8. QoE and QoS Monitoring and data analyses

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S-38.3215 Special Course on Networking Technology for Ph.D. students at TKK
Outline

- QoE and QoS assurance concept
- QoE and QoS monitoring frameworks
- QoS Service Level Agreement
  - QoS SLA for IP transport and UMTS layers
- Confidence intervals on unknown parameters
- Statistical confidence on collected data
- QoE and QoS monitoring tools
Conceptual architecture (1/2)

Network Management Layer

- Service and QoS Provisioning
- QoE and QoS Monitoring (Service Quality Management, Customers QoS Management)

Element Management Layer

- FM
- PM

Network Elements

- UE
- UTRAN/GERAN
- SGSN
- GGSN

Fault Management (FM)
- Fault Aggregation & Processing

Performance Management (PM)
- Measurement Results Aggregation, Transfer & Presentation

Measurement Data Collection
- GPS
- MOA Agent
- Content

Fault Generation

Service and QoS Provisioning

QoE and QoS Monitoring (Service Quality Management, Customers QoS Management)
Conceptual architecture (2/2)
Approaches to measuring QoE

- QoE measurements using statistical samples
  - Key service weights and performance indicators
  - Statistical sample definition and MQA utilization
  - Overall QoE score (index) for each service and service mix

- NMS using QoS parameters
  - Collection of QoS performance
  - Mapping of QoS onto QoE
QoE Metrics: reliability and quality

- **Accessibility & retainability**

<table>
<thead>
<tr>
<th>QoE KPI</th>
<th>Most Important Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service availability (Anywhere)</td>
<td>Ratio of territory under coverage to not under coverage (%)</td>
</tr>
<tr>
<td>Service accessibility (Anytime)</td>
<td>Ratio of refused connections or Ratio of PDP Context failed to</td>
</tr>
<tr>
<td></td>
<td>establish in first attempt (%)</td>
</tr>
<tr>
<td>Service access time (Service setup time)</td>
<td>Average call or session set up time (s)</td>
</tr>
<tr>
<td>Continuity of service connection</td>
<td>Service interruption ratio (%)</td>
</tr>
<tr>
<td>(Service retainability)</td>
<td></td>
</tr>
</tbody>
</table>

- **Integrity**

<table>
<thead>
<tr>
<th>QoE KPI</th>
<th>Most important measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of session</td>
<td>Service application layer packet loss ratio (%)</td>
</tr>
<tr>
<td>Bit rate</td>
<td>Average bearer bit rate achieved as ratio of bit rate demanded by</td>
</tr>
<tr>
<td></td>
<td>application (%)</td>
</tr>
<tr>
<td>Bit rate variation</td>
<td>Bearer stability: Bit rate variation around negotiated bit rate (%)</td>
</tr>
<tr>
<td>Active session throughput</td>
<td>Average throughput towards mobile (kb/s)</td>
</tr>
<tr>
<td>System responsiveness</td>
<td>Average response time (s)</td>
</tr>
<tr>
<td>End to end delay</td>
<td>Average end to end delay (ms or s)</td>
</tr>
<tr>
<td>Delay variation</td>
<td>Jitter (%)</td>
</tr>
</tbody>
</table>

See also 3GPP SA4 work on “End-to-End Multimedia Services Performance Metrics”
ESTSI QoS parameters from end-user viewpoint

Layer 1

Layer 2

Layer 3

Telephony

SMS

CSD

PSD

Service Access

Service Integrity

Service Retainability

Network Access

Network Non Accessibility (NNA)

Service Accessibility Telephony (SA-T)

Service Accessibility SMS (SA-SMS MO)

Service Accessibility CSD (SA-CSD)

Service Accessibility PSD (SA-PSD)

Setup Time Telephony (ST-T)

Access Delay SMS (AD-SMS)

Access Delay CSD (AD-CSD)

Access Delay PSD (AD-PSD)

Speech Quality (SpQ)

End to End Delivery Time SMS (DT-SMS)

Data Quality (DQ)

