Quality of Experience

QoE is not just about speed, but more about the other factors that impact our ability to deliver great video, browsing and gaming experiences

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Leone
From global measurements to local management

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Measuring Quality of Experience

Monitor and study broadband demand behaviour and performance

- **Passive measurements** – per-line usage statistics
- **Active measurements** - set of tests (speed, packet loss...) run on selected lines.
Historic traffic growth observed on Broadband

• Total network demand has grown more than 100 times over last ten years
• Core broadband traffic grows at 65%+ year on year growth
• Driven by: video (already 60% of total demand) and evolution of access
• Note – this is just broadband traffic – excludes all business and other services

To be published: The Impact of Capacity Growth in National Telecommunications Networks
Andrew Lord*, Andrea Soppera, Arnaud Jacquet. Phil. Trans. R. Soc. A.
Large-scale active measurements – helping us to handle network growth

• Identify hotspots in the network
  – At some level of aggregation
  – Understand impact on user’s experience

• Understanding the impact and operation of new devices, technology, products and services
  – Caching to mitigate growth
  – IPv6, IPTV, Home Gateways, new line cards...

• Other ISP use cases
  – Identifying and isolating failures in network
  – Identifying issues on an individual line
  – To monitor suppliers (upstream & downstream)
  – Understanding customer’s end-to-end service experience (e.g. web browsing quality; reliability)

• Also regulator and end-user use cases
Measuring Quality of Experience

- **Active reference testing**
  - able to accurately correlate & detect problems
- **End to end**
  - pick up any problems at any point/layer
- **User experience**
  - assess service & user impact
Portal Overview

- **Load and save reports and share with other users**
- **Unit and user management**
- **Options to normalise results to remove panel churn**
- **Hover-over for detail**
- **Confidence bounds depending on panel size**
- **Chart and test data export**

**Compare performance across products, network location, status and hub type**

- **Time series, cumulative distribution, histogram and data scatterplot charts**
- **Aggregation levels from weekly to individual test results**
- **Legend showing unit counts**

**Filter data of interest on any available parameter**

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Commonly-used Charts

- **Averaged Time-series**
- **Raw data Scatterplot**
- **CDF**

Service KPIs
iPlayer and caching

- Catch-up for BBC programmes
- How does caching work and how well?
iPlayer and caching

- iPlayer content comes at several characteristic rates, the most dominant being 2.8Mbps, 1.5Mbps and 0.8Mbps
- three CDNs are used
  - “a” CDN only hosts 2.8Mbps
  - “c” CDN doesn’t host 2.8Mbps
- XML manifest assigns a priority
  - ‘fast’ lines “a” or “b” 50:50 basis
  - ‘slow’ lines “b” or “b” 50:50 basis
- (Top pic) “a” and “b” have different start-up delays due to different source rate limit
- (lower pic) Test reported drops in reliably streamed bit rate (in red), due to failures on “a” CDN (in blue)
- Note: iPlayer & caching has changed recently
Web rendering test

• TCP download time may not accurately reflect user experience
  – QoE OK when first 80% of visible content downloaded?
• Test looks every 100ms to see if pixels changed on the browser screen – complete is no change for 3secs
Web rendering test - results

- Correlation of rendering time with ping (left) & throughput (right)
Some opinions

- More realistic tests (video, VoIP)
- Schedule – hourly about right
- Metadata inaccuracies – tests to check
- Data cleansing – eg outages impact pkt loss
- On-net servers
- Benefit from identifying shared issues
- Per-line potential benefit
Missing pieces & Research areas

- Finer granularity needs more probes
  - From hardware to software
  - Big stop button
- (Automated) Data analysis
  - New tools to scale performance and improve usability (big data)
  - On-demand testing (call centre)
- Improved Diagnostics
  - Available capacity testing
  - Identifying problems in the home network
  - Supply chain analysis
- Standardisation
  - Meaningful to compare measurements of same metric
  - Allow operators to use multiple vendors
Automated data analysis

- Motivation: identify sudden failures, long-term degradation...
- Assistance to network manager: Goldilocks number of alarms
- Open questions
  - Real-time?
  - Training history in /out?
  - Multiple metrics?
  - Accuracy?

Diagram:
- Probe 1 results → Probe 1 history → Combined analysis across many probes to identify anomalies → Alarm on region X
- Probe n results → Probe n history → Combined analysis across many probes to identify anomalies → Alarm on region X
- Metadata (topology)
Capacity Testing

- Running Throughput tests on many lines is heavy on the network and potentially ties up user lines (even for a few seconds)
  - Too few probes cannot give good visibility of capacity problems in the SVLAN/VP

- Solution: use large number of hubs with lightweight capacity tests
- Basic principle: send short packet trains (or pairs) into the network and analyse dispersion

- Different tests to detect capacity vs. available bandwidth
- Approaches
  - Packet pairs vs trains
  - Iterative vs. direct probing
- Overcome accuracy problems from multi-hop delays
- Don’t want to affect other traffic
- But do want to see impact of other traffic
Home Network Testing

- Self-help tool for customers
- ISP wants additional insight into home network and device performance
- Use lightweight probe-based techniques such as traceroute and device discovery?
- Passive analysis of devices connecting through home gateway?
- Install on user device?
  - Single viewpoint limited
  - Forced user participation
Supply Chain Mapping

• Try to detect where problems are in the network between users and the global services they access
• Not limited to BT on-net but gain a view of global routes, especially to popular services, and also home network
• Helps diagnose service problems and negotiate better peering and transit arrangements
Supply Chain Mapping – use Traceroute?

- Possible approach: probe delay to each ‘hop’ along the path to a range of destinations
  - Look at daily increase in delay variation
- Looking at overall delay variation can fall foul of equipment that has variable response to replying to traceroute TTL expiry
  - Ie ‘problems’ may not affect normal traffic
- How to filter out misleading data?
- High delays and variation in early hops can mean later hop delays can be hidden in the noise
  - Since each hop probe is separate packet
  - Essential to have quiet line or what you will measure is simply impact of user traffic on their own line
- Would be nice to have ping++ !
2\textsuperscript{nd} hop shows RTT variability, both on and off-peak: Not visible in subsequent hops.

3\textsuperscript{rd}-5\textsuperscript{th} Hops show nearly constant RTT and no peak/off-peak variability.
Standards perspective

- Standards for large-scale, comparability and vendor interoperability
- Standard open about how results used, analysed, shared
- Limited progress on common tests