y

Automated creation of IR.38 GSMA report
template with outcome and verdicts

IR.38 Report Template



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Agenda

- SIGOS – An Introduction
- Global LTE Statistics
- LTE: The Need for Testing
- LTE Reports
- LTE Roaming
  - LTE: IR.38 Testing
  - **GSMA LTE GRQ**
- LTE Test Scenarios
- LTE: SIGOS Customer Case Studies

SIGOS LTE GRQ

- The SIGOS LTE GRQ framework provides KPIs for:
  - LTE Attach/Detach
  - Activation/Deactivation of Default EPS bearers
  - HTTP and FTP Download, Ping
  - CSFB Service Performance
  - SMSoSG Service Performance

LTE GRQ Testing with SITE

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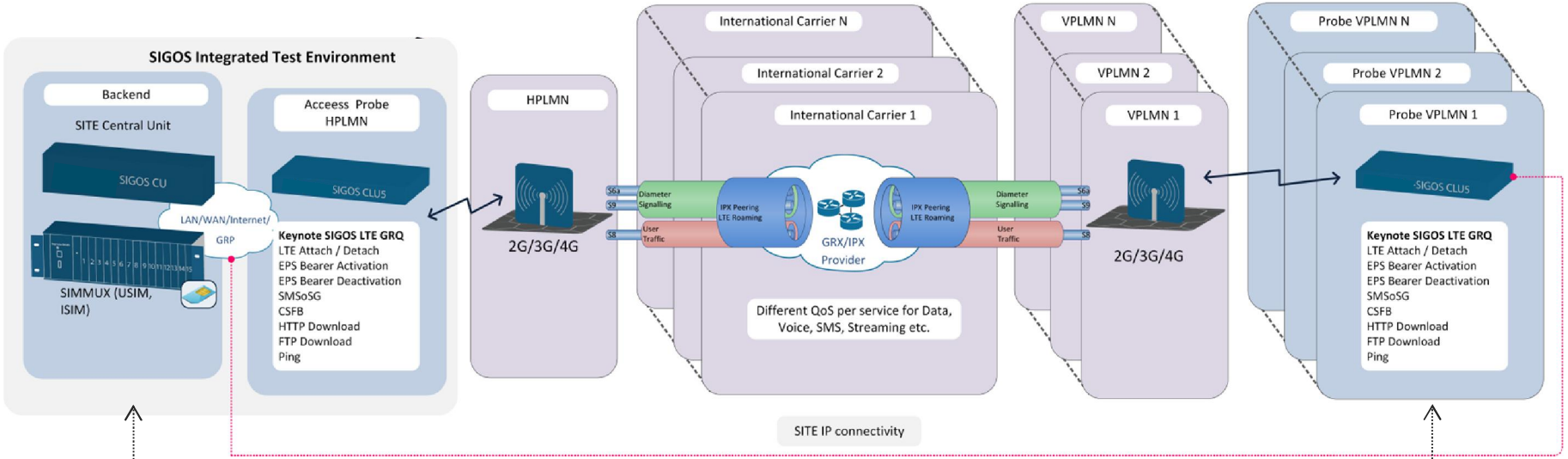

- Resources for LTE GRQ tests (SIM cards and locations) are available in SITE through GRP
- Testing can be performed ad-hoc or scheduled periodically
- Result analysis and representation are available via the SITE reporting engine

- Test cases will run on probes located in the selected VPLMNs
- Current LTE probe footprint covers 82 networks and is constantly expanding

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Example LTE GRQ Report

GRQ LTE KPIs per Operator - 2014-08-25 00:00 to 2014-09-01 00:00 UTC+01:00

KPI ↓	Operator A	Operator B	Operator C	Operator D	Operator E	Operator F	Operator G	Operator H	Operator I	Operator J	Operator K	Operator L	Operator M	Operator N	Operator O	Operator P	Operator Q	Operator R	Operator S
01AV LTE Attach Success Ratio [Percent]	94.87	62.16	72.5	100	100	100	100	93.42	100	100	99.41	100	100	100	100	100	100	100	100
02AH LTE Attach Duration [Seconds]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
03AV LTE Attach Duration [Seconds]	8.33	9.19	8.89	5.67	5.17	5.94	5.12	9.43	9.88	8.51	6.46	7.21	7.33	6.38	6.52	4.51	4.43	2.85	13.16
04AH LTE Attach Duration [Seconds]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
05AV LTE Detach Success Ratio [Percent]	100	100	100	100	100	100	100	97.87	100	100	100	100	100	100	100	100	100	100	100
06AH LTE Detach Success Ratio [Percent]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
07AV LTE Detach Duration [Seconds]	3.08	1.64	2.1	2.89	1.65	1.97	5.12	6.93	2.28	2.9	2.78	3.01	4.01	2.78	3.06	2.3	2.14	4.61	2.2
08AH LTE Detach Duration [Seconds]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
09AV LTE Default EPS SuccessRatio Activation [Percent]	98.88	96.67	100	100	100	100	100	97.65	94.64	87.25	100	100	100	100	100	100	100	100	100
10AH LTE Default EPS SuccessRatio Activation [Percent]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11AV LTE Default EPS Bearer Activation Duration [Seconds]	4.98	2.96	3.46	2.88	2.61	2.34	2.87	2.82	2.64	3.24	2.96	2.53	2.87	2.02	1.45	2.69	2.6	0.74	2.95
12AH LTE Default EPS Bearer Activation Duration [Seconds]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13AV LTE Default EPS Success Ratio Deactivation [Percent]	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
14AH LTE Default EPS Success Ratio Deactivation [Percent]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15AV LTE Detach Duration [Milliseconds]	3083.95	1644.44	2097.95	2892.8	1649.93	1973.94	5117.22	6932.22	2277.7	2898.24	2777.33	3008.75	4010.33	2776.5	3056.75	2301	2137	4611	2200.25
16AH LTE Detach Duration [Milliseconds]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17AV LTE SMSoSG Success Ratio [Percent]	92.86	57.14	100	100	100	100	100	100	96.55	86.21	33.33	90.91	100	-	100	-	100	-	100
18AH LTE SMSoSG Success Ratio [Percent]	100	100	100	100	100	100	100	95.65	100	100	-	100	-	-	-	-	-	-	-
19AV LTE SMSoSG Send Duration [Seconds]	4.12	5.32	5	3.75	3.16	4.73	5.69	4.63	7.21	6.69	6.29	3.82	4.84	-	4.57	-	4.4	-	5.73
20AH LTE SMSoSG Send Duration [Seconds]	2.8	4.03	3.81	4.39	1.62	1.53	4.39	3.29	1.4	4.54	-	1.83	-	-	-	-	-	-	-
21AV LTE SMSoSG End2End Duration [Seconds]	6.6	8.35	7.86	7.02	5.48	7.71	8.78	7.65	9.59	14.21	8.15	6.83	8.08	-	7.63	-	7.6	-	7.42
22AH LTE SMSoSG End2End Duration [Seconds]	6.83	9.86	8.16	7.84	9.54	6.61	9.62	7.67	8.74	13.99	-	7.79	-	-	-	-	-	-	-
23AV LTE HTTP DL Success Ratio [Percent]	96.15	95	95.83	100	-	-	100	90	95.56	100	100	100	-	100	100	-	-	-	100
24AV LTE HTTP TCP Handshake Duration [Seconds]	0.78	0.72	0.97	0.47	-	-	0.44	0.76	0.61	0.92	0.77	0.92	-	0.39	0.38	-	-	-	0.55
25AV LTE Data Download Duration App [Seconds]	25.82	14.75	25.48	10.72	-	-	22.48	72.04	21.21	27.91	12.98	47.86	-	4.87	22.2	-	-	-	11.92
26AV LTE DNS Duration App [Seconds]	0.49	0.42	0.66	0.89	-	-	1.09	0	0.05	0.91	0.58	1.16	-	0.93	0.98	-	-	-	1.1
27AV LTE Download Duration App [Seconds]	29.98	19.04	29.02	12.2	-	-	23.67	80.78	26.71	31.22	15.91	51.11	-	5.75	23.38	-	-	-	13.41
28AV LTE HTTP Mean Data Rate App [MBits/s]	0.22	0.24	0.19	0.34	-	-	0.25	0	0.01	0.22	0.23	0.09	-	0.48	0.11	-	-	-	0.76
29AV LTE NumberOfTcpConnections	5.44	5.26	5.61	4.63	-	-	1	10.81	9.09	5.95	5.12	2.33	-	5	5	-	-	-	2.33
30AV LTE FTP DL Success Ratio [Percent]	98.08	100	85.71	100	100	95.83	100	90.91	100	67.44	98.8	100	100	100	66.67	100	100	-	100
31AV LTE FTP TCP Handshake Duration [Seconds]	1.42	0.6	0.67	0.78	0.31	0.4	1.12	1.03	0.84	0.88	0.72	0.97	0.35	0.56	1.04	0.41	0.51	-	1.21
32AV LTE FTP Mean Download Rate [MBits/s]	0.69	0.92	0.9	1.89	1.78	2.13	1.74	0.4	0.05	0.78	0.73	0.58	0.77	0.51	0.61	1.73	0.33	-	1.2
33AV LTE Ping ps Success Ratio [Percent]	100	-	-	100	100	100	100	75	100	50	-	-	-	-	-	100	100	100	100
34AV LTE Round Trip Delay [Seconds]	0.96	-	-	0.28	0.19	0.31	0.21	0.63	0.67	0.66	-	-	-	-	-	0.35	0.29	0.32	0.68
35AV LTE PingPacketLossPercent [Percent]	0	-	-	0	0	0	0.48	27.5	0	51	-	-	-	-	-	30	46	0	0
36AV LTE Size of Ping Packet without Header [Bytes]	56	-	-	36	56	56	56	42.2	56	56	-	-	-	-	-	36	36	36	56

