Adaptive Resource Control for QoS
Using an IP-based Layered Architecture

Evaluation of the AQUILA Architecture:
Trial Results for
• Signalling Performance,
• Network Services and
• User Acceptance

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http://www.ist-aquila.org/
Outline

- Introduction • Gerald Eichler
- Network Services in a Nutshell
- Signalling Performance Tests • Dietmar Katzengruber
- Network Services Behaviour Tests
- User Acceptance Tests
- Summary • Marek Dabrowski
- Demonstration
Innovations, Trials and Test Results

Design and Implementation Phase
- Architectural Framework
- Resource Pool Algorithms
- Distributed Measurement Architecture
- Network Services
- Admission Control Strategies
- QMTool

Trial Phase
- Warsaw Trial Site
- Vienna Trial Site
- Helsinki Trial Site
- Salzburg Trial Site

Result Evaluation
- QoS Signalling Performance
- Network Service and Traffic Class Behaviour
- User Acceptance and Application Behaviour
AQUILA Inter-Domain Extension

BGRPA Border Gateway Routing Protocol Agent
RCA Resource Control Agent
ACA Admission Control Agent
EAT End-user Application Toolkit
H Host
ER Edge Router
CR Core Router
BR Border Router
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Network Services as Intermediate Level

- **A Level based Approach**
  - reflects the innovative chain: customer ⇔ ISP ⇔ operator
  - provides predefined services for Internet application support
  - allows optimised network entity configuration
  - ensures the given guarantees by measurements
  - supports a vertical and horizontal system’s scalability
QoS Parameters affecting Applications

- Throughput
- Jitter
- Delay
- Error
- Loss

Applications:
- Voice over IP
- Video conferencing
- Video on demand, FTP
- Online games
- E-mail
- Online trading
Limited Set of Network Services

- Premium Variable Bit Rate (PVBR)
- Premium Multi-Media (PMM)
- Premium Constant Bit Rate (PCBR)
- Premium Mission Critical (PMC)
- Standard (STD)

Services:
- voice over IP
- video conferencing
- video on demand, ftp
- online games
- online trading
- e-mail

Four premium services
One best effort service

Gerald Eichler, T-Systems, Technologiezentrum;
Dietmar Katzengruber, Telekom Austria, et.al

(c) 2000-2003 AQUILA consortium. Art-QoS 2003, Warsaw,
March 24-25, 2003
Traffic Classes Level - Router Capabilities

TC: Traffic Class
WRED: Weighted Random Early Detection
WFQ: Weighted Fair Queuing
PQ: Priority Queuing

- Classification
- Marking policy
- Ingress buffering
- Queue selection
- Queue length
- Egress buffering
- Drop policy (WRED)
- Scheduling (WFQ)
Traffic Classes Level - Admission Control

- **Admission Control (AC) operates on the flow level**
  - prevents the network against congestion by limiting the volume of submitted traffic

- **In AQUILA, different AC rules are implemented**
  - since the QoS objectives as well as handled traffic profiles are different for each TC

- **Additionally, AC rules named joint AC are implemented**
  - leading to full available link by dynamically allocated bandwidth for each TC
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Resource Control Test Setup

- Twenty consecutive PCBR reservations were set-up and released
  - Time between sending the request to EAT and receiving the acknowledgement of the established reservation was observed
  - The timestamps were measured with a reservation generator
Resource Control – Reservation Times

**Main result**
- Average reservation setup time is 1.45 seconds
- Average reservation release time is 0.51 seconds

**No significant impact on reservation setup & release times caused by**
- Admission Control scheme
  - Declaration based
  - Measurement based
- Selected Network Service
- Number of active reservations
Resource Control - Signalling Traffic

- **Intra-domain signalling**
  - Total signalling load
    - Initial reservation 64 kB
    - Subsequent reservation 50 kB
  - Router configuration 30 kB

- **Inter-domain signalling**
  - Major component is database signalling 30 kB
Resource Control - Conclusions