Call Completion Rate PSD (CCR-PSD)

Call Completion Rate CSD (CCR-CSD)

Call Completion Rate Telephony (CCR-T)

Call Completion Rate CSD (CCR-CSD)

Data Quality (DQ)

Session Completion Rate PSD (SeCCR-PSD)
## ITU Model for user-centric QoS categories

<table>
<thead>
<tr>
<th>Error tolerant</th>
<th>Conversational voice and video</th>
<th>Voice/video messaging</th>
<th>Streaming audio and video</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error intolerant</td>
<td>Command/control (e.g. Telnet, interactive games)</td>
<td>Transactions (e.g. E-commerce, WWW browsing, Email access)</td>
<td>Messaging, Downloads (e.g. FTP, still image)</td>
<td>Background (e.g. Usenet)</td>
</tr>
<tr>
<td>Interactive (delay &lt;&lt; 1 s)</td>
<td>Responsive (delay ~ 2 s)</td>
<td>Timely (delay ~10 s)</td>
<td>Non-critical (delay &gt;&gt;10 s)</td>
<td></td>
</tr>
</tbody>
</table>
### ITU-T performance targets for audio and video

<table>
<thead>
<tr>
<th>Medium</th>
<th>Service Application</th>
<th>Degree of symmetry</th>
<th>Typical data rates</th>
<th>Key performance parameters and target values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>Conversational voice e.g. telephony</td>
<td>Two-way</td>
<td>4-64 kb/s</td>
<td>One-way delay: &lt; 150 ms preferred* &lt; 400 ms limit*</td>
</tr>
<tr>
<td>Audio</td>
<td>Voice messaging</td>
<td>Primarily one-way</td>
<td>4-32 kb/s</td>
<td>Delay variation: &lt; 1 ms Information loss**: &lt; 3% packet loss ratio (PLR)</td>
</tr>
<tr>
<td>Audio</td>
<td>High quality streaming audio</td>
<td>Primarily one-way</td>
<td>16-128 kb/s ***</td>
<td>Information loss**: &lt; 1% PLR</td>
</tr>
<tr>
<td>Video</td>
<td>Videophone</td>
<td>Two-way</td>
<td>16-384 kb/s</td>
<td>Delay variation: &lt;&lt; 1 ms Information loss**: &lt; 1% PLR Lip-synch: &lt; 80 ms</td>
</tr>
<tr>
<td>Video</td>
<td>Broadcast</td>
<td>One-way</td>
<td>16-384 kb/s</td>
<td>Information loss**: &lt; 1% PLR</td>
</tr>
</tbody>
</table>

* Assumes adequate echo control
** Exact values depend on specific codec, but assumes use of a packet loss concealment algorithm to minimise effect of packet loss
*** Quality is very dependent on codec type and bit-rate
**** These values are to be considered as long-term target values which may not be met by current technology
### ITU-T performance targets for data