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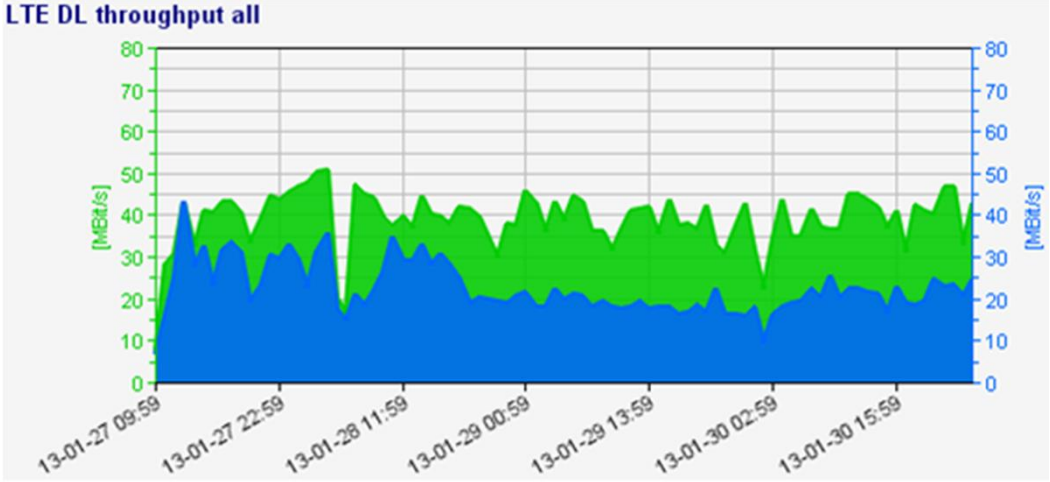
- **LTE Test Scenarios**
- LTE: SIGOS Customer Case Studies

LTE Test Scenario:
FTP Download, Web Browsing

LTE Mean Download Rate - Live Network



- Mean Download Rate LTE: ~25 Mbits/s (avg.)
- Max. Download Rate LTE: ~35 Mbits/s (avg.)

- FIELD Measurement - Operator 1
- Signal Level RSRP: -86
- FTP Download - File Size: 60 MB

→Realistic expectation in a live LTE network: Mean Download rate of 25-40 Mbit/s!

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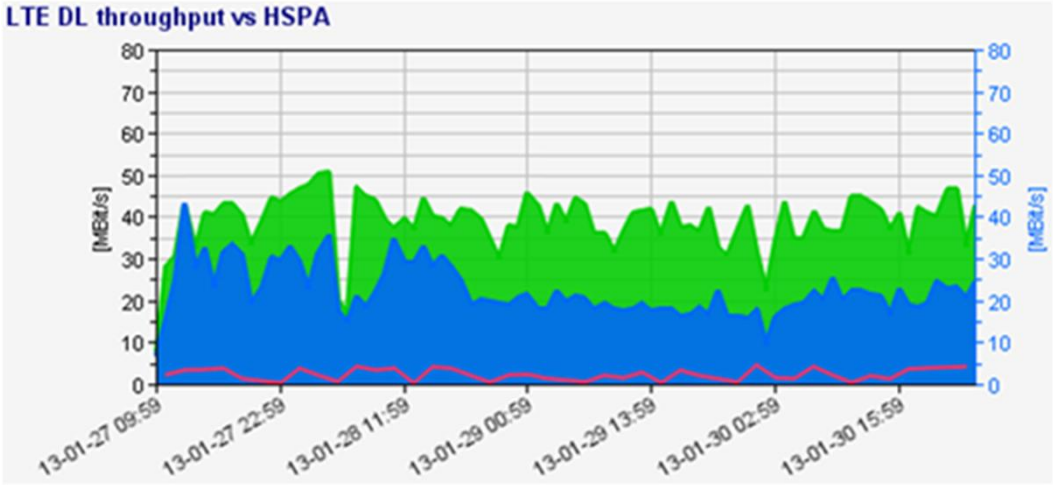
LTE Test Scenario:
FTP Download, Web Browsing



- FIELD Measurement - Operator 1
- Signal Level RSRP: -86
- FTP Download - File Size: 60 MB

Mean Download Rate LTE: ~25 Mbits/s (avg.)