- Reservation setup and release times are acceptable
- Component inter-communication is stable
- Amount of signalling traffic is relatively high but reductions are possible
  - Improved ACA - router connection (integrated solution)
- Scalability analysis for the architecture is quite promising
  - Tested architecture is a prototype, which is not performance optimised
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## Network Services Behaviour Tests

<table>
<thead>
<tr>
<th></th>
<th>QoS objectives</th>
<th>Admission Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCBR</strong></td>
<td>• Very low packet loss ratio</td>
<td>• Peak rate allocation</td>
</tr>
<tr>
<td></td>
<td>• Low delay</td>
<td>• Single Token Bucket</td>
</tr>
<tr>
<td><strong>PVBR</strong></td>
<td>• Very low packet loss ratio</td>
<td>• Measurement Based Admission Control</td>
</tr>
<tr>
<td></td>
<td>• Low delay</td>
<td>• Single Token Bucket</td>
</tr>
<tr>
<td><strong>PMM</strong></td>
<td>• TCP throughput guarantees</td>
<td>• (1) Token Bucket Marking (TBM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• (2) Advertised TCP window setting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Singe Token Bucket</td>
</tr>
<tr>
<td><strong>PMC</strong></td>
<td>• Very low packet loss ratio</td>
<td>• Rate Sharing Multiplexing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Dual Token Bucket</td>
</tr>
</tbody>
</table>
Evaluation of PCBR Service (1)

- **Test-bed topology**

  ![Test-bed topology diagram]

  - PC1
  - PC2
  - PC3
  - er1
  - cr1
  - cr2
  - er2
  - PC4
  - PC5
  - PC6

  - 10Mbps
  - 155Mbps
  - 100Mbps

- **Traffic conditions**
  - PCBR: Foreground traffic (Poisson stream) aggregated traffic load $B_1 \rho$,
    - where $\rho = 0.58$ for buffer size = 5 packets
  - STD: Background traffic (Poisson stream)
  - Total offered load: 120% of bottleneck link capacity
Evaluation of PCBR Service (2)

- **Measured parameters**
  - Packet loss ratio and delay characteristics

<table>
<thead>
<tr>
<th>$B_1$ [Mbps]</th>
<th>PCBR traffic load [Mbps]</th>
<th>Lower priority background traffic load [Mbps]</th>
<th>$P_{loss}$ of PCBR stream</th>
<th>Delay [ms]</th>
<th>IPDV [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>1</td>
<td>0.58</td>
<td>11.42</td>
<td>0</td>
<td>0.60</td>
<td>19.76</td>
</tr>
<tr>
<td>5</td>
<td>2.90</td>
<td>9.10</td>
<td>0</td>
<td>0.60</td>
<td>22.87</td>
</tr>
<tr>
<td>7</td>
<td>4.06</td>
<td>7.94</td>
<td>0</td>
<td>0.59</td>
<td>22.23</td>
</tr>
<tr>
<td>9</td>
<td>5.22</td>
<td>6.78</td>
<td>$4.5 \times 10^{-5}$</td>
<td>0.59</td>
<td>24.59</td>
</tr>
<tr>
<td>10</td>
<td>5.80</td>
<td>6.20</td>
<td>$9.0 \times 10^{-5}$</td>
<td>0.59</td>
<td>19.32</td>
</tr>
</tbody>
</table>

- **Conclusions**
  - Objectives of PCBR service are satisfied
  - The $P_{loss}$ is below the target value $10^{-4}$
  - Packet delay characteristics are acceptable
Evaluation of PVBR Service (1)

- **Test-bed topology**
  - Same as for PCBR test

- **Traffic conditions**
  - PVBR:
    - Foreground traffic: superposition of ON-OFF type flows
    - $B_2$ was changed
  - PCBR:
    - Background traffic: Poisson stream
    - $B_1$ was changed according to the joint AC rules
  - STD:
    - Background traffic: constant bit rate stream
    - Permanent congestion conditions on the bottleneck link
Evaluation of PVBR Service (2)