<table>
<thead>
<tr>
<th>Medium</th>
<th>Service Application</th>
<th>Degree of symmetry</th>
<th>Typical amount of data</th>
<th>Key performance parameters and target values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>Web-browsing - HTML</td>
<td>Primarily one-way</td>
<td>~10 kB</td>
<td>One-way Delay: Preferred &lt; 2 s/page</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acceptable &lt; 4 s/page</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Bulk data transfer/retrieval</td>
<td>Primarily one-way</td>
<td>10 kB - 10 MB</td>
<td>One-way Delay: Preferred &lt; 15 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acceptable &lt; 60 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Transaction services - high priority e.g. e-commerce, ATM</td>
<td>Two-way</td>
<td>&lt; 10 kB</td>
<td>One-way Delay: Preferred &lt; 2 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acceptable &lt; 4 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Command/control</td>
<td>Two-way</td>
<td>~1 kB</td>
<td>One-way Delay: &lt; 250 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Still image</td>
<td>One-way</td>
<td>&lt; 100 kB</td>
<td>One-way Delay: Preferred &lt; 15 s</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td>Acceptable &lt; 60 s</td>
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<td></td>
<td>Delay variation: N.A</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Interactive games</td>
<td>Two-way</td>
<td>&lt; 1 kB</td>
<td>One-way Delay: &lt; 200 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Telnet</td>
<td>Two-way (asymmetric)</td>
<td>&lt; 1 kB</td>
<td>One-way Delay: &lt; 200 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>E-mail (server access)</td>
<td>Primarily one-way</td>
<td>&lt; 10 kB</td>
<td>One-way Delay: Preferred &lt; 2 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acceptable &lt; 4 s</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>E-mail (server to server transfer)</td>
<td>Primarily one-way</td>
<td>&lt; 10 kB</td>
<td>One-way Delay: Can be several minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Fax (“real-time”)</td>
<td>Primarily one-way</td>
<td>~10 kB</td>
<td>One-way Delay: &lt; 30 s/page</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: &lt;10^-6 BER</td>
</tr>
<tr>
<td>Data</td>
<td>Fax (store &amp; forward)</td>
<td>Primarily one-way</td>
<td>~10kB</td>
<td>One-way Delay: Can be several minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: &lt;10^-6 BER</td>
</tr>
<tr>
<td>Data</td>
<td>Low priority transactions</td>
<td>Primarily one-way</td>
<td>&lt; 10 kB</td>
<td>One-way Delay: &lt; 30 s</td>
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<td></td>
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<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
<tr>
<td>Data</td>
<td>Usenet</td>
<td>Primarily one-way</td>
<td>Can be 1 MB or more</td>
<td>One-way Delay: Can be several minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay variation: N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information loss: Zero</td>
</tr>
</tbody>
</table>
QoS Monitoring framework

**Management layer**
- Collect classified counters from NEs and compute throughput using that particular subset of QoS attributes for a consistent performance monitoring.

**Network layer**
- **RNC/BSC**
  - Delivered RLC data blocks
  - Classification of counters:
    - 3G: Traffic Class, THP (1, 2, 3)
    - 2G: Precedence class (1, 2, 3)

- **3G/2G SGSN**
  - Delivered BSSGP/GTP data blocks
  - Classification of counters:
    - 3G: Traffic Class, THP (1, 2, 3)
    - 2G: Delay class (1, 2, 3, 4)

**Subsets of QoS attributes (“pipe”)**
- Definition
Example: counters/gauges classification

- IMSI for tracing subscribers
- PDP Type and address
- APN
- **QoS Profile Negotiated**
  - Delay Class (1-4)
  - Reliability Class (1-5)
  - Peak Throughput Class (1-9)
  - Precedence Class (1-3)
- Packet Flow Context
- Charging Characteristics
- Routing Area from SGSN IP address
- Micro flow
  - Source and destination addresses
  - Source and destination port numbers
  - Protocol type (ID)
- IMSI or IMEI
- Radio Priority – UL
- PDP Type and address
- APN
- GGSN Address in Use
- **QoS Profile Negotiated**
  - Delay Class (1-4)
  - Reliability Class (1-5)
  - Peak Throughput Class (1-9)
  - Precedence Class (1-3)
- Packet Flow Context
- Aggregate BSS QoS Profile
- PDP Context Charging Characteristics
- Cell ID from BVCI
- Routing Area

- **BSS QoS Profile**
  - Peak bit rate – DL and UL
  - Type of BSSGP SDU (signalling or data) – DL
  - Type of LLC frame (ACK, SACK, or not) – DL
  - **Precedence Class (1,2,3) – DL**
  - Precedence used at radio access – UL
  - RLC/MAC transmission mode (AM, UM) – DL
- Modulation and Coding Schemes (MCS-CS)
- Cell from BVCI
- RA from SGSN IP address

**UMTS-GPRS interworking**
- R99 ARP = R97/98 Precedence Class
- R99 Interactive THP + BG = Delay Class

**E2E Consistent treatment**
- ARP1-3 = THP1-3 = Precedent Class1-3 = Delay Class1-3
- Delay Class 4 = Background
Example: ‘pipes’ definition and mapping