Max. Download Rate LTE: ~35 Mbits/s (avg.)

Max. Download Rate HSPA: ~4 Mbits/s (avg.)

→Significantly higher LTE Download rates versus HSPA (approx. 8 times higher)!

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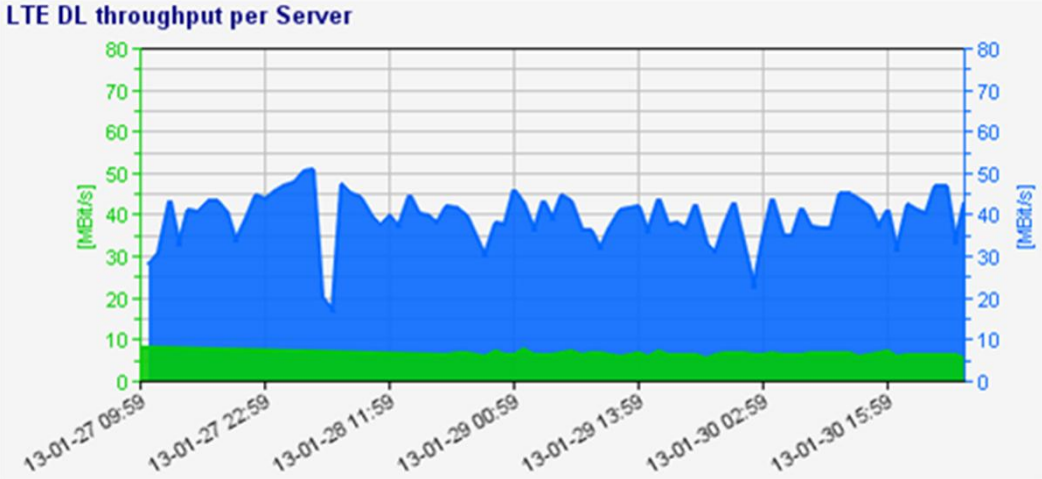
LTE Test Scenario:
FTP Download, Web Browsing

FTP Download Testing with Local server vs. External sever



- FIELD Measurement - Operator 1
- Local server: in the country
- External server: outside the country

Max. Download Rate LTE from local server: ~35 Mbits/s

Max. Download Rate LTE from external server: ~15 Mbits/s

→Server location and bandwidth have significant effects on test results!

→Compared to external server, local server delivers more than double the download rate!

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LTE Test Scenario:
FTP Download, Web Browsing

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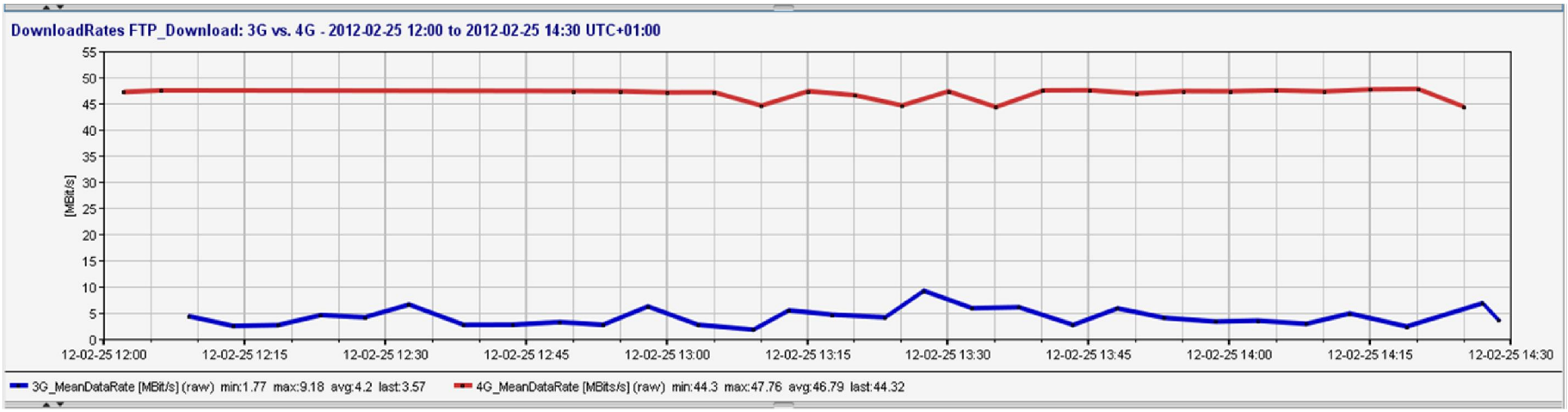

- Mean Download Rate LTE: ~47 Mbits/s
- Mean Download Rate 3G: ~5 Mbits/s

- FIELD Measurement - Operator 2

→Significantly higher LTE Download rates compared to 3G (approx. 9 times higher)!

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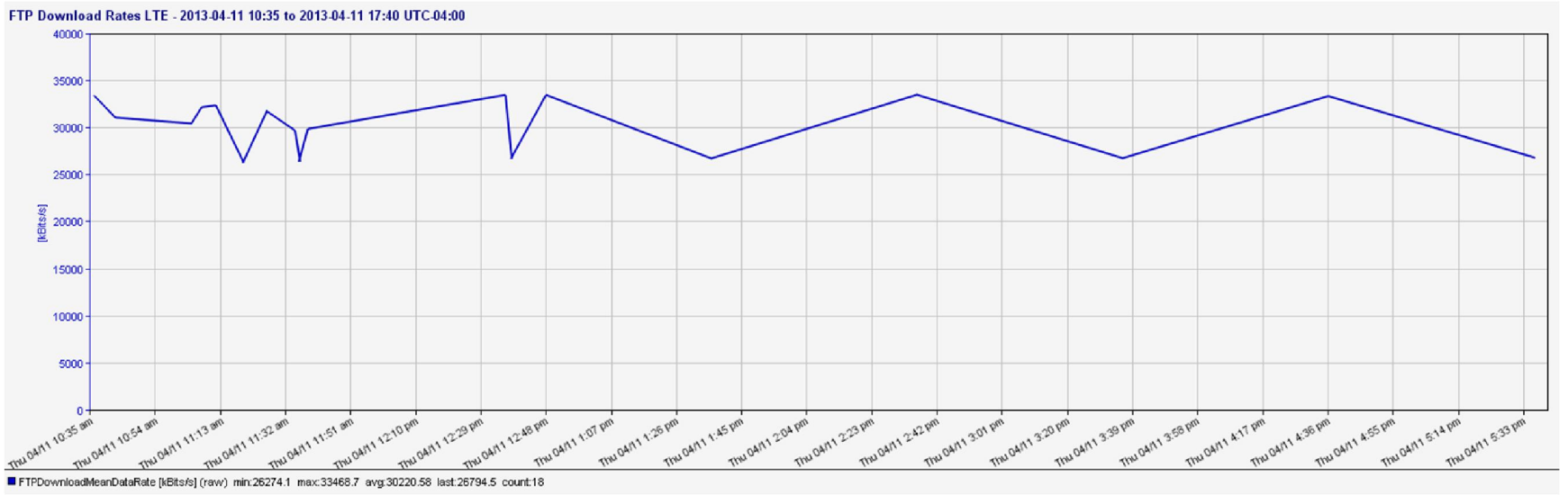
LTE Test Scenario:
FTP Download, Web Browsing



- FIELD Measurement - Operator 4
- LTE Mean Download Rate: ~30 Mbits/s

→Mean Download rate of 25-40 Mbit/s could be a realistic expectation in a Live LTE network!

