Radio networks QoS assessment and evaluation tools

ITU/BDT Arab Regional Workshop on “ICT Applications for Rural Communications”

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Summary

• QoS definition
• QoS assessment tools
Quality of Service definitions and objectives

End-to-end Quality of Service

- Support of 3GPP QoS - parameters & mechanisms in UE
  - Support of different C5
  - Internal delays in UE
  - Memory (2 effects TCP Mark)
  - Used TCP window size
  - Supported HTTP-Version (1.0/1.1)
  - Support of Wi-Fi-optimization

- Protocol processing and transport delays, 3GPP QoS support
- A-Bs and CS resource dimensioning, allocation

- Internal processing/operating delays
  - Packet core capacity
  - Configuration of interactive queue weights
  - HLR QoS profiles

- Internal delays in WAP-gateway/http process/servers
  - Application server capacity
  - Geographical location (e.g. localized content caching vs. centralized serving)
  - HTTP-version (1.0/1.1) supported
  - Support of Wi-Fi-optimisation

- More power at application layer

- Internal radio access delays
  - Interferences-propagation
  - BS.lv overload
  - Interference levels
  - C/I ratio (CQI, CQI.sg)
  - TRX capacity (peak hour, C/I)

- BSS Internal delays (e.g. High TBF
  - QoS support
  - Call admission control
  - GPRS Dedicated resources
  - Used packet scheduling criteria
  - Usage of C-parameters (C2, C11/C32)
  - Configuration of scheduling step sizes

- Internal processing/operating and L1 delays
  - Transmission buffer sizes (TCP-effects)
  - Transmission buffer capacity
  - Geographical function/layer, number of hosts

- Application Servers (co-located or remote)

- User Equipment & network node
- = application
- = network planning/dimensioning
Quality of Service – definitions (1)

**QoS (ITU-T):** «The collective effect of service performance which determines the degree of satisfaction of a user of the service».

**Network Performance, NP (ITU-T):** «The ability of a network or network portion to provide the functions related to communication between users».

Quality of Service – definitions (2)

**User domain:** throughput, accuracy, dependability (reliability, availability), …

**Provider domain:** delay, loss, utilisation, …
Quality of Service – definitions (3)

*QoS* and *NP*, *Performance network* (*ITU* Rec. E800)

Quality of Service

- Service support (ability to provide a service and help its usage)
- Service operability (capacity of a service to be used)
- Service accessibility
- Service sustainability
- Service integrity
- Service security

Serveability performance

Traffic performance

Billing (probability that the network accounts the communications by type, destination, …)

Resources and environment

Dependability (availability, reliability, maintenance, support)

Transmission

Quality of Service and user satisfaction

Commercial offer → Competition → Trends → Users expectations in terms of QoS → Users satisfaction → Technical QoS → Non-technical QoS

Network performance → Terminal performance → Sales points → Customer care
QoS interactions

ETSI Technical Report « Network Aspects (NA); General aspects of Quality of Service (QoS) and Network Performance (NP) »

SLA (Service Level Agreement)


formal definition of a relation between 2 entities at least: for example the service provider and his customer.

Consists in 2 parts:
- Legal and financial specifications,
- Service level specifications (technical).
SLA (2)

ITU-T: *QoS is the degree of conformance of the service delivered to a user by a provider with an agreement between them.*

<table>
<thead>
<tr>
<th>Negotiation Phase</th>
<th>Documentation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Phase</td>
<td>Maintenance and Reporting Phase</td>
</tr>
<tr>
<td>Satisfaction (user/provider)</td>
<td>Termination Phase</td>
</tr>
</tbody>
</table>

Yes

SLA parameters example

Generally measured on a monthly basis:
- **RTT** (*Round Trip Time)*,
- **Packet loss ratio** (ping ICMP),
- **Jitter**.