- **Bearer1**: Interactive TC, THP=ARP=1, Target bitrate EDGE UL 8 kbit/s, DL 30 kbit/s
  Target bitrate GPRS UL 8 kbit/s, DL 20 kbit/s

- **Bearer2**: Interactive TC, THP=ARP=2, Target bitrate EDGE UL 20 kbit/s, DL 30 kbit/s
  Target bitrate GPRS UL 10 kbit/s, DL 20 kbit/s

- **Bearer3**: Interactive TC, THP=ARP=3, Best effort (with some avg. bitrate targets)
  Other operator services

- **Bearer4**: Background TC, ARP=3, Best effort (with some avg. bitrate targets)

- **Note**: If one ‘pipe’ carries more service applications, only the performance of the aggregate traffic can be assessed.
Example: differentiate integrity monitoring

**EDGE/GPRS Counters**
- UL/DL correctly delivered RLC blocks
- UL/DL related duration of TBF ($i$)
- Measurement period ($S$)
- Total number of collected TBFs ($N$)

**Classification**
- RLC transmission mode (AM, UM)
- EGDE MCS 1-9 ($k$)
- GPRS CS 1-4 ($k$)
- Precedence Class $p$ or ARP (1-3)
- Cell identifier (Cell ID or BVCI)

**Differentiated throughput analysis**
- User throughput per ‘pipe’

\[
\sum_{i=1}^{N} \sum_{k=CS-1}^{MCS-9} r_{k} B_{i}^{p,k} \]

Total correctly delivered bits

\[
t_{p} = \frac{\sum_{i=1}^{N} d_{i}^{p}}{S}
\]

Total TBFs related duration

\[
t_{\text{cell}} = \frac{\sum_{i=1}^{N} \sum_{k=CS-1}^{MCS-9} r_{k} B_{i}^{p,k}}{S}
\]

Correctly delivered RLC blocks

Radio block size

Correctly delivered RLC blocks

TBF $i$ duration

Total correctly delivered bits

Measurement period

Measurement period
Example: differentiated reliability monitoring

- **RAB management**

\[ RAB.\text{SuccRatio}.m = \frac{\sum RAB.\text{Rel.UE}.m}{\sum RAB.\text{AttEstab}.m} \]

\( m = 'pipe' \)

- **Signaling connection management**

\[ RRC.\text{SetupAccessCompleteRatio.Cause} = \frac{\sum RRC.\text{SuccConnEstab.Cause}}{\sum RRC.\text{AttConnEstab.Cause}} \]

**3G: RAN**
QoS Service Level Agreement

- Definition
- **IP layer** SLA QoS management
- **UMTS layer** SLA QoS management
Service Level Agreement

- A service level agreement (SLA) is a **formal negotiated contract** between two parties, e.g., an enterprise customer and a mobile operator.

- The purpose of an SLA is to create a **common understanding about services, priorities, responsibilities** between the two parties.

- Mobile operator will likely see the popularity of SLA increases as more enterprises sign up for mobile services, and as more multimedia services are being provisioned over mobile networks.
SLA QoS management framework

**Definitions**
- SLA Contract

**Enforcement**
- translate into QoS rules
- configure network elements

**Corrective actions**
- alert operator to take corrective actions

**Monitoring**
- meet targets?
  - yes
  - no

- monitor SLA
Contents of a generic SLA QoS contract

- **Network scope**
  - Where the SLA QoS applies

- **Service schedule**
  - The period during which the SLA applies

- **Customer traffic flow identifiers**
  - Parameters to uniquely identify a customer traffic flow

- **Performance parameters and their target values**
  - To be experienced by customer traffic flows
  - Directly tied to customer traffic flow identifiers
    - Customer traffic flow identifier #1: performance targets #1
    - Customer traffic flow identifier #2: performance targets #2
Contents of a generic SLA QoS contract

- **Traffic profiles**
  - Traffic characteristics for each type of customer traffic flow

