Towards Autonomic Access Networks for Service QoE Optimization

speaker: Pieter Simoens

Joint work

**INTEC - IBBT, Ghent University, Belgium**
P. Simoens, B. De Vleeschauwer, W. Van de Meerssche, F. De Turck, B. Dhoedt, P. Demeester

**Alcatel Research & Innovation, Belgium**
E. Gilon, K. Struyve, T. Van Caeneghem
Multiplay, one single network

3 services converged in a single access network

IP/Ethernet based access network

new rich multimedia services have emerged!

telephony  internet  television

Video conferencing  Video on Demand  WAN gaming
Access Network Topology

- **home network**
  - end devices
  - home gateway
  - modem

- **aggregation network**
  - DSL
  - access node
  - aggregation switch
  - service edge router
Classification of services

- **Best effort** services still remain (very) popular
  - Web surfing
  - E-mail
  - File transfer
- **New services require** **Quality of Experience**:  
  - VOIP
  - Interactive TV
  - Video on Demand
  - Multimedia Internet Services
- **QoE includes**
  - Speed (surfing, up- and downloads)
  - Interactivity: low delay, low jitter (telephony, videoconferencing, gaming)
  - Content quality (lip synced IPTV, voice quality)
QoE in the access network

**QoE difficult to achieve**

- In the aggregation network
  - Complexity of multimedia services
  - Multiplicity of multimedia services
  - Stringent requirements
    - Network availability, packet loss, delay, jitter, bandwidth

- In the home network
  - Myriad of devices with different specifications
  - Firewall and NAT hinder access to home network access equipment

There is a need for autonomous QoE management in the access network, stretching from service edge router up to the end device
MUSE = Multi-Service Access Everywhere

European 6th Framework Program (IST)

System Vendors, Component Vendors, Telecom Operators, Universities

36 partners – 26 organizations

Two phases

- Definition of multi-service access architecture (2004 – 2005)
- Maturing the access network (2006 – 2007)
  - Service enablers in the access network elements for multimedia services
  - Fixed mobile convergence
  - Distributed architectures and node consolidation

www.ist-muse.org
Agenda

- Autonomous Access Network QoE Management
  - Architecture
  - Functionality
    - Monitor Plane
    - Knowledge Plane
    - Interaction between both layers

- Autonomic Access Node
  - Motivation
  - Functionality
2-layered architecture

**Knowledge Plane**
- root cause analysis
- restorative action

**Monitor Plane**
- QoE decrease detected

- **Device parameters**
- wireless link statistics
- noise margin
- queue filling
- reconfiguration
- BW reservation
- rerouting

- **End devices**
  - home network
  - modem

- **Home network**
  - gateway

- **Access node**
  - DSL

- **Network service**
  - aggregation network
  - edge router

- **Gateway**
  - reconfiguration

- **Home network**
  - modem

- **Monitor Plane**
  - QoE decrease detected

- **Knowledge Plane**
  - root cause analysis
  - restorative action
Monitor data forms a knowledge base for autonomous components

- Acquire accurate view on network status and QoE of running services
- Store monitor information in dedicated data structures
  - Summary
  - Format appropriate for Knowledge Plane processing
Monitor Plane

- **Monitor tools**
  - Active monitoring seldom useful
  - Passive monitoring of
    - Aggregation switches: SNMP, RMON, NetFlow, IPFIX
    - Access line quality: TR-069 + ACS
    - Home network
      - Monitoring from access node

- **Data reduction**
  - Sliding window, sampling…
  - Data structures
    - Sketches [1]
    - Deltoids [2]


Knowledge Plane

QoE Restorative actions

Root Cause analysis

Manage & Process monitoring data

- Management of Monitor Plane
- Interpret and correlate monitor data
- Detect QoE degradation
- Track root cause
- Actions to restore QoE

interaction
- **Anomaly detection**
  - Running algorithms on sketches/deltoids

- **Correlation**
  - Spatial correlation
  - Temporal correlation
    - e.g. detect latent long-term jitter increase
    - e.g. drop of BW during peak hours

> Monitor Data Processing

Knowledge Plane

Root cause most probable in aggregation network or service edge

QoE degradation of service A

QoE degradation of service A
Accurate root cause detection requires correct network model

Model must include
- All components (physical and logical)
- Relations between components

Ontologies very well suited
- reasoner can extract implicit knowledge
- e.g. packet loss on connection
  - source/destination attribute
  - topology database
  - packet route
  - query interconnecting links and switches/routers
  - localization of congested link
QoE Restorative Actions

- **Depends on:**
  - Location and nature of root cause
    - e.g. home network vs aggregation network
    - e.g. link or switch congestion
  - Type of affected service
    - IPTV service
      - Activate application layer interleaving, FEC or transcoding
    - High speed internet
      - Rerouting traffic
      - Change priorities of traffic classes

- **Take the impact on other services and the network status into account**
Interaction

**Knowledge Plane**

- Process monitor data
- Problem detection
- Change parameters
- Additional information required
- Root cause analysis
- Anomaly detection
- Spatial/temporal correlation
- Activate additional data structures or probes
- QoE restoring actions
- Restoring actions
- Additional information required
- Change parameters

**Monitor Plane**

- Data structure
- Data structure
- Data structure
- Probe 1
- Probe 2
- ...
Distributed architecture

- Tree-like topology of aggregation network
- Some problems can be solved locally
  - e.g. home network misconfiguration
- Others need central coordination
  - e.g. clients behind different access nodes suffering from QoE degradation
Agenda

- **Autonomous Access Network QoE Management**
  - Architecture
  - Functionality
    - Monitor Plane
    - Knowledge Plane
    - Interaction between both layers

- **Autonomic Access Node**
  - Motivation
  - Functionality
- **Nearest point to home user still within reach of network provider**
  - NAT/firewall issues
- **Root cause location tracking**
  - Crossing point between aggregation and home network
- **Passing point of all services of all connected users**
  - Correlation per user
  - Correlation per service
Monitor Plane in the access node

- **A lot of valuable information already present**
  - IGMP join/leave messages for IPTV multicast
  - Link connectivity
  - Subscription conditions (bandwidth, down/upload)

- **Monitor information about home network**
  - Home network access hindered by NAT/firewall
    - **Difficult to install probes**
  - Some protocols have two-way traffic
    - **Packet sniffing on access node**
    - **Retrieve information about factors affecting the QoE (as perceived by end-user)**
      - packet loss, delay, jitter, round-trip time, # retransmissions
    - e.g. TCP, RTP/RTCP
TCP

- Used for a lot of services
  - internet download, web services
  - transport of IPTV services like VoD
- Congestion control mechanism downscales bandwidth
  - packet loss causes ACK time-out and retransmission
    → wrongly triggered by non-congestion loss and excessive jitter
- Work in progress:
  - monitoring TCP traffic on the access node
  - retrieve information on
    - RTT
    - Jitter
    - Packet loss
    - # retransmissions
Real-Time Transmission Protocol (RFC 3550)
- Timely delivery of multimedia data
- Broadcast TV, Video on Demand

Two protocols
- RTP: data packets
- RTCP: control information
  - Time base synchronization information
  - Identification of session participants
  - Feedback on sent/received data
    - Sender/Receiver Reports
    - Contain valuable information on QoE as perceived by the user
    - Sniffing of the reports on the access node
RTCP reports

- A lot of valuable parameters!
- Sender report is extended version of receiver report

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<th>RC</th>
<th>PT=SR=200</th>
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<td>SSRC of sender</td>
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<td>SSRC_1 (SSRC of first sender)</td>
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<td>Fraction lost</td>
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<td>Extended highest sequence number</td>
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<td>Interarrival jitter</td>
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<td>Last SR (LSR)</td>
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<td>Delay since last SR (DLSR)</td>
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<td>Report block for other SSRCs</td>
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no. of packets and octets sent
estimated packet loss
estimated jitter
RTT estimation
Access Node Actions

- **QoE Restoring Actions**
  - Application layer FEC or interleaving
    - e.g. in case of packet loss on DSL line
  - Transcoding or transrating
    - e.g. in case of mismatch between codec and device specifications

- **QoE optimization**
  - e.g. push popular content to VoD proxy on access node to reduce bandwidth usage in aggregation network

- **Reporting to central platform**
  - e.g. report on retransmission request pattern per household
Multimedia services on the access network require QoE

QoE management very complex

Two-layer architecture

- Monitor Plane
- Knowledge Plane
- Extensive interaction between both layers

Key role for the access node

- Architecture
- Protocol sniffing for monitoring of home network
Thank you for your attention!

Any questions?