**Measured parameters**
- Packet loss and delay characteristics of PVBR traffic

<table>
<thead>
<tr>
<th>B₁ [Mbps]</th>
<th>PCBR traffic load [Mbps]</th>
<th>B₂ [Mbps]</th>
<th>NPVBR</th>
<th>PVBR traffic load [Mbps]</th>
<th>P&lt;sub&gt;loss&lt;/sub&gt; of PVBR stream</th>
<th>Delay [ms]</th>
<th>IPDV [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>8.945</td>
<td>23</td>
<td>3.45</td>
<td>1.26*10⁻⁴</td>
<td>2.84</td>
<td>17.50</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>4.238</td>
<td>7</td>
<td>1.05</td>
<td>1.30*10⁻⁴</td>
<td>2.95</td>
<td>17.37</td>
</tr>
<tr>
<td>4</td>
<td>2.32</td>
<td>5.243</td>
<td>10</td>
<td>1.50</td>
<td>1.36*10⁻⁴</td>
<td>2.87</td>
<td>23.34</td>
</tr>
<tr>
<td>4</td>
<td>2.32</td>
<td>2.658</td>
<td>3</td>
<td>0.45</td>
<td>1.00*10⁻⁴</td>
<td>2.23</td>
<td>14.88</td>
</tr>
<tr>
<td>7</td>
<td>4.06</td>
<td>2.658</td>
<td>3</td>
<td>0.45</td>
<td>1.18*10⁻⁴</td>
<td>2.43</td>
<td>21.70</td>
</tr>
</tbody>
</table>

**Conclusions**
- The impact of higher priority PCBR traffic on PVBR service is effectively regulated by the applied AC rules
- Measured P<sub>loss</sub> is close to assumed target value (10⁻⁴)
- The packet delays are acceptable
Evaluation of PMM Service (1)

- Test-bed topology

- Traffic conditions
  - Foreground traffic: PMM (1 TCP flow)
  - Background traffic: PMM (3 TCP flows)
  - Minimum RTT: 100 ms

- Measured parameter
  - TCP throughput
Evaluation of PMM Service (2)

Results for AC based on Token Bucket Marking (TBM) heterogeneous case

<table>
<thead>
<tr>
<th>Test</th>
<th>#1</th>
<th>#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustained Rate (kbps)</td>
<td>40</td>
<td>392</td>
</tr>
<tr>
<td>Bucket Size (bytes)</td>
<td>60000</td>
<td>60000</td>
</tr>
<tr>
<td>No. Flows</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Requested Rate (kbps)</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Throughput (kbps)</td>
<td>385 ± 110</td>
<td>473 ± 16</td>
</tr>
</tbody>
</table>

Conclusions

- The AC algorithm based on TBM did not meet the expectations
  - In test #2 the measured TCP throughput was below the requested rate
  - TCP flows shared available bandwidth according to the fair share rather than to the requested rates
- Maximum buffer size (25 packets) was shorter than required from theoretical studies
  - Limited buffer size of routers
Evaluation of PMM Service (3)

Results for AC based on advertised window setting heterogeneous case

<table>
<thead>
<tr>
<th>Test</th>
<th>#1</th>
<th>#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustained Rate (kbps)</td>
<td>328</td>
<td>672</td>
</tr>
<tr>
<td>Advertised Window (bytes)</td>
<td>4274</td>
<td>8688</td>
</tr>
<tr>
<td>Bucket Size (bytes)</td>
<td>4283</td>
<td>8463</td>
</tr>
<tr>
<td>Number of Flows</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Requested Rate (kbps)</td>
<td>232</td>
<td>521.7</td>
</tr>
<tr>
<td>Throughput (kbps)</td>
<td>275 ± 2</td>
<td>567.6 ± 2.5</td>
</tr>
</tbody>
</table>

Conclusions

- AC algorithm based on advertised window setting met the expectations
- Measured TCP throughput was between the requested rate and the sustained rate, but rather close to the requested rate
Evaluation of PMC Service (1)

- **Test-bed topology**

- **Traffic conditions**
  - Foreground traffic: PMC
  - Background traffic: PMC

- **Measured parameter**
  - Packet loss ratio
Evaluation of PMC Service (2)

Results for heterogeneous case

<table>
<thead>
<tr>
<th>Test</th>
<th>#1</th>
<th>#2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Flows</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>File size [bytes]</td>
<td>36200</td>
<td>73848</td>
</tr>
<tr>
<td>Peak Rate [Mbps]</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Bucket Size [bytes]</td>
<td>15000</td>
<td>30000</td>
</tr>
<tr>
<td>Sustained Rate [kbps]</td>
<td>340</td>
<td>170</td>
</tr>
<tr>
<td>Packet Loss Ratio</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Conclusions

- PMC service is able to guarantee low packet loss
- Moreover the AC algorithm designed for PMC service properly determines the maximum number of admitted flows.
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User Acceptance Tests

- **Real user listening-opinion tests with VoIP application**
  - Assessing QoS perceived by real users and expressed by their subjective opinion
  - Measurements of logatom (non-sense words) articulation
    - Statistical information about voice transfer quality
  - User acceptance

- **Tests with NetQual**
  - Software provided by SwissQual
  - Enables the playback of „Standardised“ wave files
  - Output: Mean Opinion Score (MOS) verification
Tests with VoIP Application (1)

Traffic conditions

- Scenario #1: reference scenario – single VoIP connection
- Scenario #2: tested VoIP traffic was served by PCBR
  - Background traffic: PCBR (Poisson stream, mean rate 5.136 Mbps) and STD (Poisson stream with mean rate 6.8 Mbps) services
  - Total offered traffic to the access link produced overload condition (120% of link capacity)
- Scenario #3: tested VoIP traffic was served by STD

Test procedure

- Listening-opinion test with 5 listeners and 1 speaker using VoIP application
- For each scenario: 3 logatom lists (100 logatoms each)
- Based on calculated average logatom articulation MOS index was evaluated
Tests with VoIP Application (2)

Test results

<table>
<thead>
<tr>
<th>Test scenarios</th>
<th>Average logatom articulation (Wₐ)</th>
<th>Mean square deviation (S)</th>
<th>MOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario #1: reference</td>
<td>74.1 %</td>
<td>7.1 %</td>
<td>4.0</td>
</tr>
<tr>
<td>Scenario #2: VoIP using PCBR</td>
<td>71.9 %</td>
<td>9.8 %</td>
<td>3.8</td>
</tr>
<tr>
<td>Scenario #3: VoIP using STD</td>
<td>46.1 %</td>
<td>9.6 %</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Conclusions

- Average logatom articulation for both scenarios #1 and #2 was similar and on acceptable level for IP network.
- Results obtained in the scenario #3 were much worse comparing to the scenario #2 and evaluated quality was on unacceptable level.
- The PCBR service supports VoIP in a very good way even in extremely congested traffic conditions.
Test Environment for Voice Tests

- Standardised (ETSI) reference wave sample files were injected
- Reference- and recorded file were compared
- MOS values were calculated
Voice Tests using NetQual

Use of STD (100% Background Traffic)

Use of PCBR (100% Background Traffic)
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Summary

- **Four premium Network Services cover a wide range of applications**

- There is a strong need for appropriate Admission Control to produce QoS on a DiffServ aware network

- **QoS add-ons should be manageable, scalable and well performing**

- Besides technical support user acceptance is the main focus supported by understandable operator offers
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Demonstration of the AQUILA Testbed

- Configuration of the demo network
- AQUILA portal: establishing the QoS reservation
- QoS at work: benefit for the quality of video application
- Complex Internet Service: Mediazine:
  - Combines several standard Internet applications
    - RealVideo: video streaming
    - RealAudio: music
    - NetMeeting: videoconference
    - On-line games
  - Appropriate AQUILA network services are used
    - Non-real time video and audio – PMM
    - Videoconference – PVBR
    - Games – PMC
Demonstration Network Configuration

- Foreground traffic, 0.384 Mbps
- Background traffic, 1.9 Mbps

Core network

Bottleneck on the access link

Traffic generator

Traffic analyser

AQUILA RCL
Adaptive Resource Control for QoS
Using an IP-based Layered Architecture

http://www.ist-aquila.org/

Thank you for your attention!

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