- **Non-conformance actions**
  - Treatment for the traffic flows that exceed their profile, e.g., drop or delay

- **Action of SLA violation**
  - Penalties on the operator if QoS SLA contract is violated, e.g., reduction of service fees paid by customer

- **SLA monitoring and reporting mechanisms**
  - How an operator makes monitoring results available to customers
Monitoring Technologies

- SLA QoS management solution must decide on the monitoring technologies

- Active vs. passive measurements
  - **Active**: injects test traffic into the network to measure network performance
  - **Passive**: derive network performance by monitoring existing user traffic

- External probe vs. embedded agent
  - **External**: using specialized monitoring device, e.g. Mobile QoS Agent
  - **Embedded**: monitoring component embedded inside network elements, e.g. Service assurance tool on routers
SLA for Different Layers

- IP transport layer QoS and UMTS layer QoS SLAs
  (Note that there are two IP layers: user IP and transport IP.)
SLA for IP Transport Layer
Use Case: SLA between mobile and IP operators

- The IP network that connects mobile sites are shared by multiple operators
- IP network operator signs SLA contracts with mobile operators
Customer traffic flow identifiers

- Combination of the following fields in IP packets:
  - Source IP Address
  - Destination IP address
  - Source port number
  - Destination Port number
  - Protocol
  - DSCP
  - Flow ID (IPv6)
  - Other higher layer fields

- A field can be a wild card – anything matches
Performance parameters

<table>
<thead>
<tr>
<th>Performance parameter</th>
<th>Expedited Forwarding</th>
<th>Assured Forwarding</th>
<th>Best Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (one way or round trip)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay jitter</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet loss ratio</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Throughput</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bearer availability</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
IP Transport layer SLA QoS monitoring

- **Throughput** may be monitored passively at interfaces
- **Packet delay, jitter, loss and bearer availability** may be monitored through active measurement
IP Transport layer SLA QoS management

- Three possible active measurement solutions
  - # 1, using Cisco router SAA tool for active monitoring
  - # 2, implementing active monitoring functions on GSN
  - # 3, installing dedicated active monitoring devices

![Diagram showing three solutions for SLA network scope](image-url)
Back to the Use Case

- The IP network that connects mobile sites are shared by multiple operators
- IP network operator signs SLA contracts with mobile operators
- SLA QoS contents
  - throughput, delay, jitter and loss for each Diffserv class between mobile sites
  - IP backbone availability
- PLMN can measure and verify the SLA by itself
SLA for UMTS Layer

Application

IP

PDCP

RLC

MAC

L1

MS

UTRAN

Iu-PS

GTP

Relay

PDCP

UDP/IP

ATM

GGSN

GTP

GTP

UDP/IP

AAL5

L1

L1

UDP/IP

AAL5

L2

ATM

L1

Gi

SLA for UMTS Layer
Use Case – SLA between Mobile Network Operator and Application Service Provider

- Mobile network operator (MNO) signs SLA contract with an application service provider (ASP)

![Diagram](image-url)
Customer traffic flow Identifiers

- Combination of the following parameters
  - IMSI
  - MSISDN
  - Traffic class, THP, ARP, MBR, GBR
  - Access point name
  - Source and destination IP addresses
  - Protocol, port numbers
  - Other higher layer fields

- A field can be a wild card – anything matches
## Performance parameters

<table>
<thead>
<tr>
<th>Performance parameter</th>
<th>Conversational</th>
<th>Streaming</th>
<th>Interactive</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay (one way or round-trip)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay jitter</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet loss ratio</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Throughput</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet error ratio</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Service response time</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Packet reordering</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PDP-context session blocking ratio</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PDP-context session availability</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PDP-context session retain ability</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PDP-context session access time</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
UMTS layer SLA QoS monitoring solution

- Monitor by sampling per PDP-context session performance for throughput, delay, packet loss, error ratio, service response time and traffic profile parameters by GGSN and mobile devices
  - Method one: Passively monitor application traffic
  - Method two: Active monitoring by installing responders at core sites
UMTS layer SLA QoS management solution