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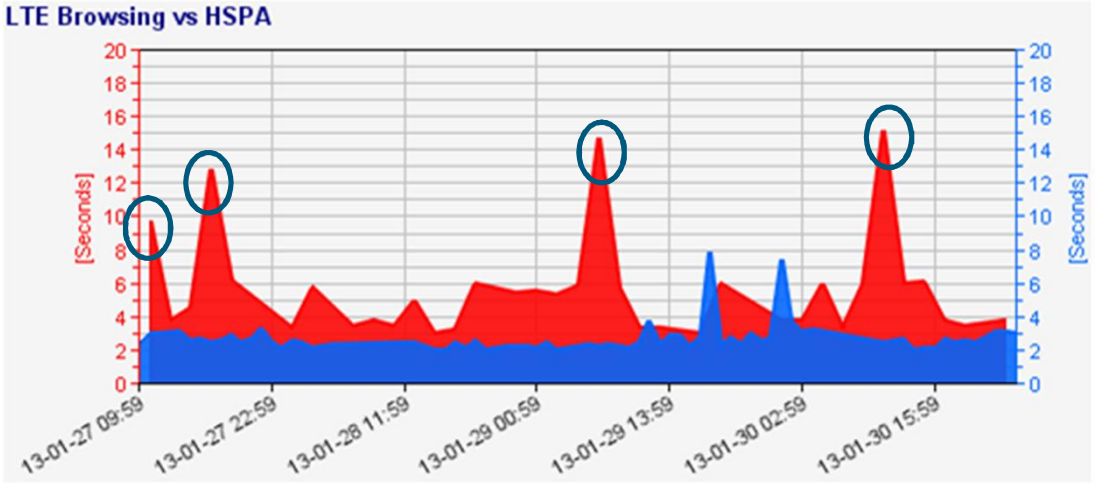
LTE Test Scenario:
FTP Download, Web Browsing



- FIELD Measurement - Operator 5

- LTE Browsing duration: ~3 sec. No clipping, relatively constant
- HSPA Browsing duration: ~6 sec . High clipping up to 15 sec

→Measured LTE Browsing duration is 50% shorter compared to HSPA!

→Improved User Experience!

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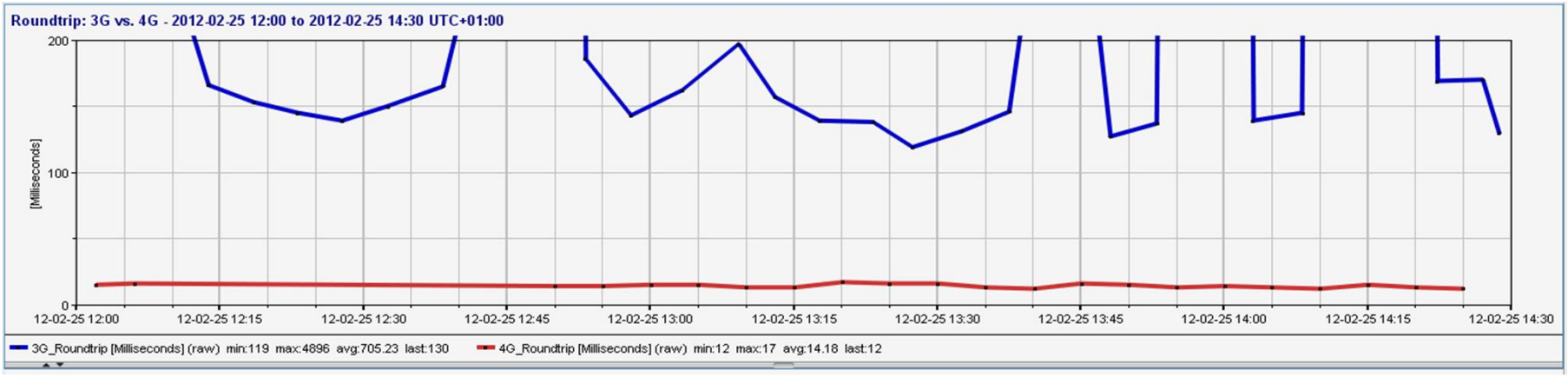
LTE Test Scenario:
Ping Round Trip Time

LTE RTT – Live Network



- RTT LTE: Min. ~12 ms, Max. ~17 ms, Avg. ~15 ms
- RTT 3G: Min. ~120 ms, Max. ~4100 ms, Avg. ~700 ms*

- FIELD Measurement - Operator 2

→Significantly shorter RTT values with LTE compared to 3G!

*3G RTT values out of scale due to huge differences to LTE RTT values

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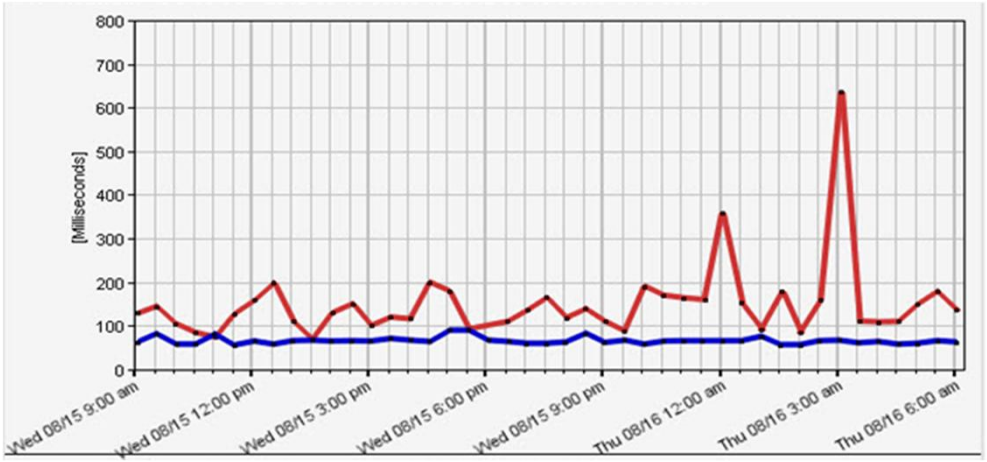
LTE Test Scenario:
Ping Round Trip Time

- FIELD Measurement - Operator 6



- RTT LTE: Stable measured values. Min. 56 ms, Max. 90 ms, Avg. 66 ms
- RTT 3G: Fluctuating measured values reaching up to 637 ms. Min. 69 ms, Max. 637 ms, Avg. 150 ms

→Average measured LTE RTT is 50% shorter compared to 3G !