Sampling can be achieved on a 5 minutes basis typically.
Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 2: Definition of Quality of Service parameters and their computation

**ETSI TS 102 250-2 V1.5.1**

(2007-10)

DNS Host Name Resolution Failure Ratio [%] = 

\[
\frac{\text{unsuccessful host name resolution requests}}{\text{host name resolution requests}} \times 100 \%
\]

Attach Failure Ratio [%] = 

\[
\frac{\text{unsuccessful attach attempts}}{\text{all attach attempts}} \times 100 \%
\]

Network Non - Accessibility [%] = 

\[
\frac{\text{unsuccessful registrations on the PLMN}}{\text{all registration attempts}} \times 100 \%
\]

Telephony Service Non - Accessibility [%] = 

\[
\frac{\text{unsuccessful call attempts}}{\text{all call attempts}} \times 100 \%
\]

Radio Network Unavailability [%] = 

\[
\frac{\text{probing attempts with mobile services not available}}{\text{all probing attempts}} \times 100 \%
\]

PDP Context Activation Time [s] = 

\[
\left( \frac{\text{PDP context activation accept}}{\text{PDP context activation request}} \right) \times [s]
\]

**Quality of Service indicators classes**

Indicators classes:

- **Network access,**
- **Service access,**
- **Service integrity,**
- **Service sustainability.**
Usage phases from the user point of view

- Network Availability
- Network Accessibility
- Service Accessibility
- Service Integrity
- Service Retainability

Quality of Service criteria
Quality of Service – user’s criteria

4 main criteria allow users to evaluate the network Quality of Service:

- Coverage,
- Call establishment,
- Voice quality,
- Call dropping.

Quality of Service – operator evaluation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coverage</strong></td>
<td>Cannot be assessed through the system. Radio measurements and subscribers.</td>
</tr>
<tr>
<td><strong>Successful call rate</strong></td>
<td>System measurements</td>
</tr>
</tbody>
</table>
| **Communication quality during the call** | Radio measurements  
|                      | System measurements  
|                      | Voice quality analysers                                      |
| **Call drop rate**   | System measurements                                           |
Quality of Service – Coverage

ITU Rec. 800: probability that the user receives a signal in specific conditions.

Reasons/Actions:
- Number of sites
- Position of the sites
- Antennas type, direction and height (RF design)
- Output power and cable losses (installation or maintenance).

Quality of Service – Successful call rates

Example: the subscriber cannot establish calls.

ITU Rec. 800: probability that a service can be obtained by the user in certain operational conditions.

Reasons/Actions:
- Minimum access level in the cell
- Difference between the dimensioning of the resources and the offered traffic
- Interferences
- Radio coverage.
Accessibility evaluation from a regulator point of view

- **Method**: conduct several call attempts spaced with 30 seconds minimum.

- **Accessibility rate** = \(\frac{\text{number successful of communications in 10 seconds maximum}}{\text{total call attempts number}}\).

Quality of Service – voice quality (1)

*Example*: bad communication quality.

**Reasons/Actions**:
- external interferences
- co-channel or adjacent channel interferences
- out-of-coverage
- bad installation
- transmission network (ex.: echo cancelor or trunks).
Main factors having an impact on the voice quality (2)

- Hardware (TRX, …)
- Coverage
- Interference
- Transmission errors (A, Abis)
- Advanced features (TFO, PC, DTX, FH, …)

Quality of Service – Call dropping

Reasons/Actions:
- coverage
- interferences
- handover problems
- radio parameters local adjustment.
Quality of Service in GSM/GPRS

GSM GoS (typical values)

<table>
<thead>
<tr>
<th>Interfaces</th>
<th>Blocking rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um/TCH</td>
<td>2% (1 to 5%)</td>
</tr>
<tr>
<td>Um/SDCCH</td>
<td>0.1% (0 to 1%)</td>
</tr>
<tr>
<td>GSM-RTC</td>
<td>0.5% (0.1 to 1%)</td>
</tr>
<tr>
<td>A</td>
<td>0.1% (0 to 1%)</td>
</tr>
<tr>
<td>Abis</td>
<td>0%</td>
</tr>
<tr>
<td>Ater</td>
<td>0.1% (0 to 1%)</td>
</tr>
</tbody>
</table>
### QoS indicators (1)