- **Aggregate throughput and traffic profile** at Gi are monitored by GGSN
- **PDP-context Session Blocking Ratio**, **PDP-context Session Availability**, **PDP-context Session Retainability**, **PDP-context Session Access Time** are monitored by
  - SGSN; or
  - mobile terminal
Back to the Use Case

- Mobile operator signs SLA contract with the ASP
- SLA QoS contains for each service and subscriber group
  - User IP packet throughput, delay, jitter, loss, error ratio and traffic profile
  - Total uplink and downlink IP packet throughput and traffic profiles at Gi interface
  - PDP-context session performance
- Mobile operator should measure the SLA parameters and make the measurement available to the ASP

![Diagram of the SLA scope]
Confidence interval on unknown parameter

- Smooth away effects of extremes or ‘outliers’
  - Median instead of Mean (Average)
  - Inter Quartile Range (IQR), i.e. 75th – 25th quartile, instead of Variance or Standard Deviation

- Calculation of C.I. on an unknown parameter
  - Find the function that approximate best the distribution of simulated or measured data, e.g. using Chi-Square test
  - A percentage confidence interval on a parameter, 100*(1-\(\alpha\)), correlates with the reliability (or repeatability) of performance results, e.g.
    - Confidence interval on a proportion (using the binomial distribution)
    - Confidence interval on the mean of a normal distribution where the variance is unknown (using the t-distribution)
Statistical confidence on measured data

- Statistical confidence on a proportion $p$
  - Find the sample size $n$ to be $100*(1-\alpha)$ percent confident that the relative error $\Delta p/p$ is less than a specified value $E$

- Statistical confidence on a measurement of time
  - Find the sample size $n$ to be $100*(1-\alpha)$ percent confident that the deviation from the real mean value is less than a specified threshold $a$ for a given expected mean and standard deviation value

- Local average power of a mobile radio signal
  - Find the sampling period for the power measurements of the radio signal to be 90% confident that the deviation from the real local mean of the signal strength is less than 1dB
**Examples**

1) **Relationship between the accuracy of the estimator of a proportion and the number of calls to be observed**

<table>
<thead>
<tr>
<th>Confidence Interval</th>
<th>95 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p )</td>
<td>5 %</td>
</tr>
<tr>
<td>( \Delta p/p )</td>
<td>10 %</td>
</tr>
<tr>
<td>Measurement interval</td>
<td>3600 s</td>
</tr>
<tr>
<td>Mean arrival rate per UE</td>
<td>600 s</td>
</tr>
</tbody>
</table>

\[ \alpha \] 0.0500
\[ \sigma(\alpha)^2 \] 3.8415
\[ (1-p)/p \] 19.0000
\[ (\Delta p/p)^2 \] 0.0100
\[ n \] 7299
\[ \text{UE} \] 1217

\[ G = D*E/F \] Required number of call attempts
\[ H = G/A*B \] Needed Mobile Agents

2) **Method of calculating the number of observations required for measurements of time**

<table>
<thead>
<tr>
<th>Confidence Interval</th>
<th>95 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>( s )</td>
<td>0.2 s</td>
</tr>
<tr>
<td>( x )</td>
<td>3.5 s</td>
</tr>
<tr>
<td>( a )</td>
<td>2 %</td>
</tr>
<tr>
<td>Measurement interval</td>
<td>3600 s</td>
</tr>
<tr>
<td>Mean arrival rate per UE</td>
<td>600 s</td>
</tr>
</tbody>
</table>

\[ \alpha \] 0.0500
\[ \sigma(\alpha)^2 \] 3.8415
\[ a^2 \] 0.0004
\[ (s/x)^2 \] 0.0033
\[ n \] 32
\[ \text{UE} \] 6

\[ G = D/E/F \] Required number of observations
\[ H = G/A*B \] Needed Mobile Agents

