

# **ITU Asia-Pacific CoE Training**

## **Broadband Quality of Service - End User Experience**

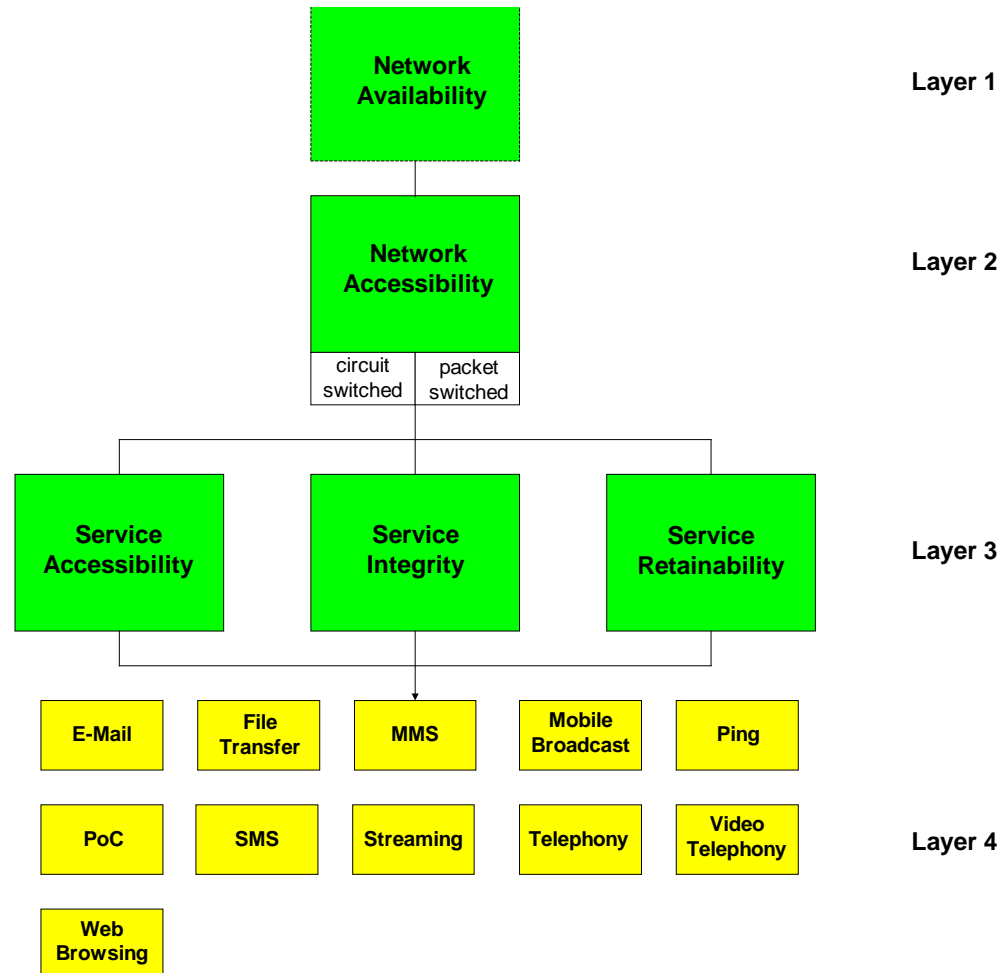
### **Session 6: Key Performance Indicators: Role and Decision Making**

**27-30 October, 2015  
Bangkok, Thailand**

- Objective: The session will detail the various key performance indicators used by operators and regulators in arriving at service level agreements and end user QoS monitoring

- Mobile KPIs
  - centric to equipment / infrastructure
  - aggregation of proprietary network counters
  - not standardized
- ITU-T Documents on Mobile QoS
  - Recommendation E.803
    - Quality of service parameters for supporting service aspects
  - Recommendation E.804
    - QoS Aspects for Popular Services in Mobile Networks
  - Supplement 9 to E.800 series of Recommendations
    - Guidelines on Regulatory Aspects of QoS
- Other ITU-T Recommendations on QoS cover
  - Aspects of Terminal requirements
  - Aspects of end-to-end quality
  - Aspects of user perceptions

- QoS model for mobile has four layers.
- First layer is the Network Availability
  - defines QoS rather from the viewpoint of the service provider than the service user
- Second layer is the Network Access
  - from user's point of view basic requirement for all the other QoS aspects and parameters
- Third layer contains other QoS aspects
  - Service Access, Service Integrity & Service Retainability
- Different services are located in the fourth layer
  - Their outcome are the QoS parameters as perceived by the user



- If we follow the layered approach
  - focussing on events that can be perceived by the user
  - focussing on most relevant services in the market
    - Telephony
    - SMS
    - MMS
    - Video Telephony
    - Video Streaming
    - Web Browsing

- Layer 1
- Radio Network Unavailability [%]
- Layer 2
- Network Selection and Registration Failure Ratio [%]

- Telephony Layer 3
  - Telephony Service Non-Accessibility [%]
- Telephony Layer 4
  - Telephony Setup Time [s]
  - Telephony Cut-off Call Ratio [%]



- SMS Layer 3
  - SMS Service Non-Accessibility [%]
- SMS Layer 4
  - SMS End-to-End Delivery Time [s]
  - SMS Completion Failure Ratio [%]

- MMS Layer 3
  - MMS Send Failure Ratio [%]
- MMS Layer 4
  - End-to-End Delivery Time [s]
  - MMS End-to-End Failure Ratio [%]

- Video Telephony Layer 3
  - VT Service Non-Accessibility [%]
- Video Telephony Layer 4
  - VT Audio/Video Setup Time [s]
  - VT Cut-off Call Ratio [%]

- Streaming Video Layer 3
  - Streaming Service Non-Accessibility [%]
- Layer 4:
  - Streaming Service Access Time [s]
  - Streaming Reproduction Cut-off Ratio [%]

- Web Browsing (HTTP) Layer 3
  - HTTP Service Non-Accessibility [%]
- Web Browsing (HTTP) Layer 4
  - HTTP Setup Time [s]
  - HTTP Session Failure Ratio [%]
  - HTTP Data Transfer Cut-off Ratio [%]

- This approach would make us end up with > 20 QoS parameter
  - All relate to user perceptual events
  - But this is just end-to-end parameters
  - Many more parameters defined for events related to network segments, hand-over etc.

# Test Scenarios

- Test scenarios need to distinguish the following principal user cases
  - User-to-user services (typically telephony)
  - Store-and-forward services (e.g. SMS)
  - Information services (e.g. accessing the internet or FTP download)
  - Push services (sender initiated transfer)

# Considerations on trigger points

- It can be assumed that
  - any feasible test equipment will contain some kind of communication terminal (UE) which may be a special type (e.g. a Trace Phone)
  - or a standard UE
- Also, it can be assumed that each such device will provide information from different communication layers
  - from Application Layer (close to the user interface)
  - down to lower layers, e.g. operating-system events, TCP/IP layer, or Layer 3 signalling information, which is used as trigger points for QOS PARAMETERS processing
  - Typically AT commands can be used in majority of cases
- Action is typically triggered
  - by some emulated user action
  - causing some action on the air interface



- Process of event propagation is deterministic
  - allowing for kind of mapping between layers
  - associated with communication and processing delay in each stage.
- Choice of the layer for trigger point information retrieval
  - determines the view expressed in a QOS PARAMETER
  - choosing lower-level events ( Layer 3) gives more network-centric view
  - events on higher levels to produce views more user-related
  - for same QoS PARAMETER source layer for events used as trigger points should be the same
- In benchmarking, for all all networks under test
  - use same type of UE, and QOS PARAMETERS
  - use trigger points from the same layer.
- Changing the source layer for a given trigger point
  - changes in QOS PARAMETERS should be expected
  - calibration measurements required
    - to assess influence on QOS PARAMETERS both quantitatively and qualitatively.

## Telephony Measurements in the Network

- Transaction definition and transaction types
  - The basic transaction for telephony testing is equivalent to a single call to a counterpart extension. It is assumed that the call partner is typically a fixed-network type extension to avoid uncertainties related to a second mobile connection.
  - Type is either Mobile Originated (MO) or Mobile Terminated (MT).
  - It is assumed that once a connection has been established, for further measurements it does not matter which side has triggered it. Therefore, the audio data flow parameter will not be logically linked to the call type.

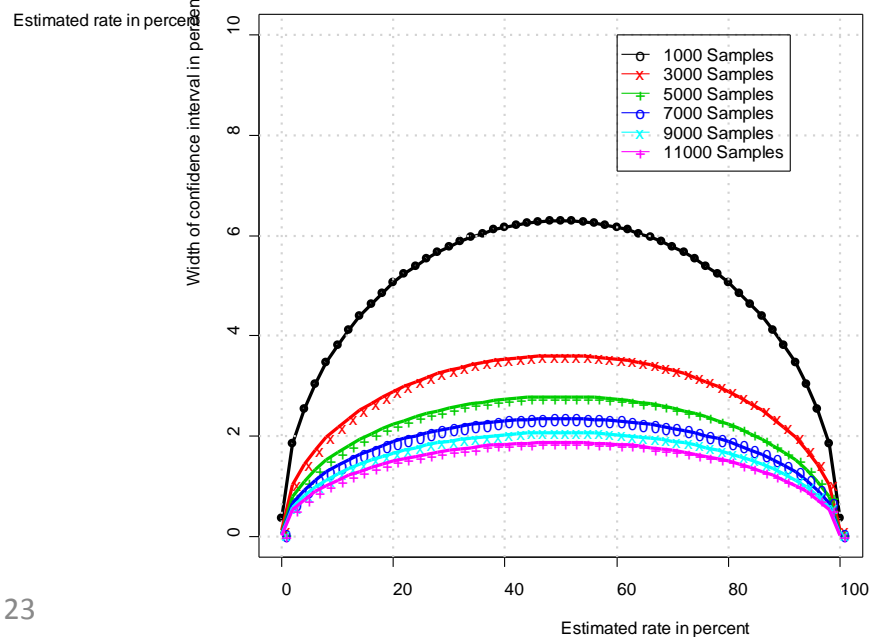
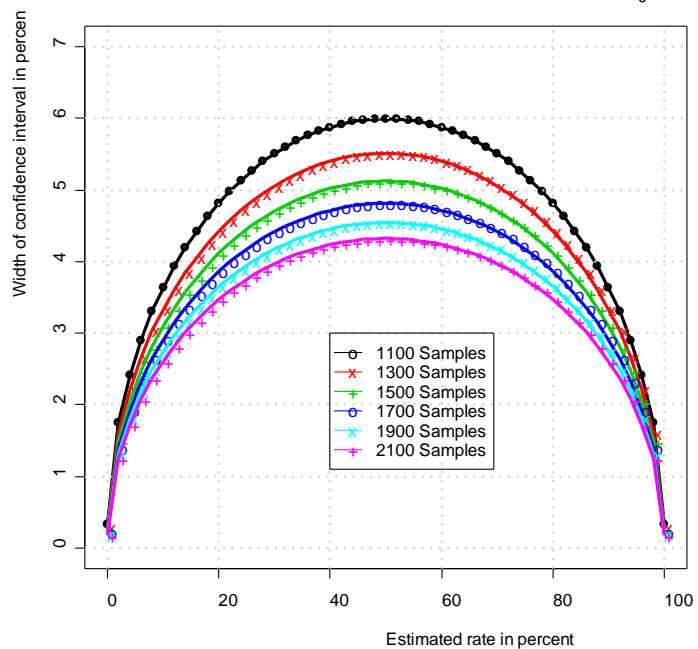
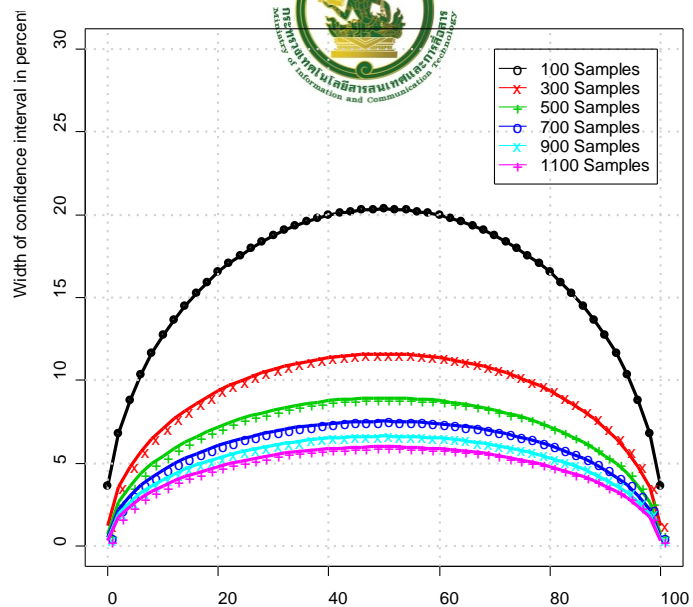
- Content quality
  - Content quality assessment data generated at receiving end
  - For downlink content data storage is straightforward
  - For uplink content, at some point in time results have to be integrated
  - For assessing content quality of complete transmitted speech samples, at least the following methods are possible:

- Content quality (ctd.)
  - Real-time assessment
    - streaming mode
    - speech quality assessment algorithm determines MOS-LQO real time
  - Offline assessment
    - content first recorded
    - being processed later
  - Data processing must ensure that only valid content quality data is processed
    - inside the "connection active" time window

- Verification of usable two-way connection
- Only calls with a valid two-way end-to-end information connection shall be considered for content quality assessment (valid calls).
- Non-valid calls treated like dropped calls
  - with indicator for this particular cause

## Statistics – Presentation of Results

- Effect of different sample sizes in a measurement campaign
  - based on the Pearson-Clopper formulas for calculation of confidence intervals
  - valid in a generic way and even for small sample sizes
  - for higher sample numbers, the calculation of confidence intervals based on the approximation of a normal distribution can be applied
  - Three different graphs are depicted: Sample sizes in the range:
    - between 100 and 1 100 samples;
    - between 1 100 and 2 100 samples; and
    - between 1 000 and 11 000 samples.



- Which pieces of information should be given to the reader when generating a test report ?
  - When quantile values are used, it should be kept in mind that the computation of quantiles separates a low percentage of outlier data from the remaining data. This means:
    - If lower values represent a better outcome from the customer's perspective, a small percentage containing the highest values could be separated by calculating a 95 %-quantile or a 90 %-quantile. This is the case for example for duration values.



- If higher values represent a better outcome from the customer's perspective, a small percentage containing the lowest values could be separated by calculating a 5 %-quantile or a 10 %-quantile. This is the case for example for throughput values.
- Related to content quality, the appropriate quantile computation orientates itself on the scale of the determined test results. In practice, some algorithms define a value of 0 on a scale from 0 to 5 as the best quality whereas others define the value of 5 as the highest possible quality

# KPIs based on Network Counters

- Vendor specific = network internal KPIs
  - different strategies
    - how to count network events
    - which events are included in which counter(s)
- Requires knowledge of specific system
  - specialists with detailed system knowledge
  - testing the counters
    - documentation may be faulty
    - approach to counter change with system update
- Mobile operators have challenges with this
  - most operator live in a multi vendor environment
  - counters from different vendors cannot be directly compared
  - requires continuous attention and a strategy

# KPIs from Users' Perspective = KQIs

- Key Quality Indicators (KQIs) = external indicators
  - can be assessed in the Field
- For Monitoring, Regulation etc.
  - a subset can be selected
    - applicable across all vendors & operators
    - not limited to mobile, but also good for broadband

# KPIs versus KQIs

- Sometimes confused
  - KPIs = internal indicators
    - part of network performance
    - based on network counters
    - essential for operation, maintenance, business model
    - could be reported, audited etc.
    - however, meaningless when out of context
  - KQIs = external indicators
    - basis for QoS assessment as perceived by the user
    - vendor independant
    - operator independant
    - ideal to compare different operators on a statistical basis
    - cannot be reported from the system itself
    - requires some kind of field testing, drive, walk etc.

...towards a new Recommendation

- From best practice of Project Self Measurement (PSM)...
- ... to a standardized benchmarking platform
  - employing the operational equipment of the service provider
  - thus assessing quality from a true user perspective

- Offer of new services requires
  - new KPIs
  - QoS measurements
  - benchmarking methods
- In order to ensure the quality of new services
  - comparability of test results
  - reference benchmarking methods
  - background traffic load profiles
- are needed for
  - the spectrum of potential applications
  - including all access technologies
  - operational equipment used by the operator under test

# Potential Applications

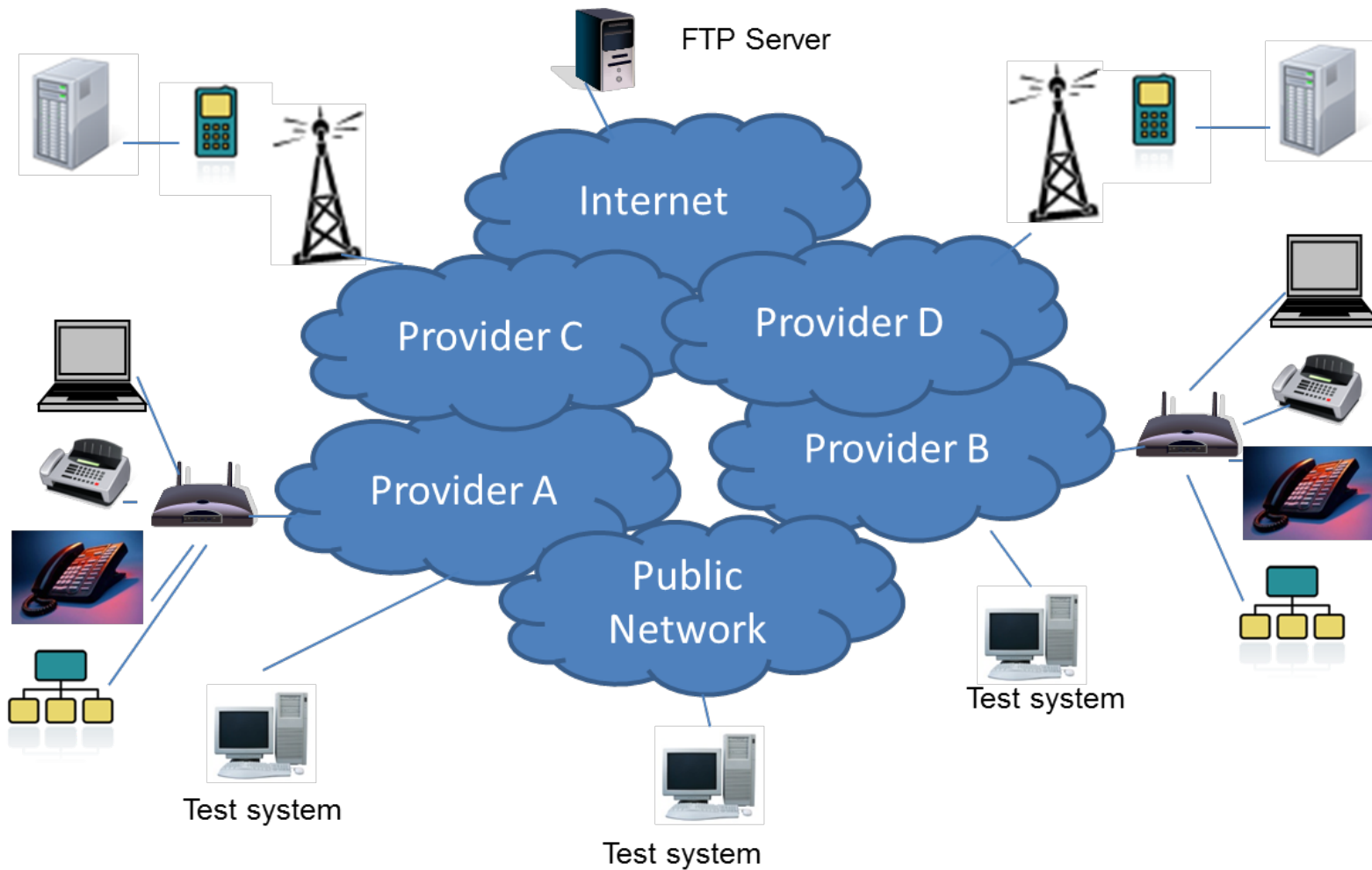
- analogue (a/b)
- ISDN
- VoIP (including SIP trunking)
- High-speed internet
- Website benchmarking
- IPTV
- UMTS
- VoLTE
- ViLTE
- ...

- Relevant for a real-world environment
  - Encompassing a mix of technologies
- This approach ensures that service quality is evaluated from a customers' point of view
  - All system components involved in a real end-to-end connection are incorporated into the test
  - ...



## Multiplay and Benchmarking Platform

- Can be distributed
  - across a larger region or
  - across an entire country
- Could include several server systems including:
  - business intelligence platform
  - data warehouse
  - management system
  - system for evaluating of media (e.g. video, audio and voice) quality
  - ...



# Simultaneous transmission of Voice and Data

- Realistic user related scenarios
  - uploads, downloads or use of IPTV in parallel to
    - voice connections
    - adaptive video streaming
  - sophisticated measurement of the media quality

- **single voice channel test** consists of the following parts:
  - through connection quality test
  - listening speech quality test
  - DTMF test

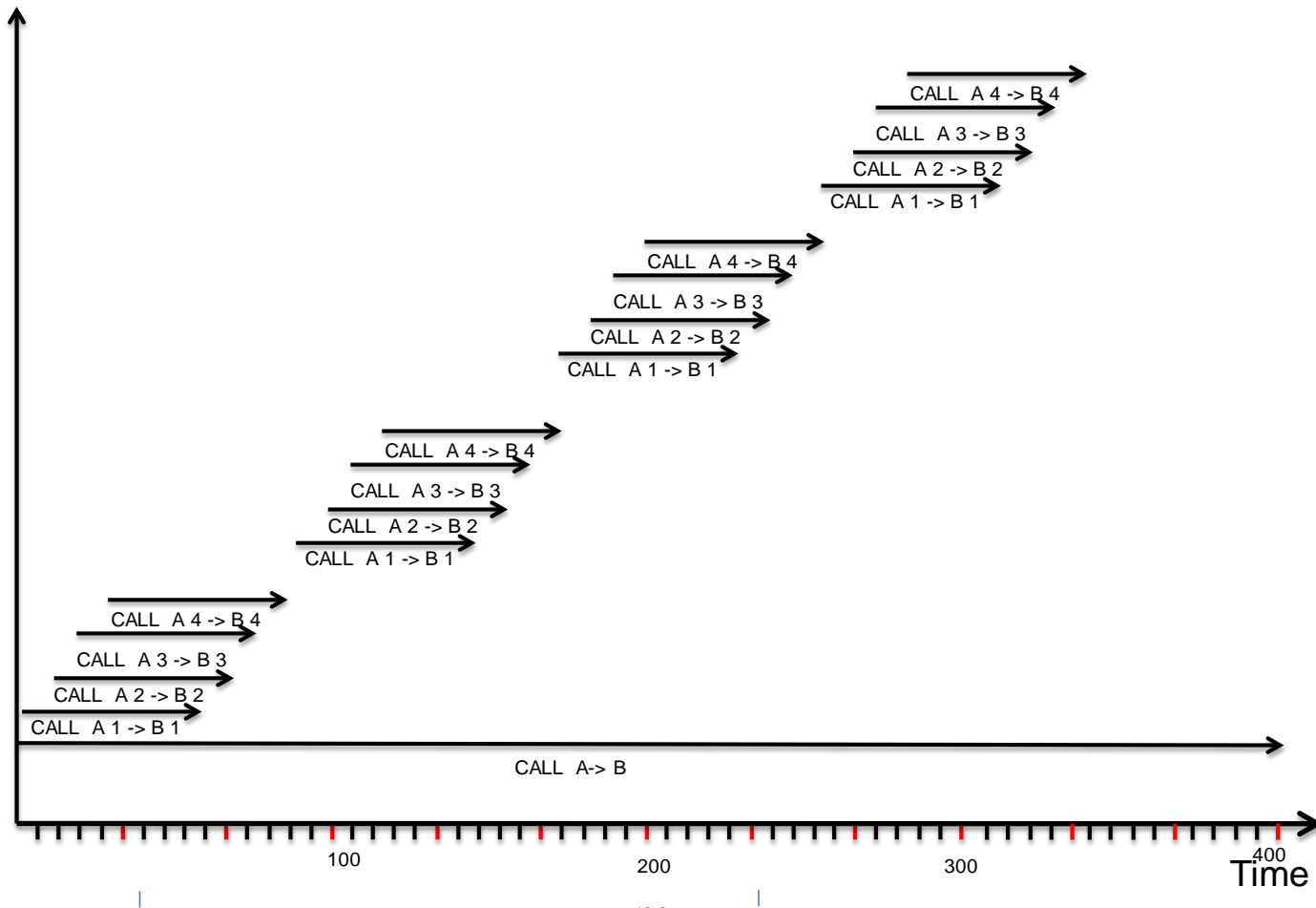
## Through Connection Quality test

- The **through connection quality test** starts with a listening speech quality test from B to A after the connection is established.
- For the analysis of the initial listening speech quality after through connection has been established the method according to Recommendation ITU-T P.863 in SWB mode based **on only two sentences** (one female voice and one male voice) is used. For this purpose a male voice ("Four hours of steady work faced us") and a female voice ("The hogs were fed chopped corn and garbage") were selected from the test sentences provided in Recommendation ITU-T P.501, Annex C

# Listening Speech Quality test

- The **transmission listening speech quality test** is using the Recommendation ITU-T P.863 analysis method in SWB Mode based on eight sentences (two male and two female voices, two sentences each).
  - For example the following English samples were selected from the test sentences provided in Recommendation ITU-T P.501, Annex C:
  - *Female 1:*
    - These days a chicken leg is a rare dish.
    - The hogs were fed with chopped corn and garbage.
  - *Female 2:*
    - Rice is often served in round bowls.
    - A large size in stockings is hard to sell.
  - *Male 1:*
    - The juice of lemons makes fine punch.
    - Four hours of steady work faced us.
  - *Male 2:*
    - The birch canoe slid on smooth planks.
    - Glue the sheet to the dark blue background.
- If the global performance data are of interest, optionally the male and female test sentences of other languages provided in Recommendation ITU-T P.501, Annex C can be used

# Example of multiple voice channel access test



# Multiple voice channel test

Relative Time	Test equipment A		NETWORK		Test equipment B
T0 - 2	SETUP / INVITE	➔		➔	SETUP / INVITE
	ALERTING / 180 Ringing	⬅		⬅	ALERTING / 180 Ringing
T0	CONNECT / 200 OK	⬅		⬅	CONNECT / 200 OK
	CONNECT ACK/ ACK	➔		➔	CONNECT ACK/ ACK
	Start through connection quality test				
T0	Start Audio Send BA_1 (male & female) Start Audio Receive BA_1	⬅		⬅	Start Audio Receive BA_1 (female & female) Start Audio Send BA_1
	End Audio Receive BA_1	⬅		⬅	End Audio Send BA_1
1 s	Stop through connection quality test				
	Transmission quality test				
T0 + 10 s	Start Audio Send AB_1 (female 1)	➔		➔	Start Audio Receive AB_1 (female 1)
	End Audio Send AB_1 (female 1)	➔		➔	End Audio Receive AB_1 (female 1)

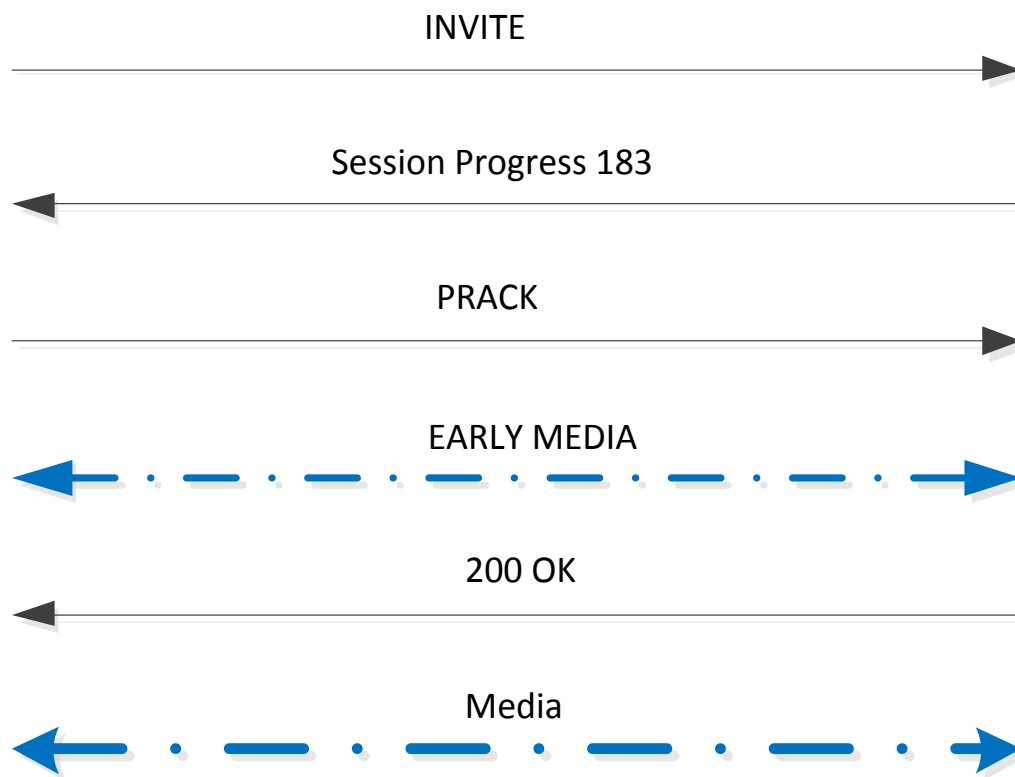


Relative Time	Test equipment A		NETWORK		Test equipment B
T0 - 2	SETUP / INVITE	→		→	SETUP / INVITE
	ALERTING / 180 Ringing	←		←	ALERTING / 180 Ringing
T0	CONNECT / 200 OK	←		←	CONNECT / 200 OK
	CONNECT ACK/ ACK	→		→	CONNECT ACK/ ACK
	Start through connection quality test				
T0	Start Audio Send BA_1 (male & female) Start Audio Receive BA_1	←		←	Start Audio Receive BA_1 (female & female) Start Audio Send BA_1
	End Audio Receive BA_1	←		←	End Audio Send BA_1
1 s	Stop through connection quality test				
	Transmission quality test				
T0 + 10 s	Start Audio Send AB_1 (female 1)	→		→	Start Audio Receive AB_1 (female 1)
	End Audio Send AB_1 (female 1)	→		→	End Audio Receive AB_1 (female 1)
	Start Audio Send AB_2 (female 2)	→		→	Start Audio Receive AB_2 (female 2)
	End Audio Send AB_2 (female 2)	→		→	End Audio Receive AB_2 (female 2)
	Start Audio Send AB_3 (male 1)	→		→	Start Audio Receive AB_3 (male 1)
	End Audio Send AB_3 (male 1)	→		→	End Audio Receive AB_3 (male 1)
	Start Audio Send AB_4 (male 2)	→		→	Start Audio Receive AB_4 (male 2)
	End Audio Send AB_4 (male 2)	→		→	End Audio Receive AB_4 (male 2)
1 s	Pause				
	Start Audio Receive BA_1 (female 1)	←		←	Start Audio Send BA_1 (female 1)

## Early media listening speech quality

- Early media refers to media (e.g. audio and video) which are exchanged before a particular session is accepted by the called user (in terms of the signalling). Within a dialogue, early media occurs from the moment the initial INVITE is sent until the User Agent Server (UAS) generates a final response. It may be unidirectional or bidirectional, and can be generated by the caller, the called party, or both. Typical examples of early media generated by the called party are ringing tone and announcements (e.g. queuing status). Early media generated by the caller typically consists of voice commands or dual tone multi-frequency (DTMF) tones to drive interactive voice response (IVR) systems.

# Early media SIP overview



# Call setup delay configurations

Call set up delay	From	To
	VoLTE	MMTel (IMS) fixed access
	MMTel (IMS) fixed access	VoLTE
	VoLTE	VoLTE
	UMTS	IMS PES with AGCF with AGCF (or PSTN or ISDN Access)
	IMS PES with AGCF with AGCF (or PSTN or ISDN Access)	UMTS
	IMS PES with AGCF with AGCF (or PSTN or ISDN Access)	LTE with CS fallback
	UMTS	IMS PES with VGW
	IMS PES with VGW	UMTS
	IMS PES with VGW	LTE with CS fallback
	UMTS	UMTS
	UMTS	LTE with CS fallback

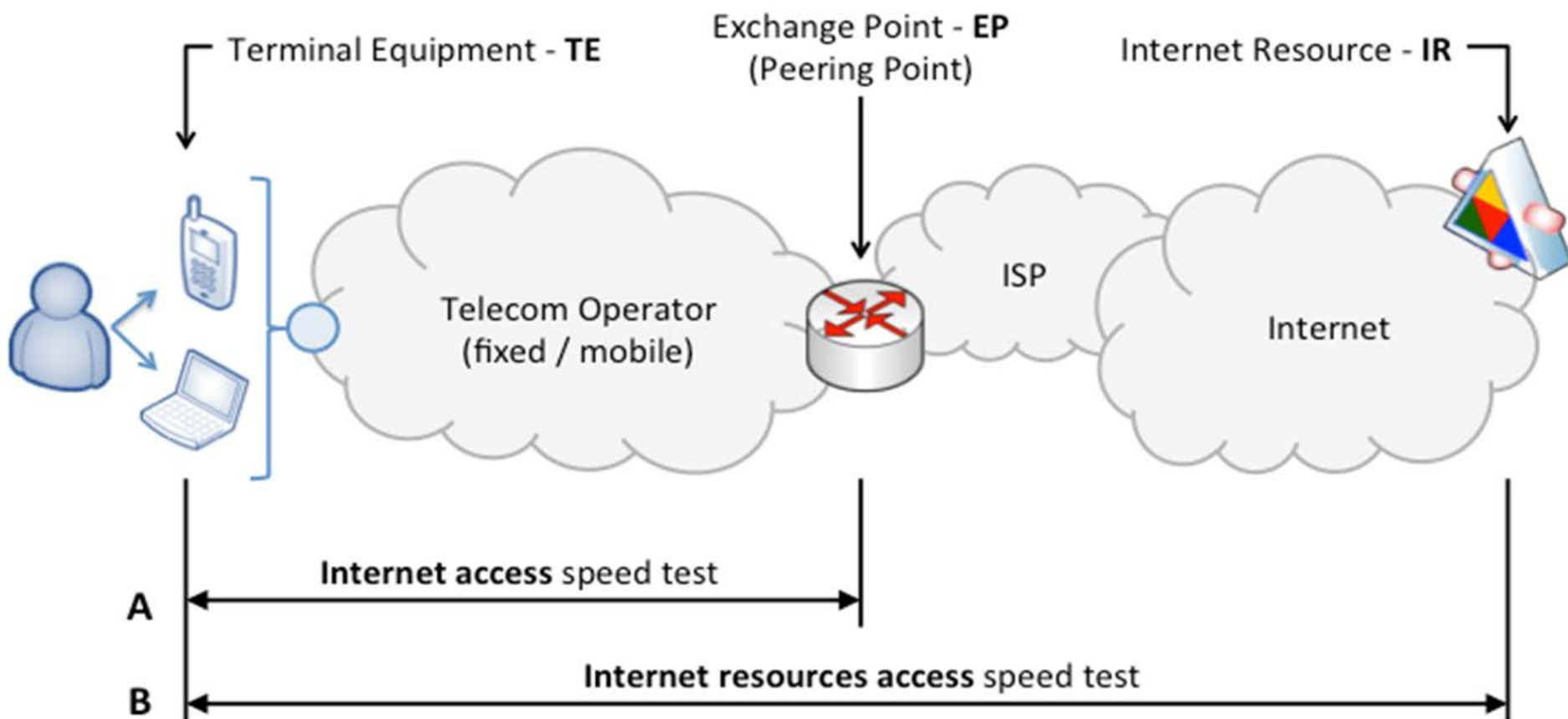
# Connections with parallel data transfer

Connections with parallel data transfer	Voice from	Data fr o m	Voice to	Data to
	VoLTE	LTE	MMTel (IMS) fixed access	WEB Server
	VoLTE	LTE	VoLTE	WEB Server
	LTE Mobile network with CSFB	LTE	IMS PES with AGCF with AGCF (or PSTN or ISDN Access)	WEB Server
	UMTS	UMTS	IMS PES with AGCF with AGCF (or PSTN or ISDN Access)	WEB Server
	LTE Mobile network with CSFB	LTE	IMS PES with VGW	WEB Server
	UMTS	UMTS	IMS PES with VGW	WEB Server
	UMTS	UMTS	UMTS	WEB Server

# ...under Construction

- Gaming
- Adaptive video streaming
- IPTV
- High speed internet
- Multithreaded broadband test
- ...

## Current ITU proposed approach



	Parameter	Unit	Range	Default value
<b>n</b>	Number of parallel connections	#	$1 \leq n \leq 10$	$n = 3$
<b>T<sub>p</sub></b>	Duration of pre-test	s	$0 \leq T_p \leq 5$	$T_p = 2 \text{ s}$
<b>T<sub>d</sub></b>	Duration of the downlink subtest	s	$5 \leq T_d \leq 10$	$T_d = 7 \text{ s}$
<b>T<sub>u</sub></b>	Duration of the uplink subtest	s	$5 \leq T_u \leq 15$	$T_d = 10 \text{ s}$
<b>T<sub>o</sub></b>	Timeout value*	s	$5 \leq T_o \leq 10$	$T_o = 5 \text{ s}$
<b>p</b>	Number of 'pings' during delay subtest	#	$10 \leq p \leq 40$	$p = 20$
<b>T<sub>I</sub></b>	Maximum elapsed time between ping starts	ms	$200 \leq T_I \leq 1000$	$T_I = 500 \text{ ms}$
<b>z</b>	Reference size of data block (chunk size)	KB	TBD	$z = 4 \text{ KB}$
<b>c</b>	Number of received chunks after which the ME answers back to the TE	#	$5 \leq c \leq 20$	$c = 10$



## Case Study from existing country (NN)

- Regulator considers to measure the following KPIs with his own resources:
- Mobile services:
  - Radio network unavailability
  - Coverage
  - Unsuccessful call attempt -international
  - Call set up time
  - Network latency
  - Average HTTP Mean Data Rate and Ratio
  - Packet loss
  - Jitter

- SMS End to End Delivery Time - International
- SMS Completion Failure Ratio – International
- Video Streaming Service Non Accessibility
- Video Streaming Reproduction Cut-off Ratio
- HTTP Service Non Accessibility
- HTTP Set-up Time
- HTTP Session Failure Ratio
- Fixed services:
  - Network latency
  - Average HTTP Mean Data Rate and Ratio
  - Packet loss
  - Jitter

- Video Streaming Service Non Accessibility
- Video Streaming Reproduction Cut-off Ratio
- HTTP Service Non Accessibility
- HTTP Set-up Time
- HTTP Session Failure Ratio
- In addition the regulator will measure the following KPIs which have to be already measured by the operators (double-checking):

## – Mobile services:

- Unsuccessful call attempt -National
- Call Set-up Time
- Dropped Call Ratio
- Voice Quality
- SMS End to End Delivery Time - National
- SMS Completion Failure Ratio - National

## – Fixed service KPIs:

- Unsuccessful call attempt
- Call Set-up Time
- Dropped Call Ratio
- Voice Quality

# Types of measurements

- OECD report categorises the types of clients that initiate each performance test at the end-user side and examines their characteristics:
  - End-user Application Measurement (EAM)
  - End-user Device Measurement (EDM)
  - Project Self Measurement (PSM) and
  - PSM by Internet Service Provider (PSM-ISP)

## Official measurement projects in OECD area

- “Mobile” is Yes
  - if any indicator is provided in publicised data to show performance of Internet access by a mobile access technology (LTE/3G/Wi-Fi...)
  - which can be used in motion. Measurements can be undertaken at fixed points.
- Categories of metrics are as follows:
  - DATA, also referred to as Internet speed, is amount of data transferred within a certain time such as a second between a client and a server; DNSR is DNS response time; WEB is length of time to load an webpage from a certain major website to a client; LT is latency; JT is jitter; PL is packet loss

Country or organization	Client type	Mobile	Purposes	Measured metrics	Geographical and topological location of	Number of clients
Austria	EAM	Yes	Consumer protection, Competition enhancement, Network development (information on network quality), Net neutrality (planned)	DATA,LT,JT,PL (DNSR and WEB are planned)	Immediate proximity to the Vienna Internet exchange (VIX)	Approx. 27 000 clients, 300 000 tests, (current value, on- going measurements)
Chile	PSM-ISP	Yes	Quality of services indicators	DATA, DNSR and Aggregation rate. (parameters informed by operators, not necessarily verified by SUBTEL)	Depending on ISP (Example: domestic on-net and off- net servers as well as an US server, statistics reported for each)	Depending on ISP
France	PSM	Yes	Verification of license obligations, consumer protection, competition enhancement, network development	Voice quality, SMS, MMS, data rates (DL and UL), web surfing, video service quality	off-net (dedicated to the study) for data rate measurement	Measures in 2000 different locations (for a total of about 20.000 tests for each operator)

Country or organization	Client type	Mobile	Purposes	Measured metrics	Geographical and topological location of	Number of clients
Germany	EAM and PSM	Yes for PSM	Consumer protection Net neutrality	Platform measurement: DATA, DNSR, WEB, LT, HTTP response time End user measurement: DATA	Off net with a direct connection to domestic points of interchange between the networks of different operators	Approx. 550 thousands end-users and 26 points of platform measurement
Greece	EAM	No	Consumer protection Competition enhancement, Net neutrality	DATA, LT, JT, PL, ISP's restriction on certain services such as P2P and video streaming	Nearest available M-Lab server	Approx. 10000 users
Italy	PSM and EAM (fixed), PSM (mobile)	Yes	Consumer protection. The results can be used as evidence in cases where promised speed is not realized and thus the user wishes to exercise the right of withdrawal of contract	DATA, LT, PL, error rate. Only for mobile: WEB, web failure rate, JT	Domestic points of interchange between the networks of different operators (Rome and Milan)	Fixed: 21 points for PSM, 25 535 end user software downloads for EAM Mobile: 1013 points in 20 cities



Country or organization	Client type	Mobile	Purposes	Measured metrics	Geographical and topological location of	Number of clients
Korea	EAM for fixed, PSM for mobile	Yes	Consumer protection Network development	Fixed : DATA, WEB Mobile: WEB, Rates of "successful" download and upload that were faster than certain speed, web loading time, (calling quality)	ISP on-net server	200 points for mobile PSM, 2000 users from each ISP for fixed EAM
Mexico	EAM	Yes	N/A	DATA, LT	Mexico city	(Approx. 1 million tests per month)
New Zealand	EDM	No	Consumer protection Competition enhancement	DATA, WEB (onshore and offshore), LT, JT, PL, DNSR	Auckland and Wellington in the country, Sydney in Australia, Dallas in the US	N/A
Norway	EAM	Yes	Consumer protection	DATA, LT	Norwegian Internet exchange	(Approx. 8000 tests done in September 2013, if the tests for ISPs with more than 40 tests are counted)

Country or organization	Client type	Mobile	Purposes	Measured metrics	Geographical and topological location of	Number of clients
Portugal	EAM	No	Consumer protection Market supervision Net neutrality	DATA, LT, traffic shaping		
Spain	PSM-ISP	Yes	Consumer protection	DATA, successful log-in ratio (probability of successful connections to the ISP for Internet browsing), unsuccessful data transmission ratio (probability of file transmissions without error)	Accordance with Section 5.2 of ETSI 2005 (ideally the server should be as near as possible to the gateway of the measured ISP to the access network but final choice has to be made by that ISP)	More than 210 clients (probes) deployed for each measured service. 5.6 million tests per year performed in total.
Slovenia	EAM	No	Consumer protection Competition enhancement, Net neutrality	DATA, LT	Server is located in Ljubljana at the web hosting provider with a 1 Gbit/s connectivity to the internet.	Measurement is at the early stage. Currently 220 tests.
Sweden	EAM	Yes	Consumer protection, self-help, ISP- statistics, reports	DATA, LT	5 locations close to urban centers of Sweden. Stockholm, Malmö, Gothenburg, Sundsvall, Luleå	100000 users/day, 100 million since launch 2007.

Country or organization	Client type	Mobile	Purposes	Measured metrics	Geographical and topological location of	Number of clients
Turkey	PSM-ISP	No	Consumer protection and Competition enhancement	DATA	The cities are categorized into five groups according to internet traffic from high to low. ISPs pick two cities from each category.	Under development
United Kingdom	EDM	No	Consumer protection	DATA, WEB, LT, PL, JT, DNSR	5 servers located in London and its outskirts	Approx. 2000 devices
United States	Fixed EDM, Mobile EAM	Yes	Consumer protection	DATA, WEB, LT(UDP and ICMP), PL(UDP and ICMP), video streaming, VoIP, DNS R, DNS failures, latency under load, availability of connection, data consumption	Core measurement points: 9 geographically diverse off-net servers placed by M-Lab Secondary points: 121 on-net servers placed by ISPs (Results are based on off-net points only. On-net points are to check differences)	Fixed: Approx. 7000 devices Mobile: (Just started)
European Commission	EDM	No	Network development (Digital Agenda for Europe)	DATA, WEB, LT, PL, DNSR, VoIP	24 M-Lab test nodes and 11 SamKnows servers in 14 cities across Europe. All are off-net points and located at major peering points or IXPs	Approx. 9000 devices

# Any questions ?



Contact:  
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# IMPROVING QUALITY OF LIFE..



Emergency



Education



Health



Agriculture



Investment



Applications



Policy & Regulation



Governance



Transport



Sensor Networks



Universal Broadband



Green ICT & E-Waste



Capacity Building



Measurements



Electricity



SMART  
SUSTAINABLE  
CITIES



Infrastructure Security



Privacy & Security



Water



Digital Inclusion



Spectrum Management



Standards, Conformity &  
Interoperability



Teleworking