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Good</th>
<th>Average</th>
<th>Best Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOS</strong></td>
<td>4-5</td>
<td>3.8-4.2</td>
<td>2.9-3.8</td>
<td>2-2.9</td>
</tr>
<tr>
<td><strong>Call establishment delay</strong></td>
<td>&lt; 1.5 sec.</td>
<td>1.5 – 3 sec.</td>
<td>&gt; 3 sec.</td>
<td>&gt; 3 sec.</td>
</tr>
<tr>
<td><strong>Round-trip delay (ms)</strong></td>
<td>&lt; 150</td>
<td>150 – 250</td>
<td>250 – 450</td>
<td>&gt; 450</td>
</tr>
<tr>
<td><strong>Jitter (ms)</strong></td>
<td>&lt; 1</td>
<td>&lt; 18</td>
<td>&gt; 18</td>
<td>&gt; 80</td>
</tr>
<tr>
<td><strong>Packet loss (%)</strong></td>
<td>&lt; 1</td>
<td>&lt; 5</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

### Other QoS indicators (2)

- **Transmission delay**:  
  - fixed network (PSTN): 35 msec end-to-end,  
  - Node B – RNC [3GPP]: < 10 ms,  
  - UTRAN (real time services): < 5 ms,  
  - UTRAN (non real time services): < 10 ms,  
  - Radio interface: 70-80 msec in each direction.  

- **Loss rate**:  
  - UTRAN: < 10^-4 (real time traffic), 10^-7 (non real time traffic).
Other QoS indicators (3)

- Round-trip transmission delays for IP packets:
  - GPRS: 650 msec,
  - EDGE (R99): 300-500 ms,
  - UMTS: 200 ms.

Quality of Service in UMTS
UMTS QoS classes

<table>
<thead>
<tr>
<th>Traffic classes</th>
<th>Conversational</th>
<th>Streaming</th>
<th>Interactive</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main characteristics</td>
<td>- Minimum jitter, - Low delay</td>
<td>- Minimum jitter</td>
<td>- Question/answer mode, - Minimises the errors</td>
<td>- No delay constraints, - Minimises the errors</td>
</tr>
<tr>
<td>Example</td>
<td>Voice</td>
<td>Video</td>
<td>Web browsing</td>
<td>Emails</td>
</tr>
</tbody>
</table>

Multimedia services

- real time communications
- voice
- text
- video
- non real time communications
- audio streaming
- video streaming
- data files
- text messaging (ex. SMS)
- Email
- Web browsing
- multimedia messaging
### Some values of QoS UMTS parameters classes

<table>
<thead>
<tr>
<th>Traffic class</th>
<th>Conversation</th>
<th>Streaming</th>
<th>Interactive</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum throughput</td>
<td>&lt; 2048</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kb/s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>scheduling</td>
<td>Yes / No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max. SDU size (octets)</td>
<td>≤ 1 500 or 1 502</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrupted SDU delivery</td>
<td>Yes / No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>residual BER</td>
<td>5<em>10^{-2}, 10^{-2}, 5</em>10^{-3}, 10^{-4}, 10^{-6}</td>
<td>5<em>10^{-2}, 10^{-2}, 5</em>10^{-3}, 10^{-4}, 10^{-6}</td>
<td>4<em>10^{-3}, 10^{-3}, 6</em>10^{-8}</td>
<td>4<em>10^{-3}, 10^{-3}, 6</em>10^{-8}</td>
</tr>
<tr>
<td>SDU error rate</td>
<td>10^{-2}, 7*10^{-3}, 10^{-3}, 10^{-4}, 10^{-5}</td>
<td>10^{-2}, 10^{-2}, 7*10^{-3}, 10^{-3}, 10^{-4}, 10^{-5}</td>
<td>10^{-3}, 10^{-4}, 10^{-6}</td>
<td>10^{-3}, 10^{-3}, 10^{-6}</td>
</tr>
<tr>
<td>transfer delay (ms)</td>
<td>100 – maximum value</td>
<td>250 – maximum value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### QoS negotiation

- **UE**
- **UTRAN**
- **CN**

End-to-end service

CM (Communication Mgt)
- throughput max,
- throughput garantit,
- delay de transfert,
- QoS negociable (O/N)

UMTS Bearer Service: Request for UMTS QoS Class

RRM
Admission control

RAB Assignment Request

RAB and radio link establishment
QoS negotiation

RAB Assignment Response

UMTS service bearer with the negociated QoS
QoS parameters measurements tools

Measurement types

<table>
<thead>
<tr>
<th>Call</th>
<th>SpQ</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTS</td>
<td>BSC</td>
<td>MSC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counter</td>
<td>Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>3.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.95</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NE counters

<table>
<thead>
<tr>
<th>Subs. A</th>
<th>Subs. B</th>
<th>Dropped Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>+33 6 XXXX XXXX</td>
<td>+33 1 XXXX XXXX</td>
<td>No</td>
</tr>
<tr>
<td>+33 0 XXXX XXXX</td>
<td>+33 4 XXXX XXXX</td>
<td>Yes</td>
</tr>
</tbody>
</table>

CDR: Call Data Record
**Measurement tools typology**

- Measurement tools
  - Field measurements
    - System measurements
  - OMC counters
    - Generic
    - Specific
  - Passive capture tools
  - Calls generators

**A. Field measurements**
**Drive test equipment**

- Controller
- GPS
- Energy
- External antennas
- Mobile QoS test equipment
- Man to machine interface

**Drive tests (1)**

**TEMS example**

Measurement tool based on the TEMS includes:
- PC software with a serial port for the data,
- TEMS mobile,
- GPS receiver.
Drive tests (2)

TEMS information

- **service cell and neighbouring cells.**
- **radio parameters:** RXLev, RXQual, TXPower, DTX, Timing Advance, FER, SQI (voice quality), C1, C2, ...
- **current channel:** CGI (MCC, MNC, LAC, CI), BSIC, BCCH ARFCN, TCH ARFCN, Time slot, Channel type, Channel mode (FR, EFR, HR), Hopping Channel, Hopping Frequencies, HSN (Hopping Sequence Number).
  - **Map** to display the measurement itinerary.
- **level 2 messages** (RR-RSP, DISC-CMD, UA-RSP, SABM-CMD, ...) et 3 (Synch Channel Information, System Information Type 6, Measurement Report, Synch Channel Information, Paging Request, Assignment Complete, Handover Complete, ...).
- Frequency scanning.

Benchmark
Drive tests

3 parts: **QVM** (QV Mobile), **QVS** (QV Stationary) et **QVP** (QV Post processing).
B. System measurements
B.1. OMC measurements

Some tools

Specific
- **Alcatel**: RNO
- **Siemens**: SPOTS
- **Ericsson**: TEMS Analyzer
- ...

Generic
- **APIC** from Metrica
- **MyCom** from MyCom
- **AirCom**
- **NetAct SQM**: Nokia
- **OVPI**: HP (for IP equipments)
KPI processing tools
Commercial tools:

- BiVision,
- ADC/Metrica,
- NetAct (Nokia, for 3G),
- UTRAN Network and Service Analyzer (Tektronix),
- Actix.

Analysis based on OMC-R counters
Analysis tools using these counters (generally they are specific). Example: RNO or NPA of Alcatel, SPOTS from Siemens, etc.
B.2. Passive capture tools

Examples (1)

- *Tektronics*: K12/15XX
- *Network General*: Sniffer Pro + NPO
- *MyCom*: NIMS-PrOptima
- *Tekelec*: Steleus 2.5 G (GPRS) and Steleus 3G (Iu interfaces).
Examples (2)

- **HP**: Ovis (data services tests, produces KPIs).
- **RadCom**: Network Consultant (A, Gb, Gi, Gn, Iub, Iur, Iu, Gi and Gn interfaces)
- **Trafica** (NetAct from Nokia)
- **Ipanema**: Ipanema (2,5 G and 3G data traffic).
- **Cigale** (Astellia): 2 and 3G traffic.

B.3. Protocol analysers
## Network interfaces analysis

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nethawk</td>
<td>3G Analyser</td>
</tr>
<tr>
<td>Agilent</td>
<td>Signaling analyser</td>
</tr>
<tr>
<td>Tektronix</td>
<td>K15</td>
</tr>
<tr>
<td>Radcom</td>
<td>Performer analyser</td>
</tr>
<tr>
<td>Acterna</td>
<td>Telecom Protocol Analyzer</td>
</tr>
</tbody>
</table>

---

### Network interface analysis

*K12/15XX From TEKTRONIX*
B.4. Calls generators

Some tools

- $P3$: Vodafone specific
- $WQM$ (Agilent).
B.4. Measurements combination

GIS display

Mapping of call drop using system information

Sites and sectors with call drop rates higher than the average
C. QoS assessment examples for network optimization

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**Optimization throughout Life Cycle**

- RF adjustment
- Parameter adjustment
- Maintenance and upgrade
- Network expansion

- Customized and differentiated services
- Billing strategies
- Investment return

- Construction phase
  - Troubleshooting

- Booming phase
  - Potential Seeking

- Mature phase
  - Balancing

- Time

- Subs. Number

- Single site verification
- RF plan review
- Pre-launch optimization

- Drop call
- Congestion
- Poor quality
- Access failure

- DT & CQT
- KPI analysis
- Complaints

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Pilot channel pollution

- *Pilot channel pollution*: when receiving multiple pilots with high power but without a predominant signal do not allow to synchronize on one of them.
- *Solutions*: sectorization, antennas tilting, power adjustment.

Soft HO tuning

- SHO parameters:
  - *AS_Th*: macrodiversity threshold (report margin),
  - *AS_Th_Hyst*: AS-Th hysteresis,
  - *AS_Rep_Hyst*: AS-Rep hysteresis,
  - *T*: triggering duration,
  - *AS_Max_Size*: AS maximum size.
Optimization process

1. Drive tests
2. Post processing
3. Change proposal

UETR: user equipment traffic recording
CTR: Cell traffic recording
GPEH: General performance event handling

Network KPI

- **Accessibility**
  - RRC establishment SR (LA/RA update, SMS)
  - CSSR (CS + PS) (RRC+RAB)
  - Paging SR
- **Retainability**
  - Soft/Softer HO SR
  - Inter-frequency HO SR
  - IRAT HO SR
  - IRAT CC SR
  - LA/RA update
  - Cell selection/reselection SR
- **Integrity**
  - Drop rate (CS + PS)
  - Data throughput (PS)
  - Congestion
Dropped call classification

Dropped call classification:

1. Missing neighbors
2. Poor coverage
3. Pilot pollution
4. Congestion
5. Not radio
6. Equipment fault
2. Poor coverage

3. Pilot pollution
Dropped call classification

4. Congestion

5. Not radio
Dropped call classification

- Equipment fault

Blocked call classification:

1. Security & authentication mode failure
2. UE freeze
3. Disconnect on RAB setup
4. Unavailable resources
5. UE sensitivity fault
6. Unanswered RRC requests
7. Barred network
1. Security & authentication failure

2. UE freeze
3. Disconnect on RAB setup

4. Unavailable resources
5. UE sensitivity fault

6. Unanswered RRC request
7. Barred network

Poor Coverage example
Poor Cell Dominance example

Too many pilots leading to excessive soft handoff.

Example of too many lost server changes.

Pilot Pollution example

An example of too many pilots.
Example of missing neighbor
(*China Mobile, Dongguan City*)

Example of neighbor missing (Ec/Io)
Example of neighbor missing (RSCP)

Example of neighbor missing
Corner effect (RSCP)

Conclusions

- Network QoS allows assess the planning and operating efficiency.
- Many tools are used to evaluate the network performance from many the sides.