3) **Estimate of local average power of a mobile radio signal (90% confidence, 1 dB accuracy)**

| \( \nu \) | 3 km/h |
| \( f \)  | 2150 MHz |
| \( \lambda \) | 0.14 m |
| Minimal Sampling Period | 134 ms |

\[ D = 1000*0.8*C*3.6/A \] (W. C. Y. Lee)
Mapping of QoE onto QoS performance

- Objective Indicators vs. Subjective Measurements

```
<table>
<thead>
<tr>
<th>QoS KPIs</th>
<th>Excellent</th>
<th>Very good</th>
<th>Average</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-to-end delay</td>
<td>≤ 2s</td>
<td>≤ 4s</td>
<td>≤ 8s</td>
<td>≤ 15s</td>
<td>≥15s</td>
</tr>
<tr>
<td>(median)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet loss ratio</td>
<td>≤ 0%</td>
<td>≤ 0.1%</td>
<td>≤ 1%</td>
<td>≤ 5%</td>
<td>≥ 5%</td>
</tr>
<tr>
<td>Mean Throughput</td>
<td>≥ 200kb/s</td>
<td>≥ 120kb/s</td>
<td>≥ 60kb/s</td>
<td>≥ 20kb/s</td>
<td>≤ 20kb/s</td>
</tr>
</tbody>
</table>
```

QoE subjective scale

- Excellent
- Very good
- Average
- Fair
- Poor

<table>
<thead>
<tr>
<th>Cancellation Rate (%)</th>
<th>0</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Time (ms)</td>
<td>0</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
QoE monitoring tools

- **Application layer tools**
  - E.g. Ping, FTP, HTTP browsing, MMS, SIP, WAP, etc…

- **Field measurement tools**
  - Radio measurements + application layer performance

- **Protocol analyzers**
  - Protocol stack performance analysis at any interface

- **Mobile QoS agents**
  - L1-L7 measurements, position and location
  - Active and passive measurements
Mobile Quality Agent (MQA) functions

- **Measuring** mobile multimedia service quality, radio parameters, and producing **and reporting performance** statistics to central management servers
- **Active probing** and/or **passive monitoring**, which turns thousands of commercial mobile phones into (secure and non intrusive) service quality probing stations
- A **central management server** derives KPIs out of the reports from QoS agents, and manages QoS agents, i.e. dynamically dispatches, installs, and activates or deactivates them.
What is a Mobile Quality Agent (MQA)?

- **Dispatch table**
  - Maps service names to Sub-agent names, it is stored in a file that comes with the installation of the agent to make the agent architecture scalable.

- **Monitoring Profile**
  - Contains all instructions on how to monitor each type of service.

- **Agent Engine**
  - Coordinates all activities, executes commands from SyncML DM and reports measurements or configurations to the external server as scheduled or as requested by the server.

- **GUI**
  - Stores measurements and persistent data such as agent ID, the name of the active profile, the list of services that are being monitored, etc...
  - Contains all instructions on how to monitor each type of service.

- **Sub-agent**
  - Monitors a specific service, stores, retrieves & deletes measurements from repository, and aggregates measurements to derive performance indicators for the specific service.

- **Repository**
  - Protocol as interfaces to external servers.
Use cases: why an MQA?

- **Network planning** and **optimization**, monitoring multimedia services quality and radio interface performance where subscribers exactly are, **reducing the needs of traditional drive or walk tests**
- **Benchmarking** with the competition or collecting quality of foreign networks for a fact based comparison
- **Taking care of particular customers segments**, such as corporate or VIP users (e.g. business travelers) and keeping **service level agreement** promise
- **Selling what the operator can deliver**, understanding customers better (helpdesk) by collecting data of different categories, and launching only **successful services**
- **Solution for emerging Mobile Virtual Network Operators** to monitor service quality and check whether the mobile operators meet the service level agreements
Experimental validation by means of prototyping