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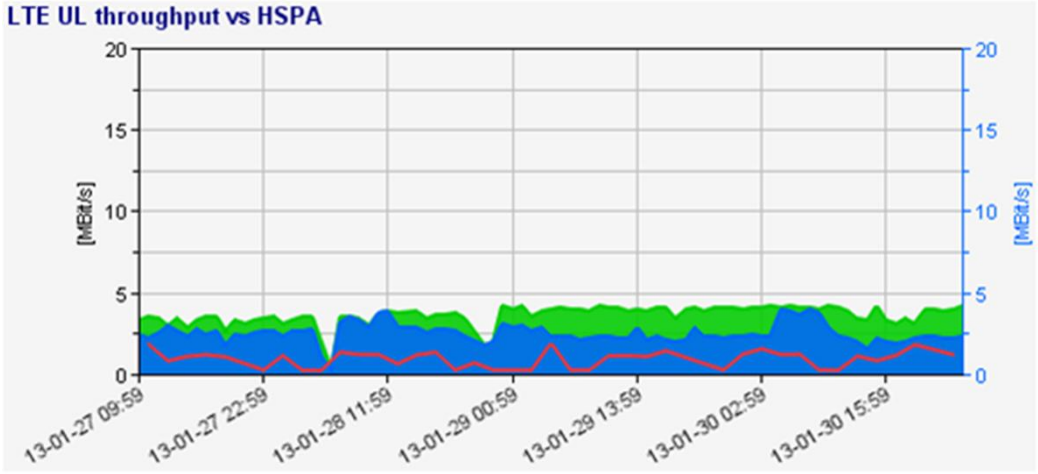
LTE Test Scenario:
FTP Upload



- FIELD Measurement - Operator 7
- Signal Level RSRP: -96
- FTP Upload - File Size: 27 MB
- External FTP server used

Mean Upload Rate LTE: ~2.5 Mbits/s (avg.)

Max. Upload Rate LTE: ~4 Mbits/s (avg.)

Max. Upload Rate HSPA: ~2 Mbits/s (avg.)

→Limitations due to the use of an external FTP server!

→Maximal Upload Rate of LTE double to that of HSPA!

→Improved user experience!

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- **LTE: SIGOS Customer Case Studies**

Customer Case Study #1:
Claro Argentina

SITE deployment

Argentina – 15 locations
- ✓ Bahía Blanca
- ✓ Buenos Aires - Av. de Mayo
- ✓ Buenos Aires - Forest
- ✓ Buenos Aires - Jonte
- ✓ Buenos Aires - Torcuato
- ✓ Comodoro Rivadavia
- ✓ Córdoba
- ✓ Corrientes
- ✓ Mar del Plata
- ✓ Mendoza
- ✓ Neuquén
- ✓ Rosario
- ✓ Salta
- ✓ Santa Fe
- ✓ Tucumán

Uruguay
- ✓ Montevideo

Paraguay
- ✓ Asunción

Installed
- GSM and 3G
- GSM, 3G and PSTN
- LTE
- IuPS card
- LAN card
- Mobile LU

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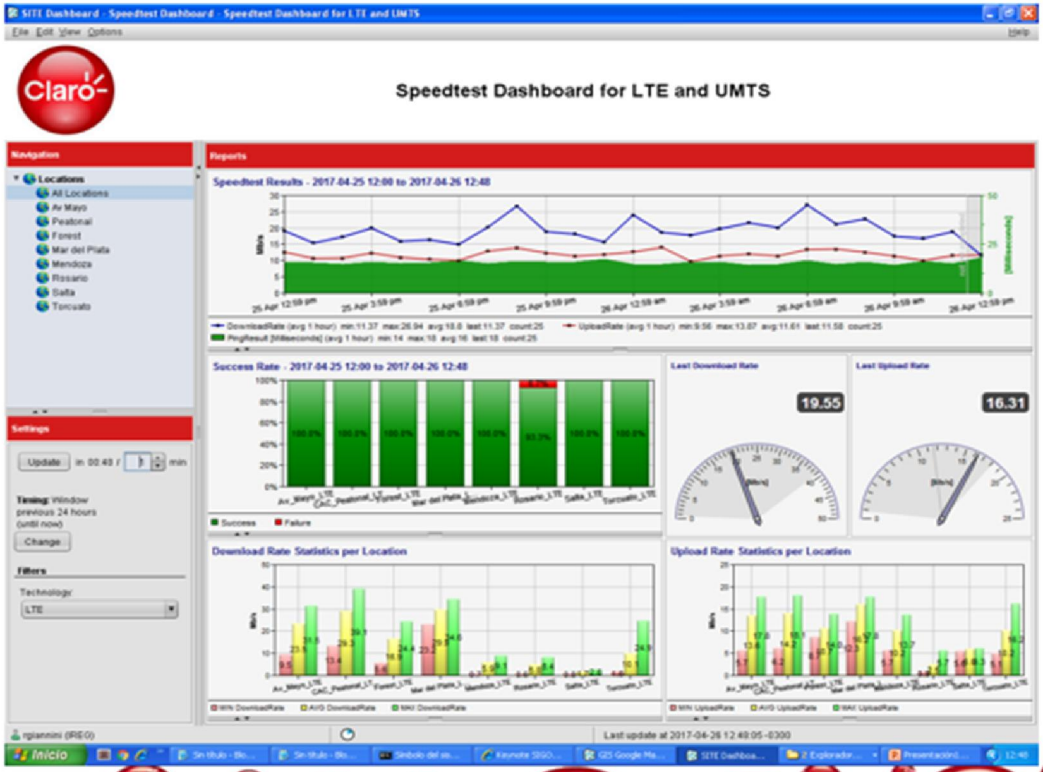
Customer Case Study #1:
Claro Argentina

Speed Tests for LTE and UMTS



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Customer Case Study #2: Vodafone Netherlands

Test Interfaces of SITE

Um (2G air)

Uu (3G air)

LTE_Uu (4G air)

Device Gateway (CSFB & HD Voice)

VoIP

GSM_A (BSC -> MSC)

GSM_Gb (BSC -> SGSN)

IuCS (RNC -> MSC)

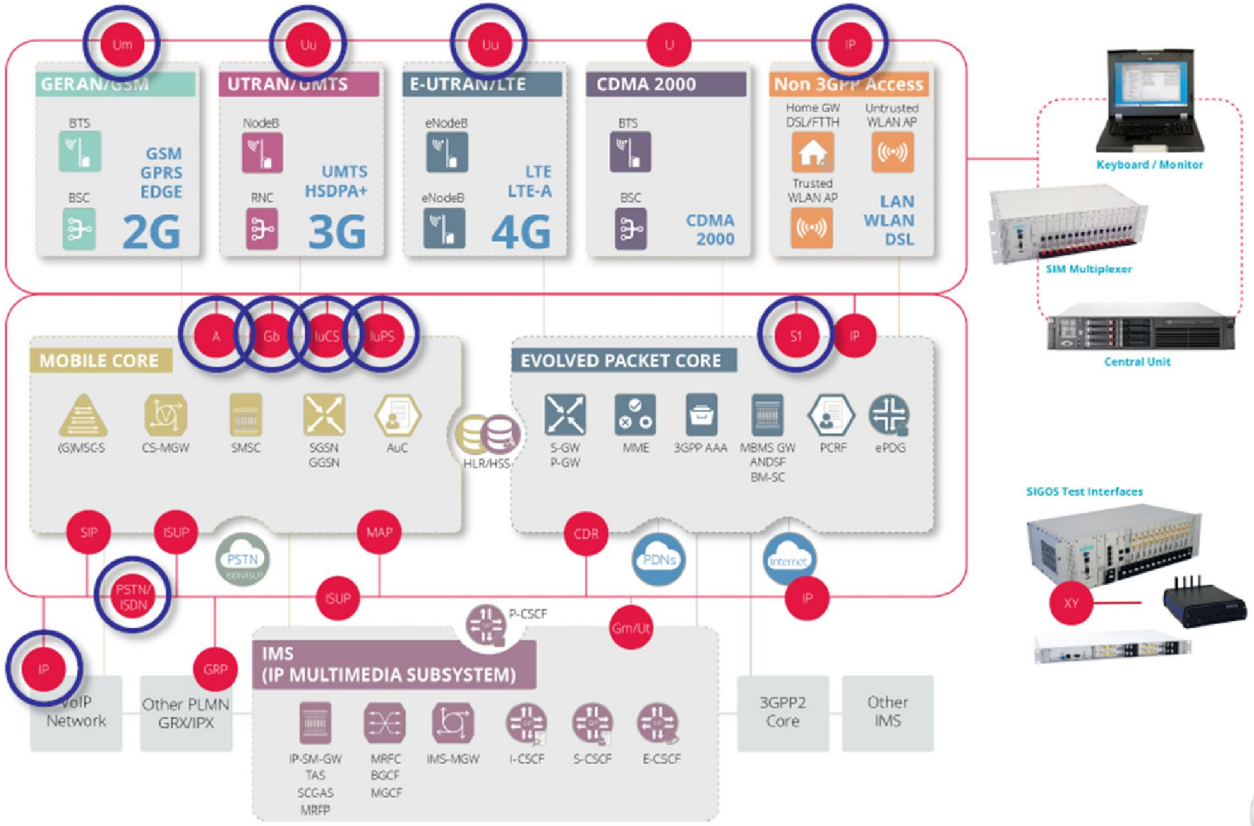
IuPS (RNC -> SGSN)

S1 (eNodeB -> MME)

PSTN

ISDN

(W)LAN



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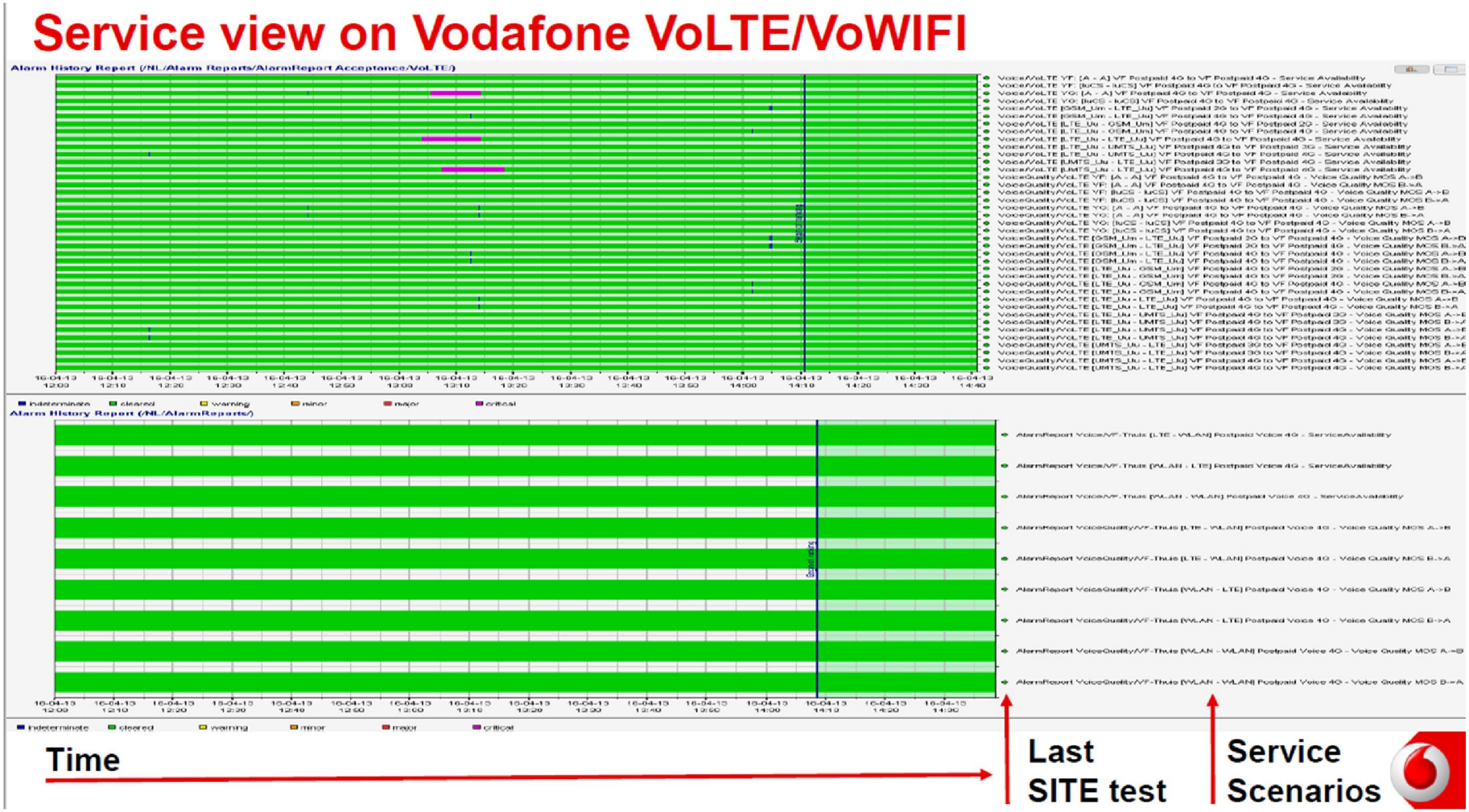
Customer Case Study #2:
Vodafone Netherlands



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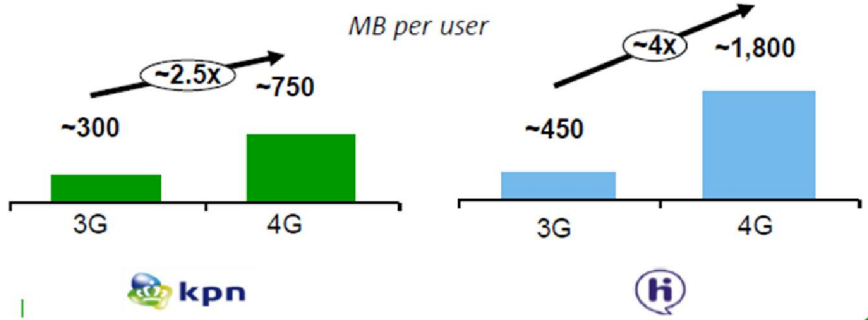
Customer Case Study #3:
KPN Netherlands

A growing customer base, using an increasing amount of data .

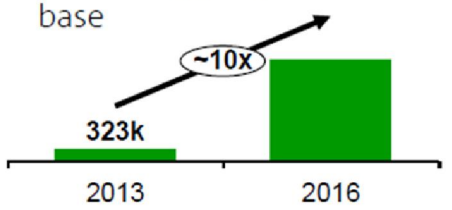
4G providing upselling opportunities for higher data bundles

- Nationwide 4G coverage; significantly ahead of competition
- 4G accessible to all customers
  - Included in all KPN and Hi propositions
  - Add-on available for other brands



Customer growth

- 4G to support focus on increasing postpaid subscriber base



- Overall mobile NPS highest in the market supported by 4G

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Customer Case Study #3:
KPN Netherlands

Achievements LTE roaming roll-out
SIGOS Roaming Implementations

100 unilateral LTE roaming services in first 8 months

200 unilateral LTE roaming services after 12 months

kpn

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Customer Case Study #3:
KPN Netherlands

Fast LTE Roll Out PROFITABLE???

YES!

600.000 EURO!

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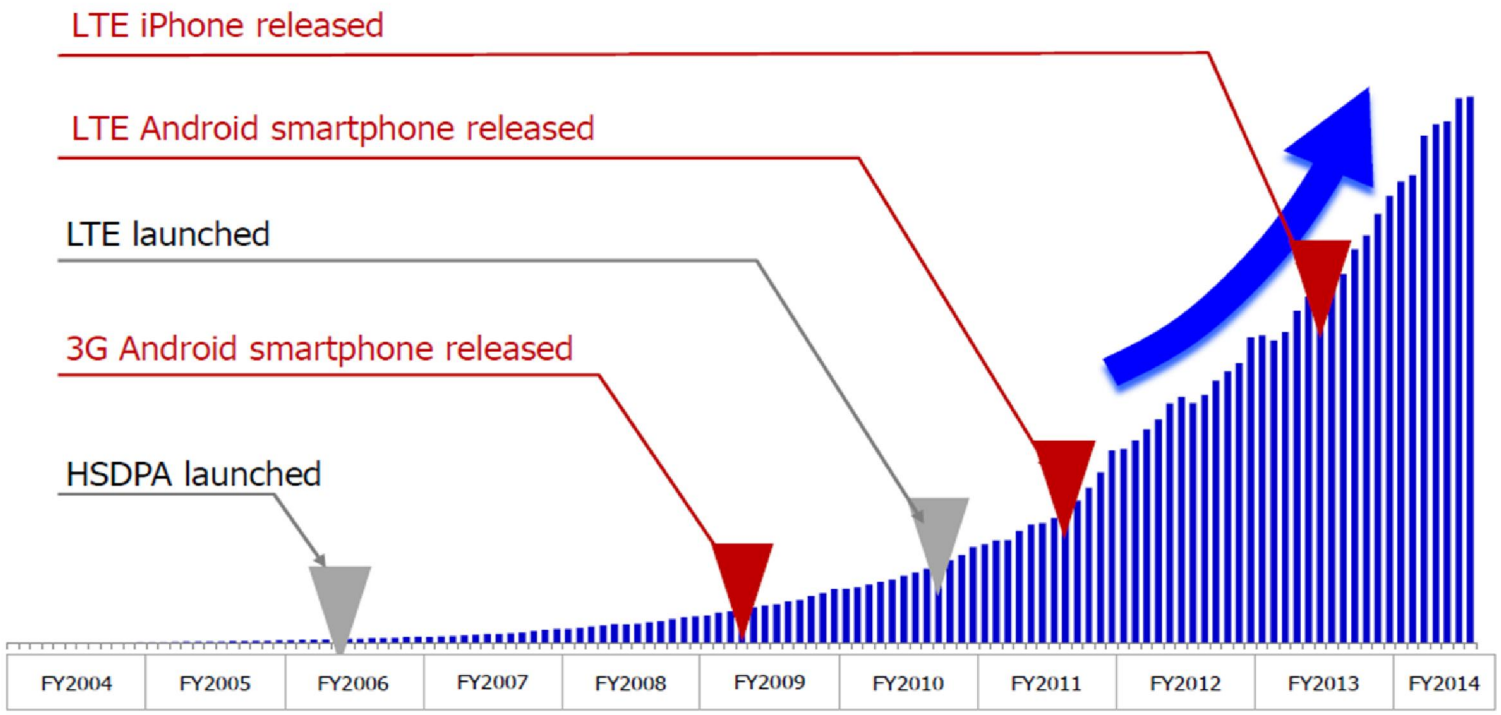
Customer Case Study #4:
NTT DoCoMo Japan

Data Traffic Trend on DOCOMO Network

docomo

Traffic steadily increasing after LTE launched
→ Increasing trend expected to continue



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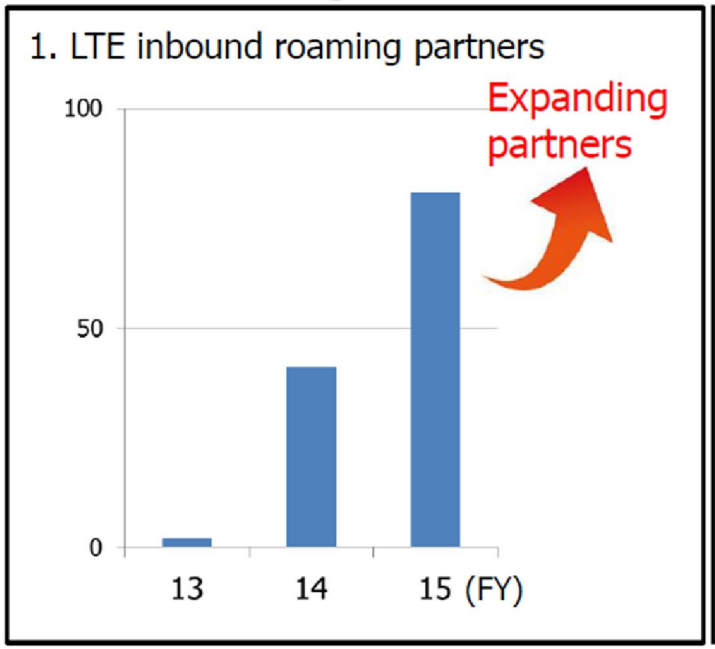
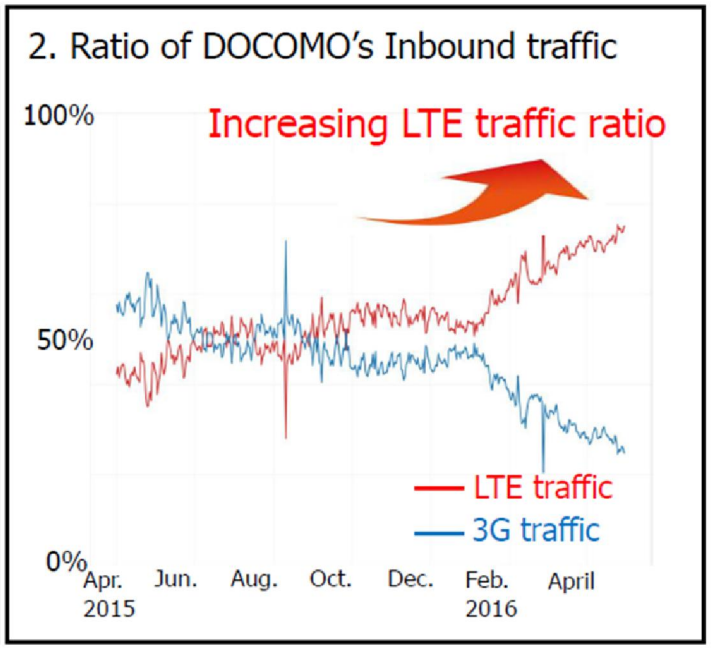
Customer Case Study #4:
NTT DoCoMo Japan

Increasing LTE Inbound Traffic

docomo

1. Expanding DOCOMO's LTE inbound roaming partners
2. Increasing LTE inbound traffic ratio





Improving LTE network quality of inbound roaming services becomes more important

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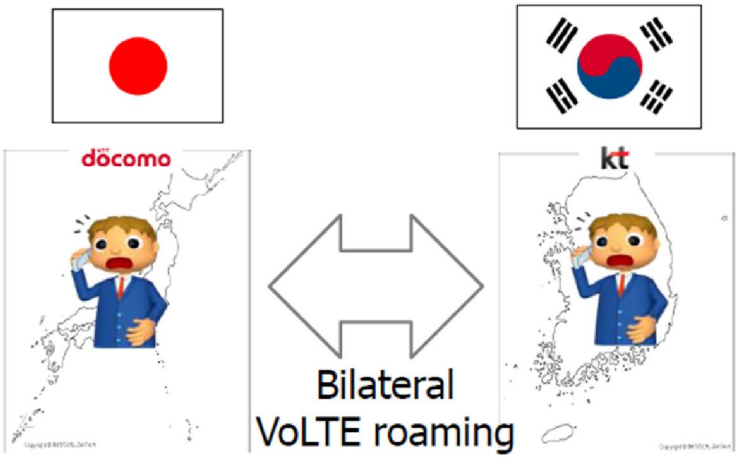
Customer Case Study #4:
NTT DoCoMo Japan

Launching VoLTE Roaming

docomo

Docomo launched bilateral VoLTE roaming service in 2015 for the first time in the world



Press release

https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0930_00.html

DOCOMO expects to expand its VoLTE roaming service with other countries

VoLTE roaming service quality is expected to become important

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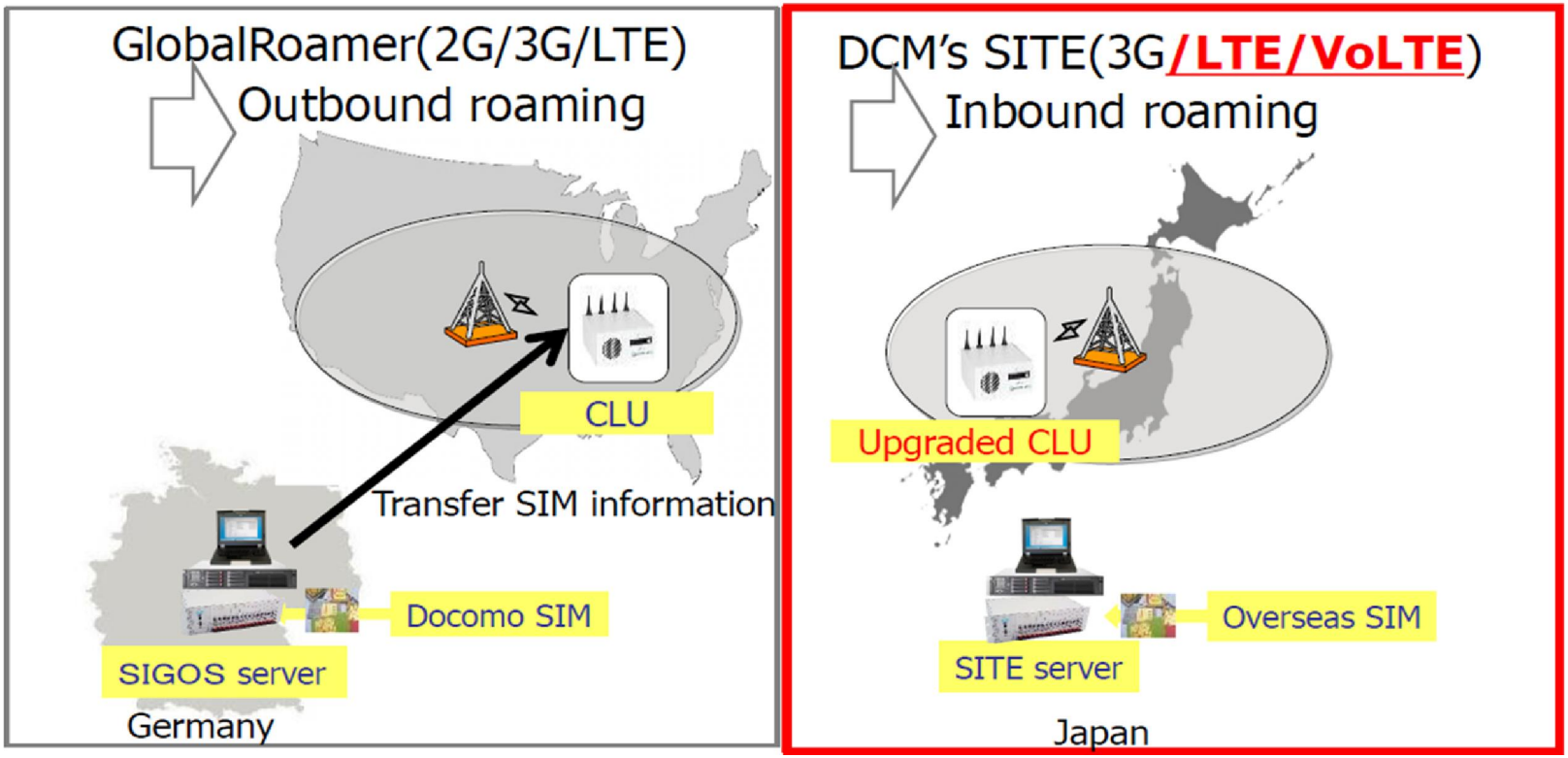
Customer Case Study #4:
NTT DoCoMo Japan

Adding LTE/VoLTE Features for SITE

docomo

DOCOMO expands SITE system in 2016
LTE tests for inbound roaming service become available



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