- **Active measurements and one Sub-agent for Web browsing + Radio counters**
- **Sampling period of 1-2 s; session period of 10 minutes; reporting period of 30 minutes**
- **Download of two Web pages at a fixed and changing the handset position**
  - 92.26 kB (54.63 kB text, 37.63 kB for 15 images)
  - 500 kB (text only)
- **Bearer service counters**
  - Number of successful PDP context activations and activation times
  - Service application setup time (request for a web page is sent - http response header is received)
  - Function time (http response header received - page completely downloaded)
  - Number of successful browsing attempts; total number of data received (in bytes)
  - Total number of packets received
  - Average throughput for the download during the session
- **Bearer types**
  - GPRS, EGPRS, and UMTS
- **3G radio measurements**
  - RSCP and Ec/N0 of 4 best cells (A, M and D); Active set size; UE Tx power max and received SIR
- **2G radio measurements**
  - Rx Level; DL and UL BLER; CS1-4/MCS1-9 coding scheme classes; and timing advance
- **GPS position and network location**
Measurement setup:
- Real 3GSM network
- 10 handsets (Nokia 6630, 6680) connected to a GPS via Bluetooth

Functions:
- MQA control
- Reports collection
- Data forwarding to NMS

Legend:
- Green: Data Flow
- Blue: Control Flow
- Red: Probing

Diagram:
- Operator Intranet
- Mobile NW
- Internet
- NMS Server At secure zone
- Mirror agent (Measures Station)
-MQA
-Browsing
-Radio NW parameters
-GPS
-Watch dog
-Nokia 6630, 6680

Measurement setup: "Real 3GSM network"
10 handsets (Nokia 6630, 6680) connected to a GPS via Bluetooth
GPRS attach & PDP context setup time
Average throughput per session

User plane performance

- EGPRS
- WCDMA
- GPRS
WCDMA average throughput per session
Interference analysis per cell

Interfered areas:
High RSCP, Low Ec/N0
Example: **Nokia Mobile Quality Analyzer**

1. Self registration, MQA Agent and configuration download
2. Secure measurement reporting via https post
3. Download and update MQA configuration if available
4. Measurement collection in database
5. Measurement forward to Reporting System (e.g. Nokia NetAct™, 3rd party, …)
6. Data Analyze and Report generation
QoS monitoring tools: end-to-end

Network Management System (NMS) Tools

User terminal/PC having:
- Field Measurement Tool
- Application Layer Tools
- Protocol Analyser
- Mobile Agent(s) in the UE

Iub and Iu-PS test laptops/units with protocol analysers

Gn and Gi test laptops/units with protocol analysers

Test server(s) having protocol analyser(s)

Client to Iub delay
Client to Iub packet loss
Client to Iub attach time
Client to Iub PDP context activations time (Both way)

Iub to IuPS delay
Iub to IuPS packet loss
Iub to IuPS PDP context activation time (Both way)

Iu-PS to Gn delay
Iu-PS to Gn packet loss
Iu-PS to Gn PDP context activation time (Both way)

Gn to Gi delay
Gn to Gi packet loss

Gi Network

Application servers

Gi to Server delay
Gi to Server packet loss (Both way)
Centralize performance monitoring solution

Data distribution, Visualisation and analysis

Data pre-processing, preparation and summarisation

Data Collection

Network wide reporting

DB

Vendor A

Vendor B

Vendor C

CM, PM, SM, FM statistics

Data pre-processing, preparation and summarisation

Data Collection

Data distribution, Visualisation and analysis
Active measurements: use cases

1. Verify QoE, e2e via MT connected to Stethoscope
2. Verify Mobile Network only (GPRS or 3G)
3. Verify IP Backbone (between Core Sites)
4. Verify Service Platform (services offered via AP)
Service Quality Manager: e.g. data sources

Service level

Network level

Alarm information

KPIs, KQIs

Real time traffic data

Active and Agent measurements

Integrate all data from the network to determine service levels and problems

Drill down for detailed troubleshooting

Multi-vendor integration

3rd party

Service Quality Manager

network and service infrastructure

access
core

service platforms

IT
References

    (Contact Mr. Geoff Farrell @ Wiley gfarrell@wiley.co.uk)

See also: