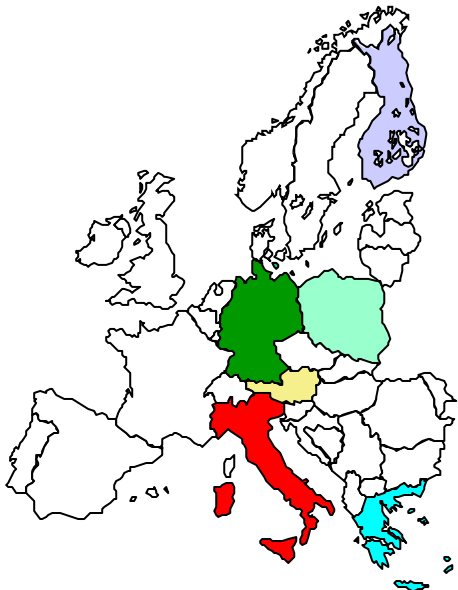


**Adaptive Resource Control for QoS  
Using an IP-based Layered Architecture**

**Project Review No. 2**

*Anacapri, Italy*

*April 3 - 4, 2001*



<http://www-st.inf.tu-dresden.de/aquila/>

## Outline

- Project Overview
  - *Bert F. Koch (Siemens)*
- Trial Scenarios and Results
  - *Wojciech Burakowski (Warsaw Univ.)*
- Complex Internet Service
  - *Andreas König (Bertelsmann)*
- Inter-Domain Architecture
  - *Martin Winter (Siemens)*

## Consortium

**SAG** Siemens (Co-ordinator), Germany

**I&C  
manufacturer**

**BAG** Bertelsmann mediaSystems, Germany

**DTA** T-Nova Deutsche Telekom, Germany

**TAA** Telekom Austria, Austria

**ELI** Elisa Communications, Finland

**TPS** Polish Telecom, Poland

**Internet Service  
Providers  
and  
Network Operators**

**NTU** National Technical University of Athens, Greece

**WUT** Warsaw University of Technology, Poland

**COR** CoRiTel, Italy

**TUD** Dresden University of Technology, Germany

**SPU** Salzburg Research, Austria

**Universities  
and  
Research  
Institutes**

**QSY** Q-Systems, Greece

**Web application  
provider**

## Project Meetings and Co-operation since last Review

### ■ Project Meetings

- Project Review, Sophia Antipolis, 10.11.2000
- Project Workshop, Dresden, 04.-06.12.2000
- Project Workshop, Warsaw, 26.-28.03.2001

### ■ Concertation Meetings

- Prague, 19.-20.02.2001
- Warsaw, 09.03.2001

### ■ Next Generation Networks (NGN) Activities

- Preparation & Start of NGN Initiative (Thematic Networks Project)
- Joint activities of CADENUS, AQUILA & TEQUILA
  - Submission of IETF drafts on **Service Level Specification (SLS)**
  - Presentation at IETF meeting in San Diego, 13.12.2000

## Major Achievements in Current Period

- **Finalization of Implementation**
- **Successful Integration**
- **Start of First Trial**
- **Preparation for Second Phase**

## Deliverables in Current Period (1)

### ■ Reporting Period: 01.09. - 28.02.2001

- PRR reports until 28.02.2001 only
- major development results accomplished since

### ■ Deliverables within Reporting Period

- D2101 Design and functional specification of the Resource Control Agent for the first trial
- D2201 Specification of End-user Application Toolkit
- D2301 Report on the development of measurement utilities for the first trial

## Deliverables in Current Period (2)

### ■ Deliverables in March 2001

- D2102 Report on implementation of the Resource Control Agent for the first trial
- D2202 Description of user applications for the first trial
- D3101 First trial integration report

### ■ All deliverables were submitted on or even before schedule

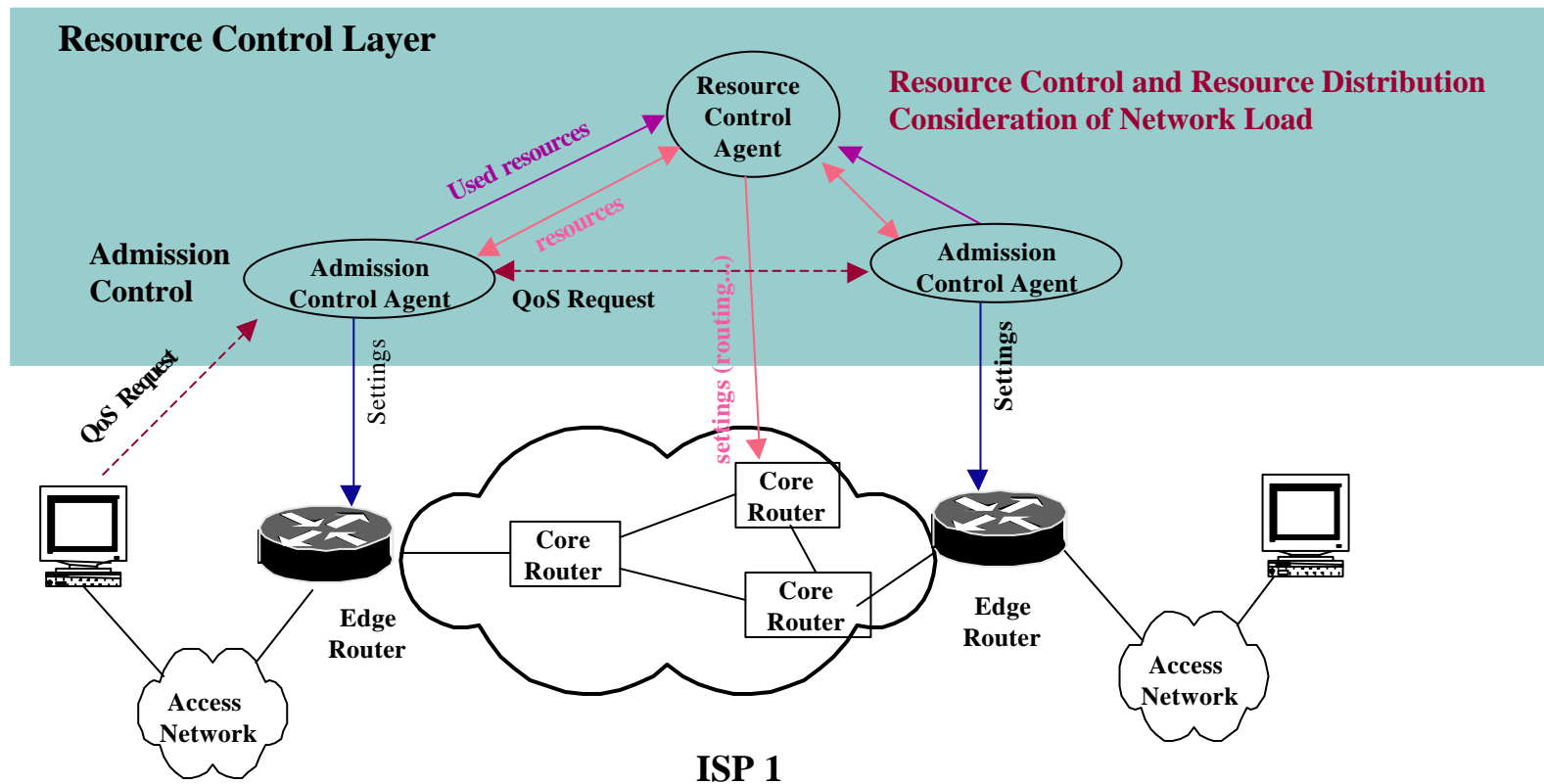
# Trial Scenarios and Results

## Outline

- Objectives
- Testbeds
- Exemplary trial results
- Demonstration
- Achievements

# Resource Control Layer

## A Two Layered Architecture



## Objectives

### ■ Experimental verification of AQUILA concepts

- Network Services and Traffic Classes
- Resource Control Layer (RCL)
- Measurement tools

## Objectives - Network Services

### ■ Differentiated QoS

- each flow served in the same TCL should experience similar QoS
- separation of TCLs
- different offered QoS for flows from different TCLs

### ■ Effectiveness of associated AC algorithms, to guarantee predefined QoS for each admitted flow

### ■ Correctness of traffic descriptor mapping from application parameters

## Network Services

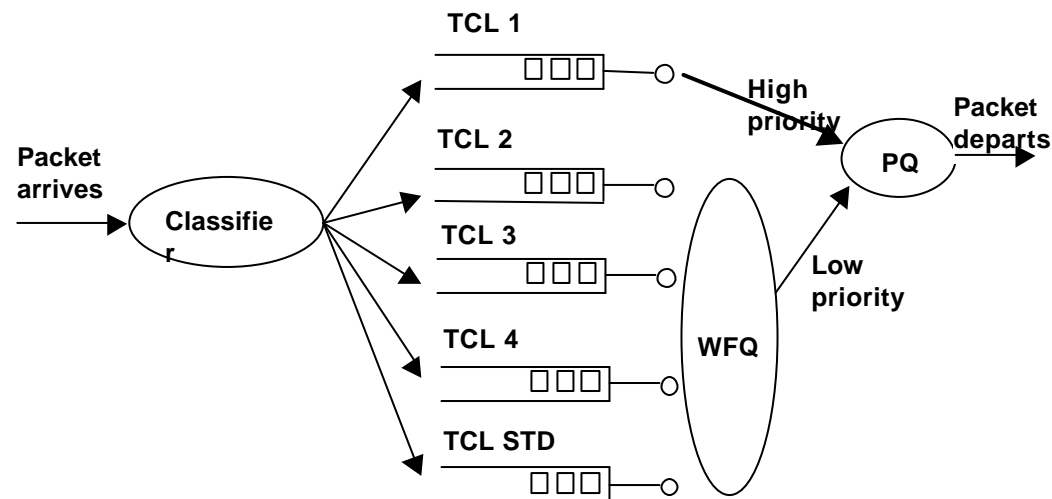
- **Premium CBR for IP Telephony and Voice Trunking**
  - very low delay and jitter, very low loss, hard bandwidth guarantee, small packets
- **Premium VBR for Video Streaming and Teleconferencing**
  - low delay and jitter, low loss, bandwidth guarantee
- **Premium Multimedia for adaptive applications (TCP), e.g. ftp**
  - bandwidth guarantee, moderate delay
- **Premium Mission Critical for interactive games, online banking**
  - very low delay and loss, non-greedy flows and rather small packets
- **Standard**
  - classical best effort traffic

# Traffic classes

- 5 Traffic Class have been specified

<b>Network service</b>	Premium CBR	Premium VBR	Premium MultiMedia	Premium Mission Critical	Standard
<b>Traffic class</b>	TCL 1	TCL 2	TCL 3	TCL 4	TCL STD

- ... as well as the related Traffic Control mechanisms in the routers



## Objectives - RCL

### ■ Resource pool mechanism

- performance of resource pool mechanism in the case of stationary and non-stationary traffic load
- one or two levels of hierarchy, two or four leaves

### ■ Correctness of Admission Control implementation

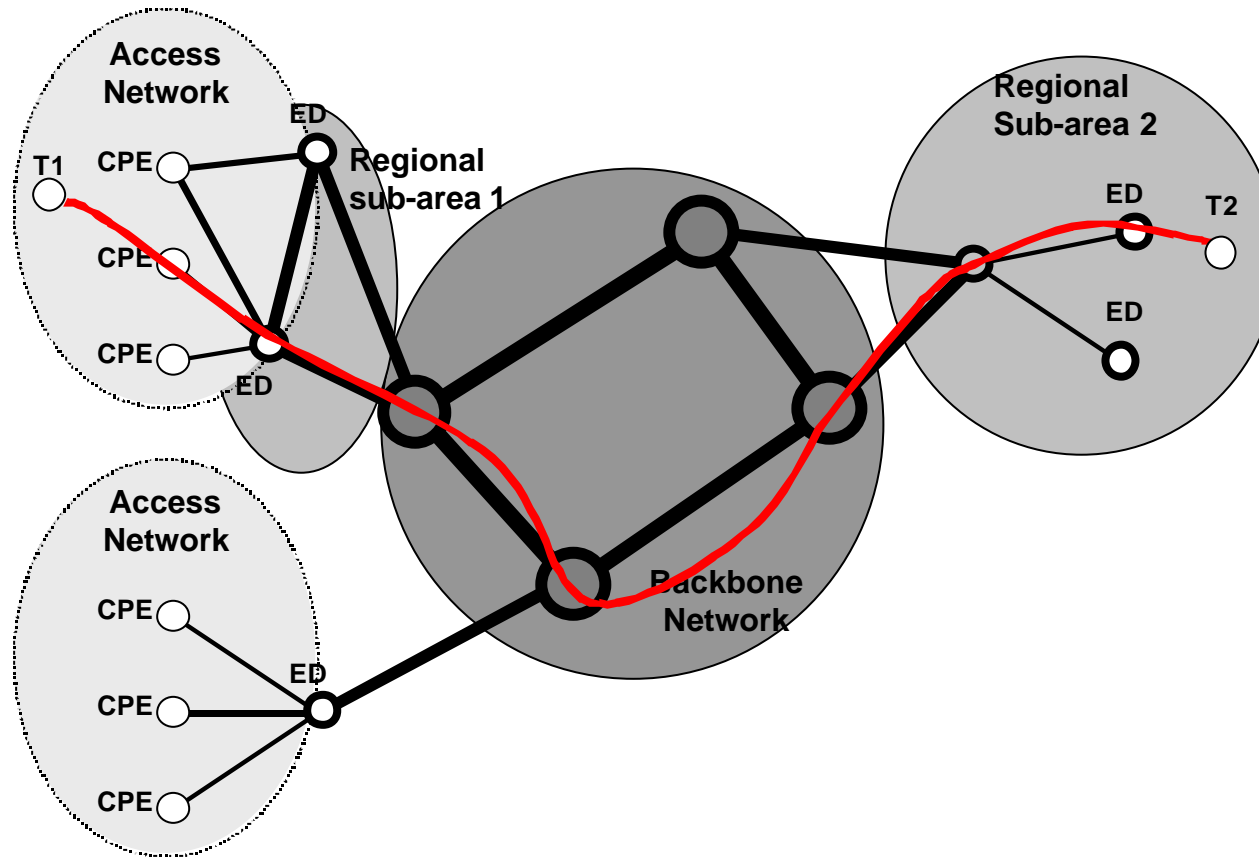
### ■ RCL performance signalling

- low speed links issues
- scalability issues
- measurement of signalling traffic load
- set of failure scenarios (releasing of reservations, measuring of timing), RCA failures, router failure

## Outline

- Objectives
- **Testbeds**
- Exemplary trial results
- Demonstration
- Achievements

# Example of AQUILA network topology



## Warsaw - main trial site (Polish Telecom)

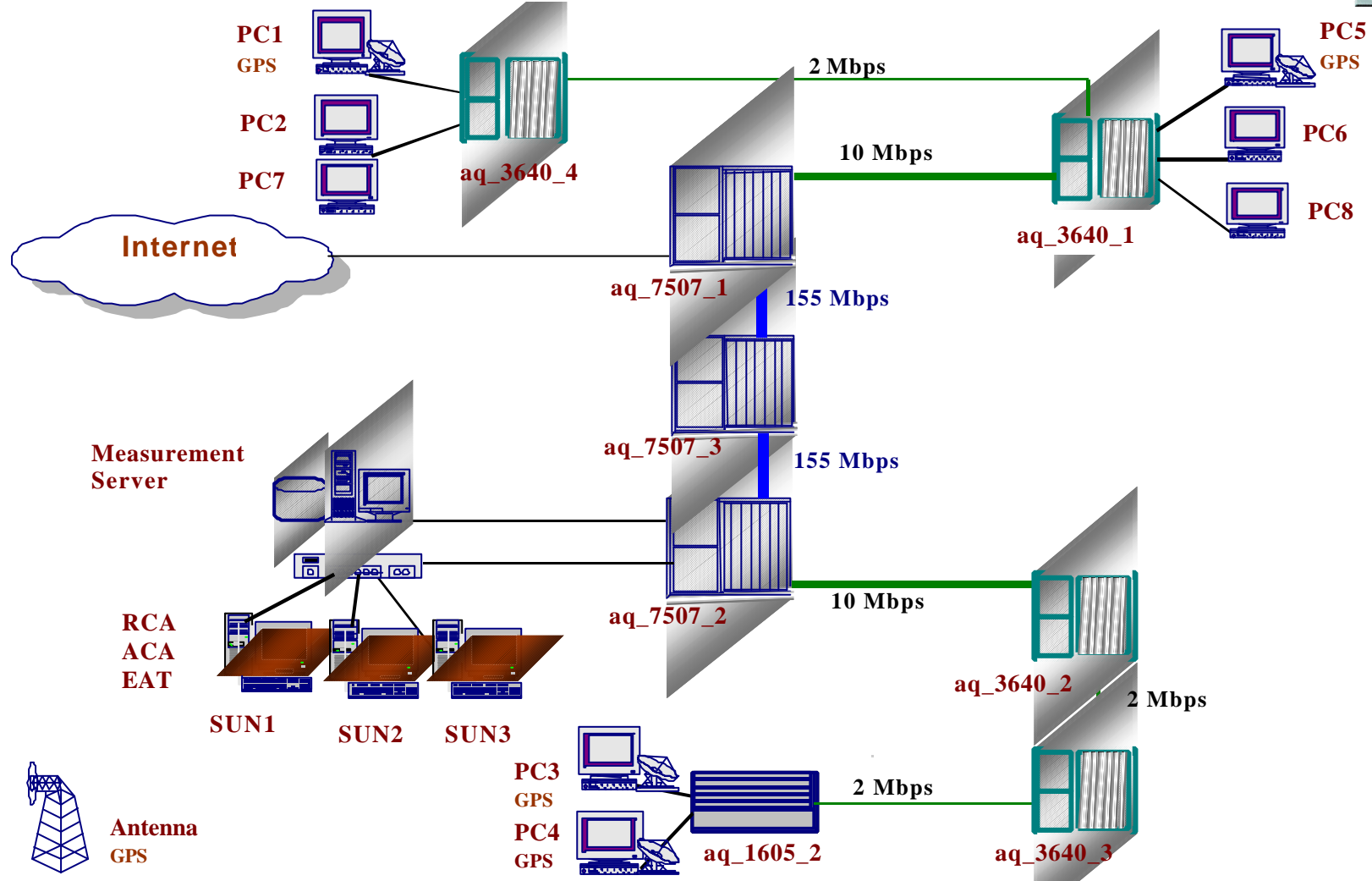
### ■ Special interest

- real-time streaming applications (IP telephony, video conference)
- non real-time streaming applications (e.g. Real System)

### ■ Trial scenarios

- Network services (PCBR, PMM)
- QoS differentiation - mixture of network services
- AC mechanisms

# Warsaw Testbed



# Warsaw Testbed



## Vienna Testbed (Telekom Austria)

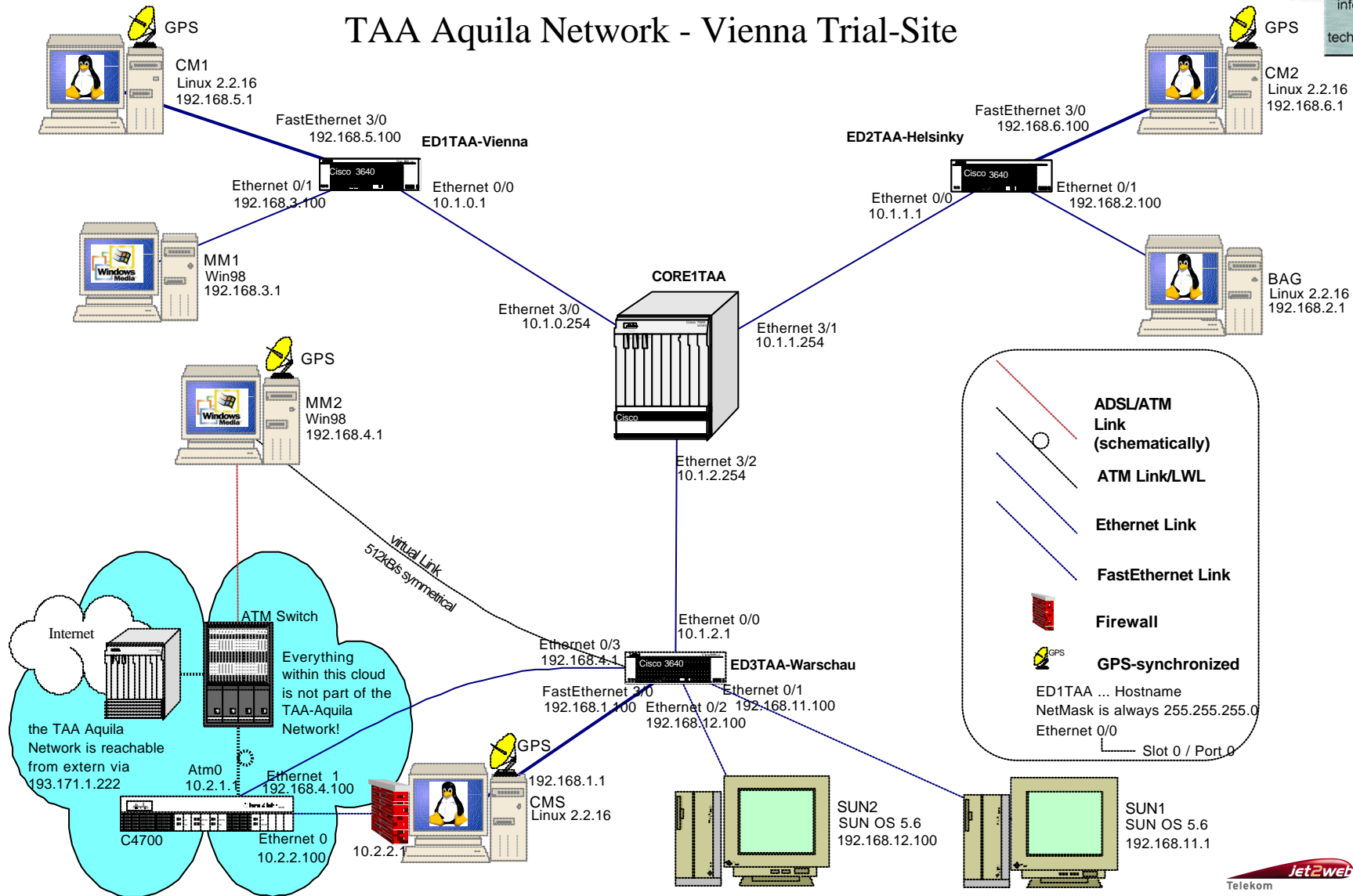
### ■ Special Focus

- Low bandwidth real-time applications
- NetMeeting, Multi-user network games, VoIP (WinSIP)
- ADSL timing behaviour with real-time applications

### ■ Trials scenarios

- network services (PVBR, PMC)
- RCL performance

# TAA Aquila Network - Vienna Trial-Site



## Helsinki Testbed (Elisa Communications)

### ■ Signalling load measurement

- purpose is to measure the amount of traffic needed to establish a single reservation

### ■ Set-up time measurement

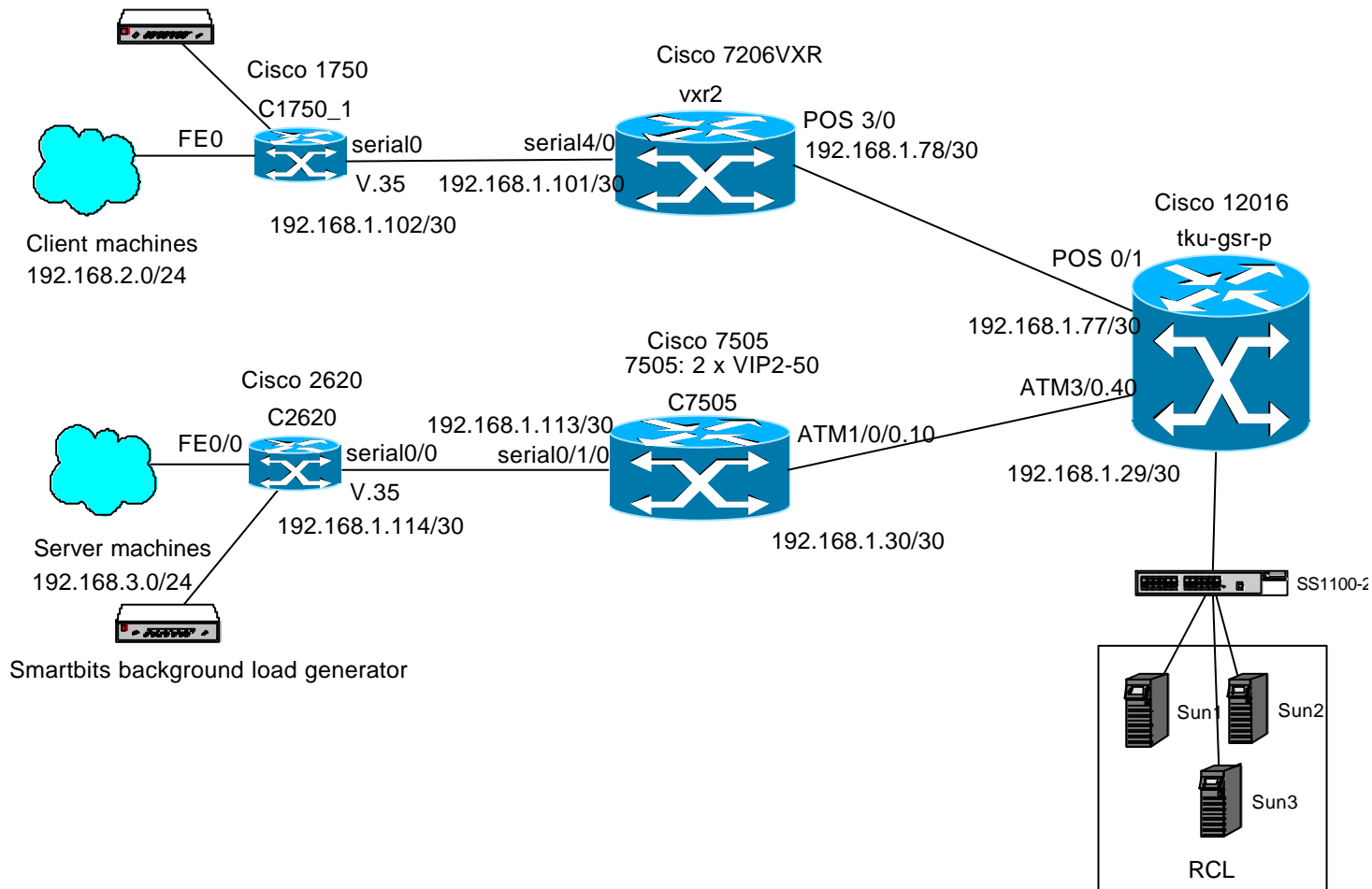
- measure overall set-up time and evaluate the effort of each component to the overall set-up time
  - single request, multiple requests

### ■ Measurements under error conditions

- purpose is to measure the amount of signaling messages in case of network element failure or recovering from the failure

# Helsinki Testbed (Elisa Communications)

Smartbits background load generator



## Outline

- Objectives
- Testbeds
- **Exemplary trial results**
- Demonstration
- Achievements

## First Trial Experiments

- **PCBR service**
- **PMM service**
- **Mixture of traffic classes**
- **Demonstration**
- **Measurement tool**

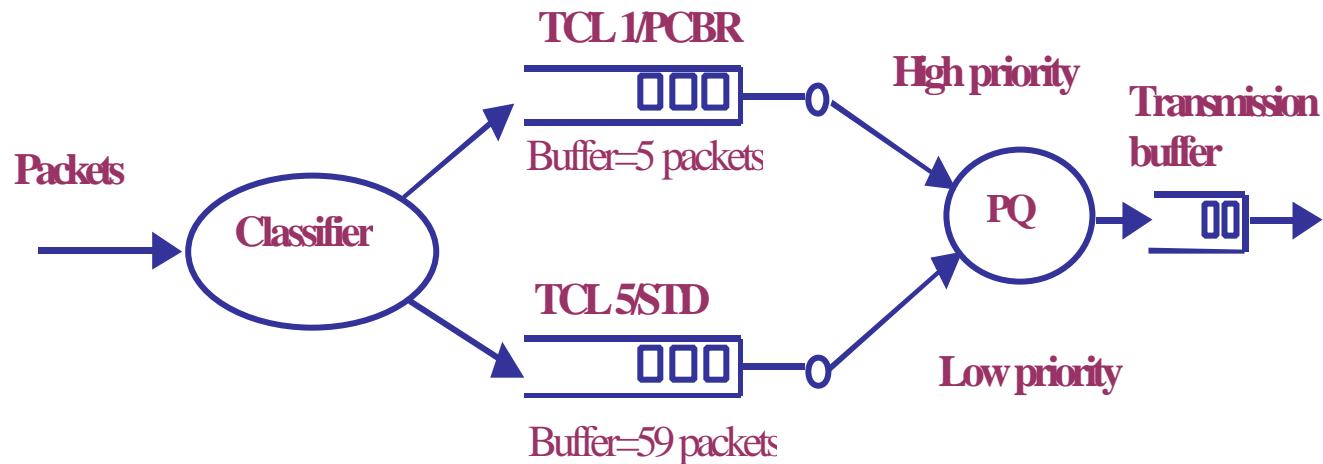
## PCBR Service

- **PCBR is mainly proposed for streaming flows (packets represent an audio or video signal)**
- **This service should constitute a base for providing VLL link**
- **PCBR uses TCL1 class: packet are carried by the network with the highest priority**
- **QoS parameters:**
  - Low end-to-end delay:  $\leq 150\text{ms}$
  - Low packet loss ratio:  $\leq 10^{-4}$

## PCBR Trial Objectives

- **Practical verification of expectations from PCBR service, defined in deliverable D1301**
- **Part A: to identify limitations of edge and core routers, having an impact on quality of PCBR service**
- **Part B and C: to verify quality of PCBR service**
  - Part B: for artificial traffic patterns
  - Part C: for WinSIP application
- **Measured parameters**
  - End-to-end delay
  - Packet loss ratio

## Router Output Port Architecture



### ■ QoS objectives of PCBR service trial

- AC limit for 2Mbps links = 200kbps
- Assumed target packet loss ratio =  $10^{-2} \Rightarrow \rho=0.685$
- $\Rightarrow$  **TCL1 target utilisation = 137 kbps**

## Worst case traffic patterns

- **Traffic pattern #1 for tested PCBR flow (Foreground Traffic- FT):**
  - CBR (Constant Bit Rate) flow
- **Traffic pattern #2 for aggregated PCBR flow (FT):**
  - Superposition of CBR flows – Poissonian stream
- **Traffic patterns for Background non-PCBR Traffic (BT):**
  - CBR flow (sufficient to load the other traffic classes/network services)
  - ON/OFF flow

## Part A: limitations of CISCO routers

- **The interface cards in the CISCO routers series 16xx, 36xx and 75xx are equipped with transmission buffers (tx ring) that store packets already scheduled for transmission to the output links**
  - Concerning the AQUILA scheduling algorithm the presence of additional buffering level, after the scheduler's queues, with FIFO discipline can degrade the QoS parameters of traffic served by PCBR.
  - If any of the lower priority queues (WFQ queues) is overloaded then the low priority packets can be placed in the tx ring (the high priority packets can see the tx ring always full).

## Part A: Cisco router 1605, interface 2Mbps

### ■ Purpose

- Verification of the impact of the transmission buffer size in the CISCO router 1605 (interface 2Mbps) on the PCBR packet delay

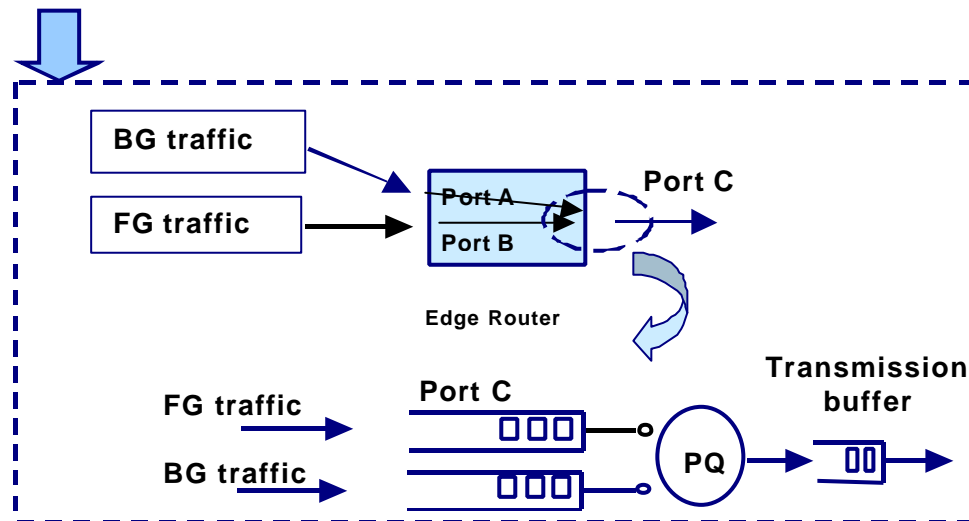
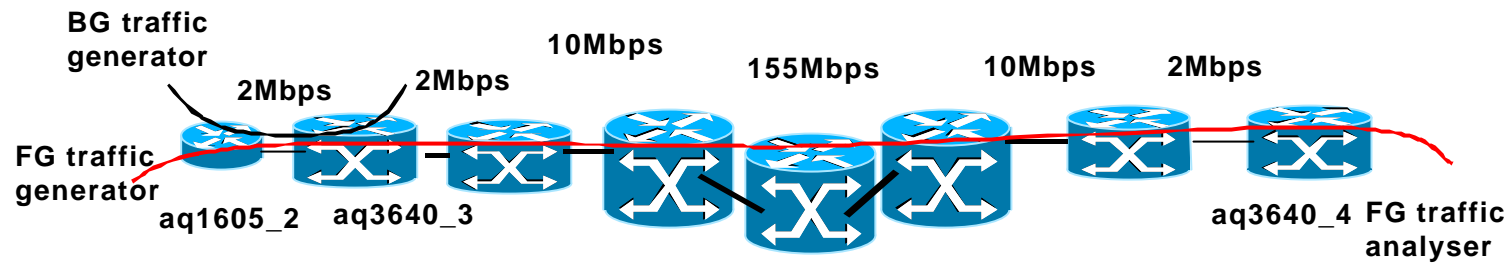
### ■ Traffic conditions

- FT: CBR flow, traffic rate=133kbps, packet size=100B, transport protocol UDP, traffic class TCL1 (DTA measurement tool)
- BT: ON/OFF flow: ON period=55ms (peak rate=10Mbps), OFF period=500ms, variable BG packet size, transport protocol UDP, traffic class TCL5 (HP BSTS measurement equipment)

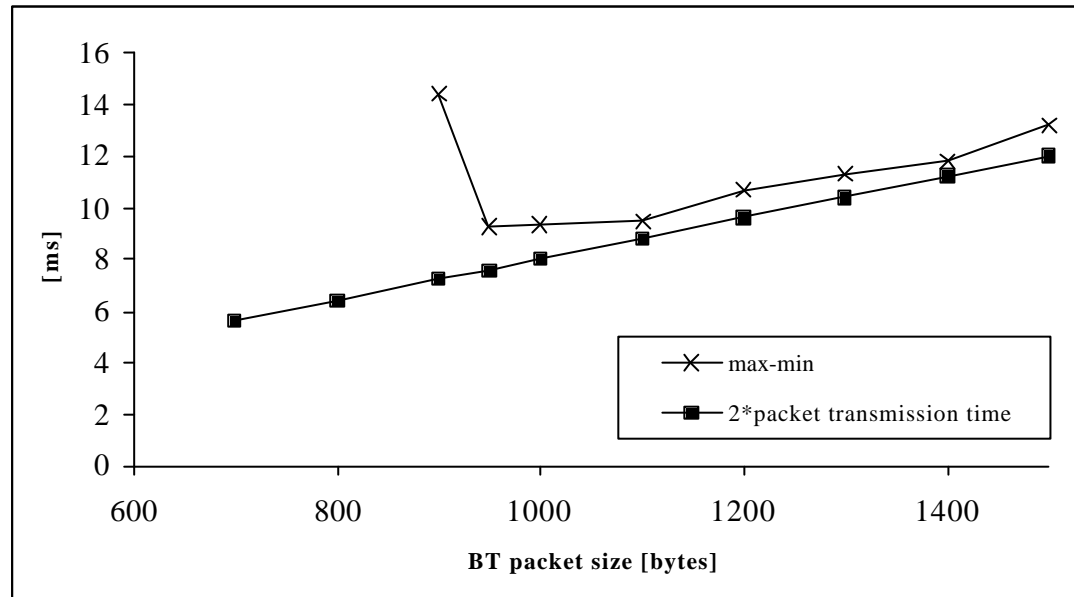
### ■ Tx ring size has default value

- there is no possibility to change that

# Part A: Scenario



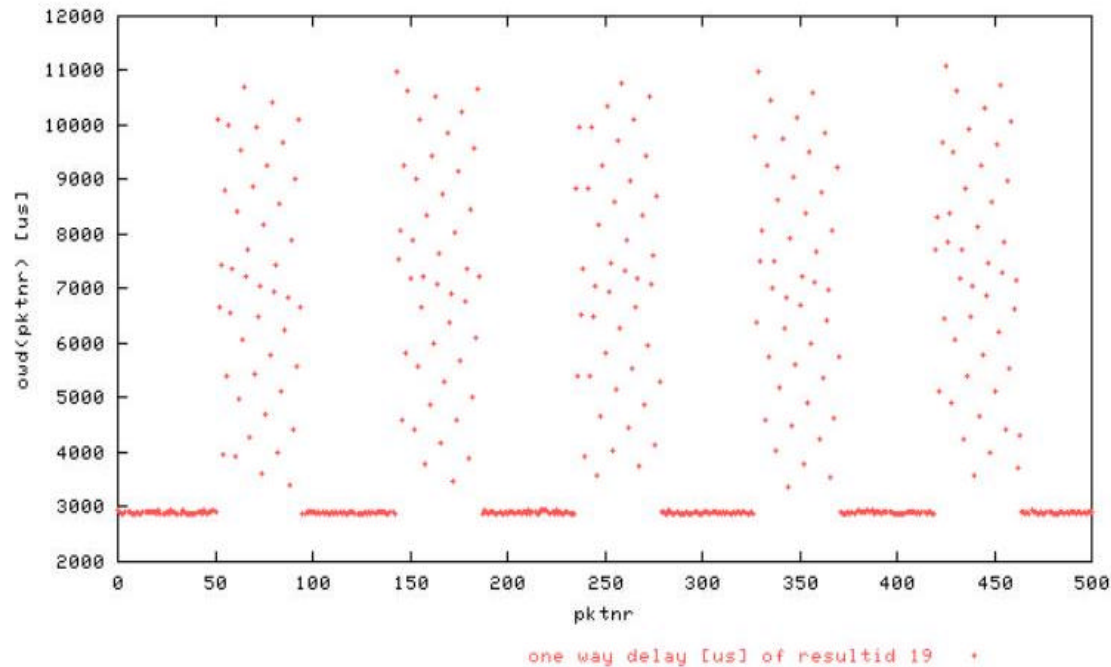
## Part A: tx ring delay



- The delay introduced by tx ring is proportional to the background packet size and is equivalent to two background packet transmission times

## Part A: One way delay

generation date: 01/03/2001 11:04 (measurement server)



*One way delay as a function of packet number (TF packet size = 100 bytes; BGT packet size = 1000 bytes).*

- **Presence of background traffic: the delay of TCL1 packets increases significantly during ON periods even though the TCL1 packets have strict priority over the STD packets**

## Summary of the additional trials of part A

- **Similar tests were made for other types of CISCO routers**
- **In all cases tx ring introduces additional delay for PCBR packets**
- **Maximum value of this additional delay is difficult to predict and depends on**
  - Router interface type
  - Packet length of background traffic
- **Maximum observed value of additional delay was 12 ms (per 7507 router - interface 155 Mbps)**

## Part B: to verify quality of PCBR service

- **Measured QoS parameters (assuming upper limits for traffic load)**
  - Packet end-to-end delay characteristics
  - Packet loss ratio
- **Artificial traffic patterns for foreground and background traffic**

## Trial B.1: End-to-end packet delay

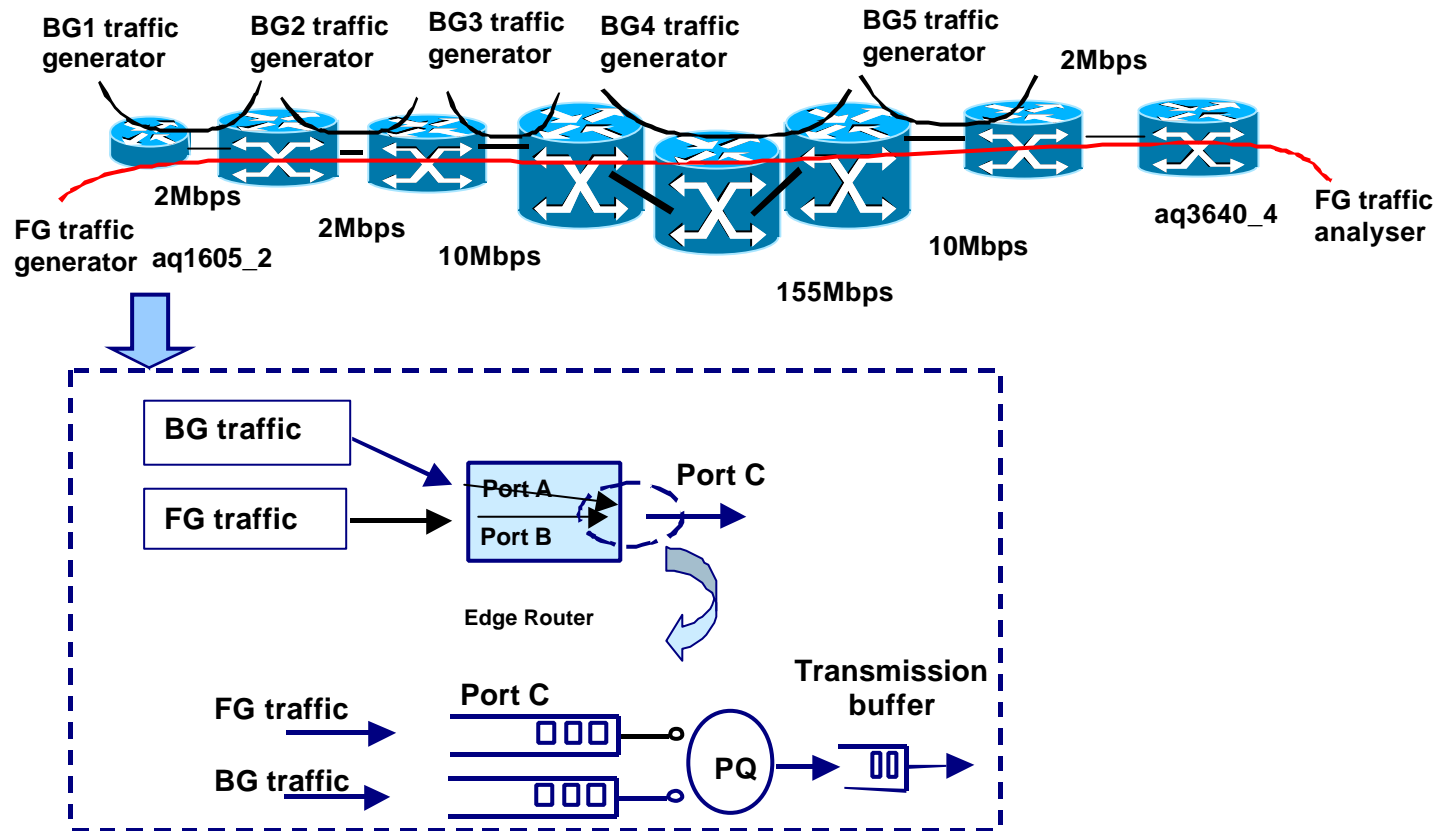
### ■ Purpose

- To verify the assumptions made for development of admission control algorithms for PCBR service .

### ■ Traffic conditions

- FT: traffic class TCL1 (network service PCBR), Poissonian flow (minimum packet inter-arrival time = 1 ms), traffic rate=133kbps, variable packet size, transport protocol UDP.
- BT: In this trial, the assumed worst-case background traffic patterns (ON/OFF) allowed to load output links of all routers through the way of foreground traffic.

# Trial B.1: Scenario



## Trial B.1: Results

Results for trial of minimum, maximum, and average end-to-end packet delay

Packet size of FG traffic [bytes]	Min. Delay [ms]	Max. Delay [ms]	Avg. Delay [ms]
64	20.1	35.2	27.5
128	20.9	36.9	28.6
256	26.2	37.6	31.7
512	29.6	41.5	35.3
1024	37.1	48.4	42.7

- The measured values of maximum delay for all types of foreground traffic packets: 64, 128, 256, 512, and 1024 bytes are less than the target value for PCBR service (<<150 ms)

## Trial B.2: Packet loss ratio – output link 2Mbps

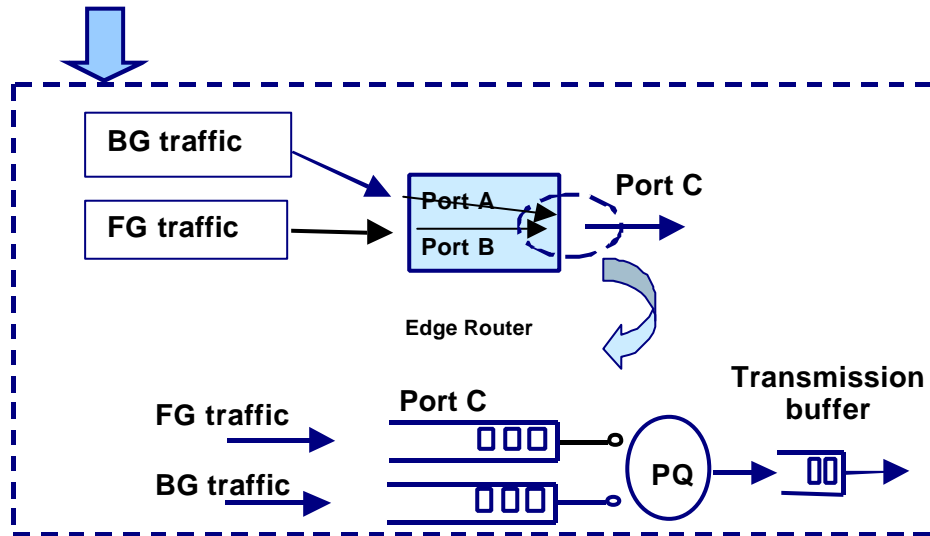
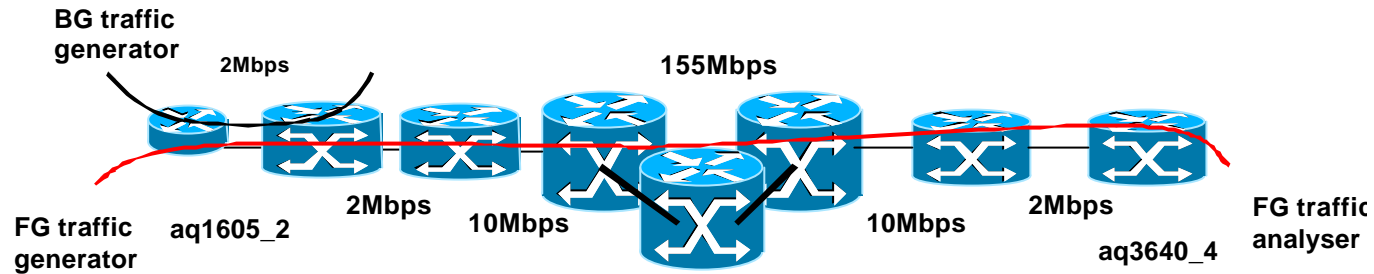
### ■ Purpose

- To verify the assumptions made for development of admission control algorithms for PCBR service.

### ■ Traffic conditions

- FT: traffic class TCL1 (network service PCBR), Poissonian flow (minimum packet inter-arrival time = 1 ms), variable traffic rate, packet size=100B or 200B, transport protocol UDP
- BT: CBR flow with traffic rate=3Mbps, packet size: 7% of volume - 44B, 21% of volume – 256B, 72% of volume – 1280B, transport protocol UDP, traffic class TCL5 (network service STD)

# Trial B.2: Scenario



## Trial B.2: Results

### Results for trial of packet loss ratio

FG traffic [kbps]	Packet size of FG traffic [bytes]	Number of transmitted packets	Number of lost packets	Packet loss ratio
100	100	415537	2	$4 \cdot 10^{-6}$
<b>133</b>	<b>100</b>	<b>543223</b>	<b>7</b>	<b><math>1 \cdot 10^{-5}</math></b>
160	100	641689	5	$7 \cdot 10^{-6}$
200	100	783082	44	$5 \cdot 10^{-5}$
400	200	783082	31	$3 \cdot 10^{-5}$

- Packet loss ratio is much smaller than target packet loss ratio =  $10^{-2}$

## Part C: to verify quality of PCBR service for real application (WinSIP)

- **Measured QoS parameters (assuming upper limits for traffic load)**
  - Rough subjective assessment of voice transfer
  - Packet end-to-end delay characteristics
- **Real WinSIP and artificial traffic patterns (model of the WinSIP) for foreground traffic**
- **Artificial traffic patterns for background traffic**

## Trial C.1: WinSIP - assessment of speech quality

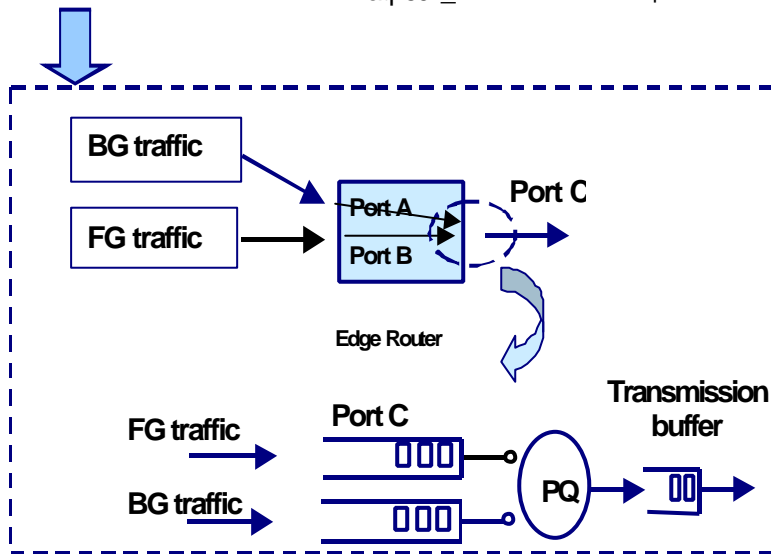
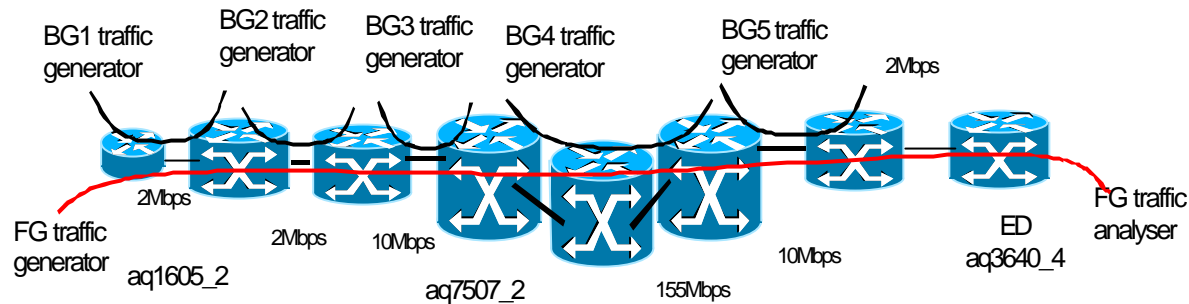
### ■ Purpose

- To assess quality of speech

### ■ Traffic conditions

- Traffic generated by WinSIP application: 16 Ethernet frames/sec (71.4 kbps). The coded voice information is conveyed with RTP/UDP/IP protocols.
- BT: In this trial, the assumed worst-case background traffic patterns (ON/OFF) allowed to load output links of all routers through the way of foreground traffic.

## Trial C.1: Scenario



- Quality of the speech was acceptable (subjective assessment).
- Persons, who assessed the quality of speech, noticed the echo effect in this trial. Such effect arises when round-trip delay is more than 50 ms (the payload size of packets generated by WinSIP application is 500 bytes, it introduces 62 ms delay using PCM).

## Trial C.2: WinSIP– end-to-end packet delay

### ■ Purpose

- To measure end-to-end packet delay

### ■ Traffic conditions

- FT: artificial traffic pattern modelling WinSIP: CBR flow, traffic rate=64kbps, packet size=512B
- BT: as in trial C.1

### ■ Trial topology as in trial C.1

## Trial C.1: Results

### ■ Results

- Minimum end-to-end delay: 23 ms
- Maximum end-to-end delay: 37 ms
- Average end-to-end delay: 32 ms

### ■ Conclusions

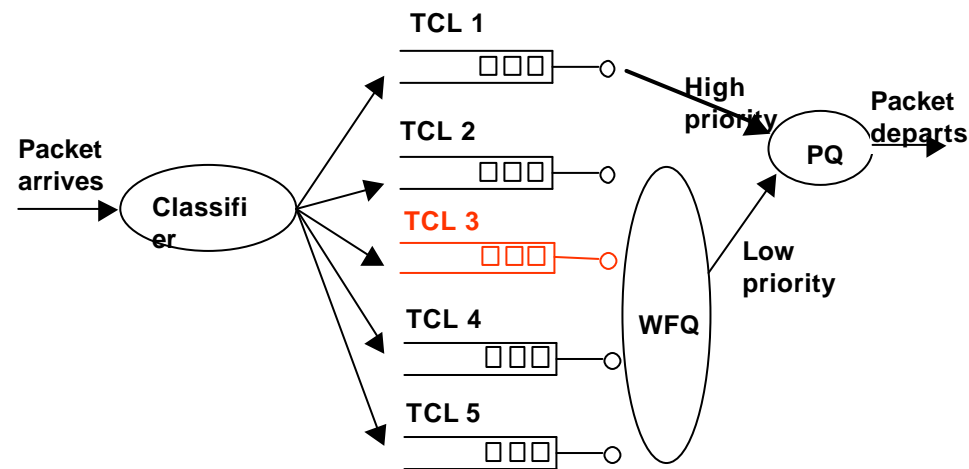
- These results correspond to the delay introduced by the network only. In the case of WinSip application we should add 62 ms (due to voice packetisation). Total end-to-end delay is about 100 ms.

## Summary

- **The presented measurement results confirm the assumptions made for PCBR service**

# PMM service

- QoS Requirements: low packet loss ( $10^{-3}$ ) for in-profile packets
- Destinated mainly for TCP controlled flows (for elastic traffic)
- Access to dedicated bandwidth by WFQ
- Single rate characterisation



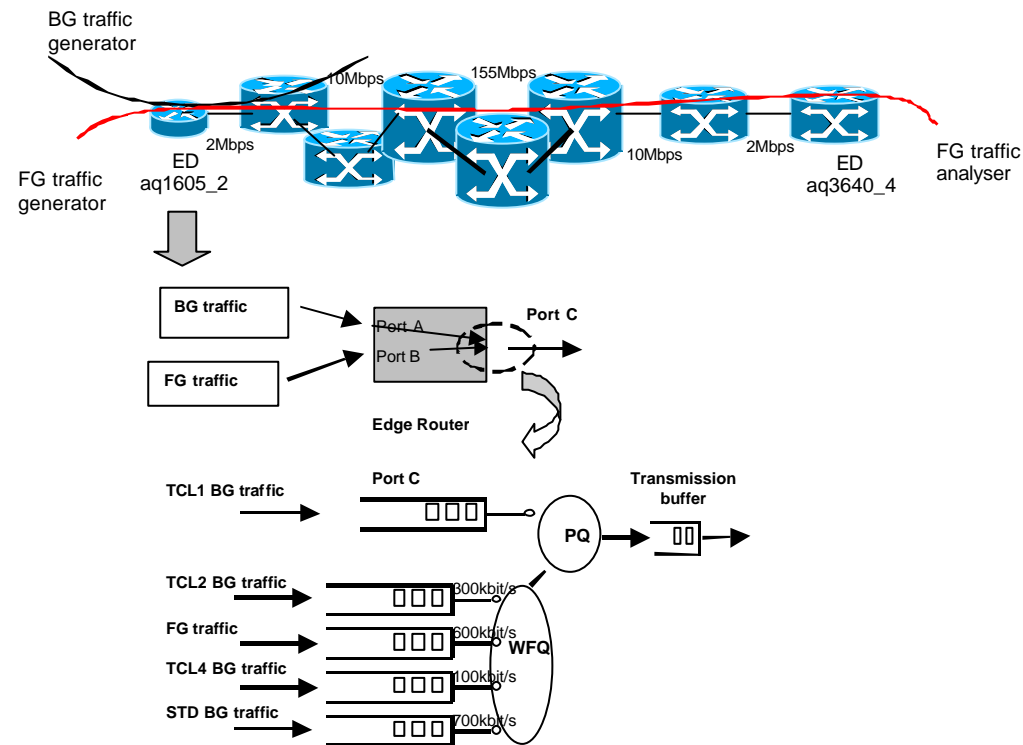
## PMM trial objectives

- **Practical verification of the assumptions made for the PMM service**
- **Testing areas**
  - Affected QoS (packet level) under different traffic conditions
  - Effectiveness of applied admission control
- **Traffic in the system**
  - Foreground PMM traffic: greedy TCP flow(s)
  - Background PMM traffic (TCP flows)
  - Background non-PMM traffic (CBR traffic submitted for other network services)
- **Measured parameters: Throughput**

# Topology for the PMM trials

## ■ Measurement equipment

- Foreground TCP flows are generated using the SPU tool
- Background flows in other network services are generated using HP BSTS



## Trial #1: Single TCP flow in PMM

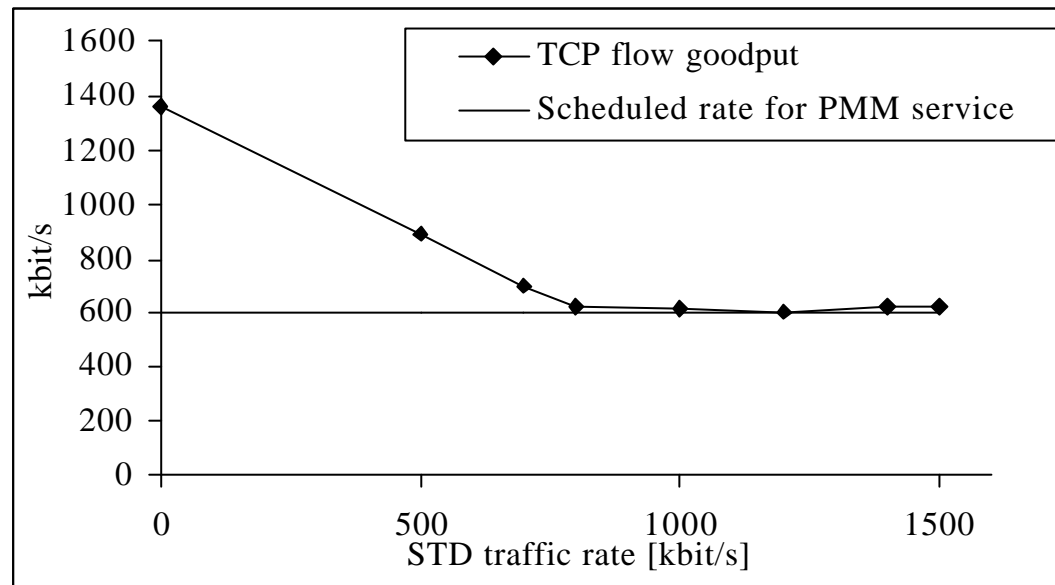
### ■ Purpose

- Verify, that single TCP flow served by the PMM can adapt to the available capacity of the link

### ■ Traffic conditions

- Total link capacity – 2000kbit/s
- Foreground traffic
  - 1 greedy TCP source, reservation set with SR=250kbit/s, BSS=15000B
- Background traffic – to fill the capacity assigned to other traffic classes
  - TCL1 – 200kbit/s
  - TCL2 – 300kbit/s
  - TCL4 – 100kbit/s
  - TCL5 – rate changing from 0 to 1500kbit/s

## Trial #1: Results



- **TCP flow overtakes the capacity unused by the STD service**
- **Minimum link capacity used by TCP flow is close to the dedicated capacity for PMM (this value does not depend on traffic conditions inside other network services).**

## Trial #2: 4 TCP flows in PMM – identical traffic declarations

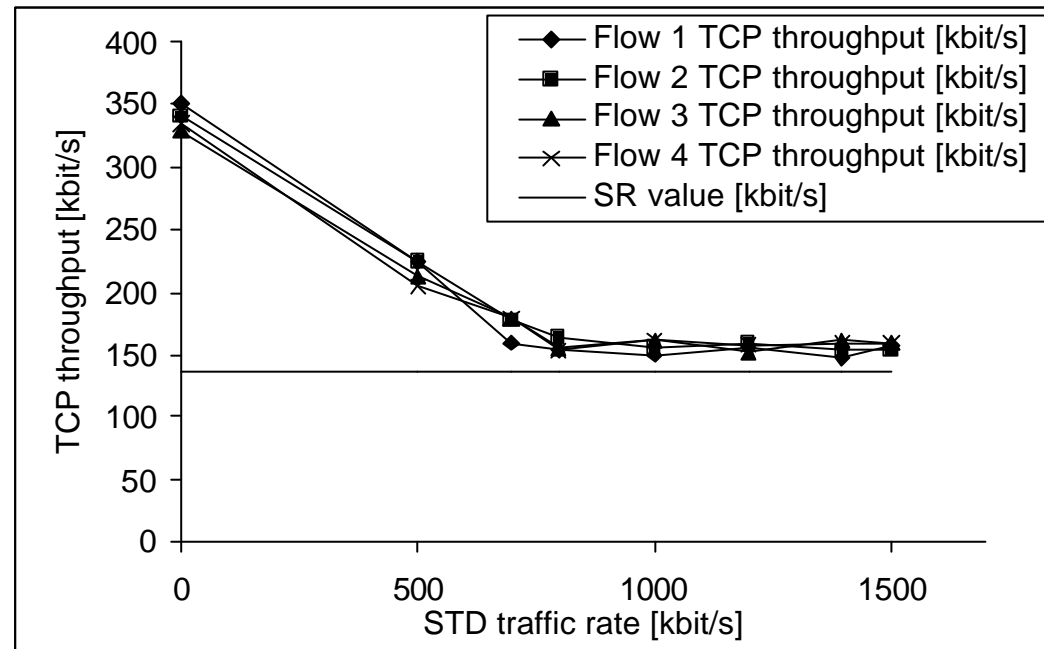
### ■ Purpose

- Verify, that multiple TCP flows served by the PMM service achieve the assumed quality of service

### ■ Traffic conditions

- Comparing to trial #1 - now we have 4 TCP flows
- The SR values are the same for each TCP flow (SR=135kbit/s)
- Admission limit is not exceeded

## Trial #2: Results



- TCP flows fairly share the available bandwidth
- Minimum capacity is close to the one dedicated to PMM
- Spare bandwidth inside PMM is also fairly shared

## Trial #3: 4 TCP flows in PMM – different traffic declarations

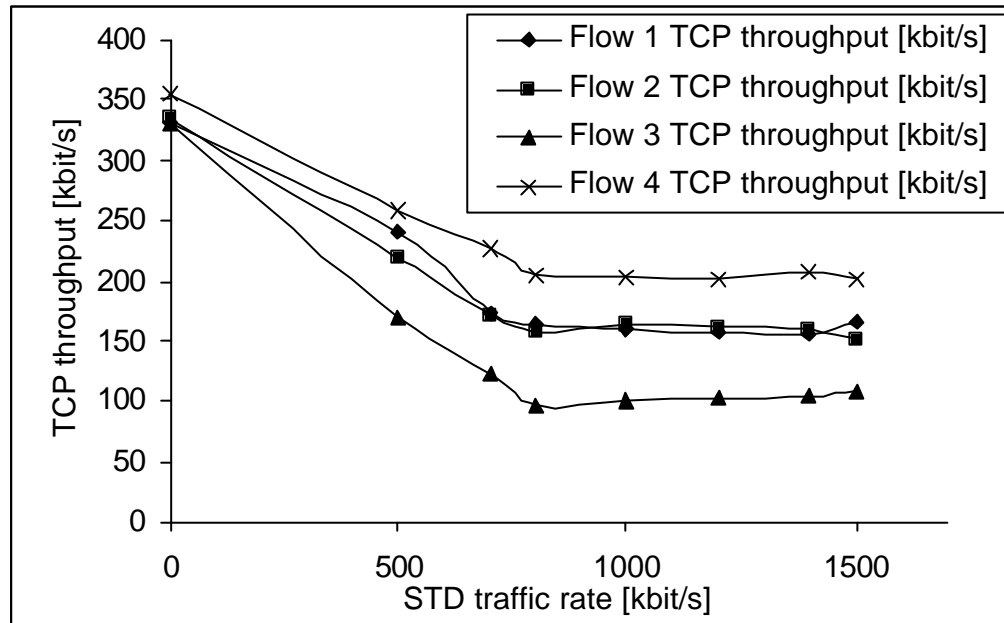
### ■ Purpose

- Verify the possibility to differentiate flows within the PMM service with respect to the value of SR parameter

### ■ Traffic conditions

- Comparing to trial #2 - the SR values are the different for each TCP flow
- Admission limit is not exceeded

## Trial #3: Results



### 4 flows in PMM service

- SR=135 kbps
- SR=135
- SR=70
- SR=200

- TCP flows fairly share the available bandwidth according to the SR values
- Spare bandwidth inside PMM is almost fairly shared according to the SR values
- Minimum capacity is close to the one dedicated to PMM

## Trial #4: N TCP flows in PMM – identical traffic declarations

### ■ Purpose

- Verify that target QoS guarantees are met when the number of TCP flows is defined by the admission control function

### ■ Traffic conditions

- Comparing to trial #1 - now we have N TCP flows
- The SR values are the same for each TCP flow (SR=50kbit/s)

## Trial #4: Results

N (number of TCP flows)	Throughput of N TCP flows [kbit/s].
1	622,1
2	322,2 / 305,4
5	120,2 / 136,4 / 133,4 / 125 / 130,4
7	94 / 84,6 / 82,9 / 95,7 / 79,8 / 96,9 / 91,1
10 (AC limit, delta=0.9)	64,7 / 61 / 60,6 / 57,9 / 63,9 / 60,9 / 67,4 / 64,4 / 66,6 / 58,7
11	61 / 59,6 / 58 / 57,4 / 57,1 / 51,2 / 56,9 / 57,4 / 57,8 / 53,9 / 59,2
12 (AC limit, delta=1)	53,5 / 52,2 / 51,8 / 50,6 / 51,5 / 49,6 / 62,0 / 52,7 / 48,9 / 52,1 / 52,4 / 54,4
13	43,7 / 46,5 / 48,3 / 52,2 / 50,1 / 46,4 / 49,8 / 51,3 / 48,7 / 49,4 / 46,1 / 52,9

- **Flows submitted into the PMM service achieve the target level of QoS, if limit of AC is not exceeded**
- **Admitting more flows than AC allows causes that received TCP throughput is lower than SR**

## Summary

### ■ PMM service works according to the expectations

- Minimum received link capacity for the traffic carried inside PMM service is very close to the dedicated capacity
- By applying AC we guarantee minimum capacity per flow, not lower than the declared SR value

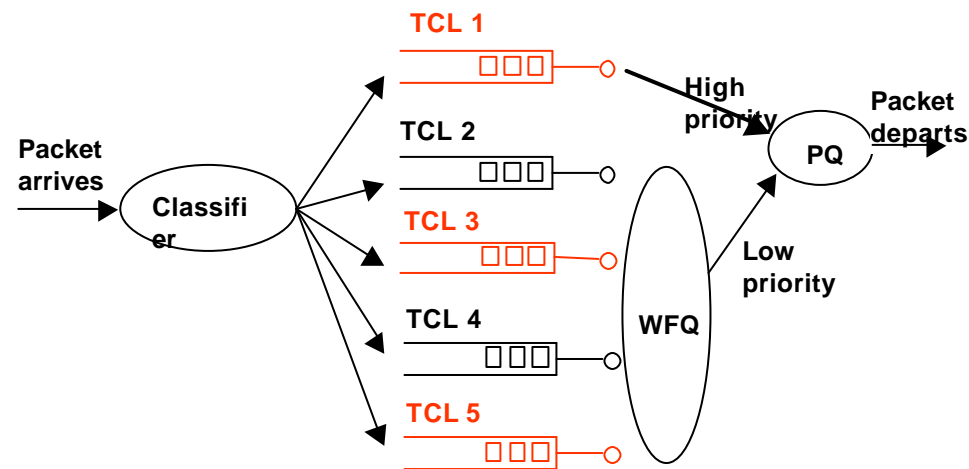
### ■ Plans

- Measure packet loss rate and in-profile and out-of-profile traffic
- Impact of the RED/WRED algorithm parameters on PMM performance

## Mix of network services

### ■ Mix of typical expected network services

- TCL1 for streaming applications (the higher priority)
- TCL3 for elastic applications (medium priority)
- TCL5 for best effort traffic (the lowest priority), for traffic exceeding allocated capacity



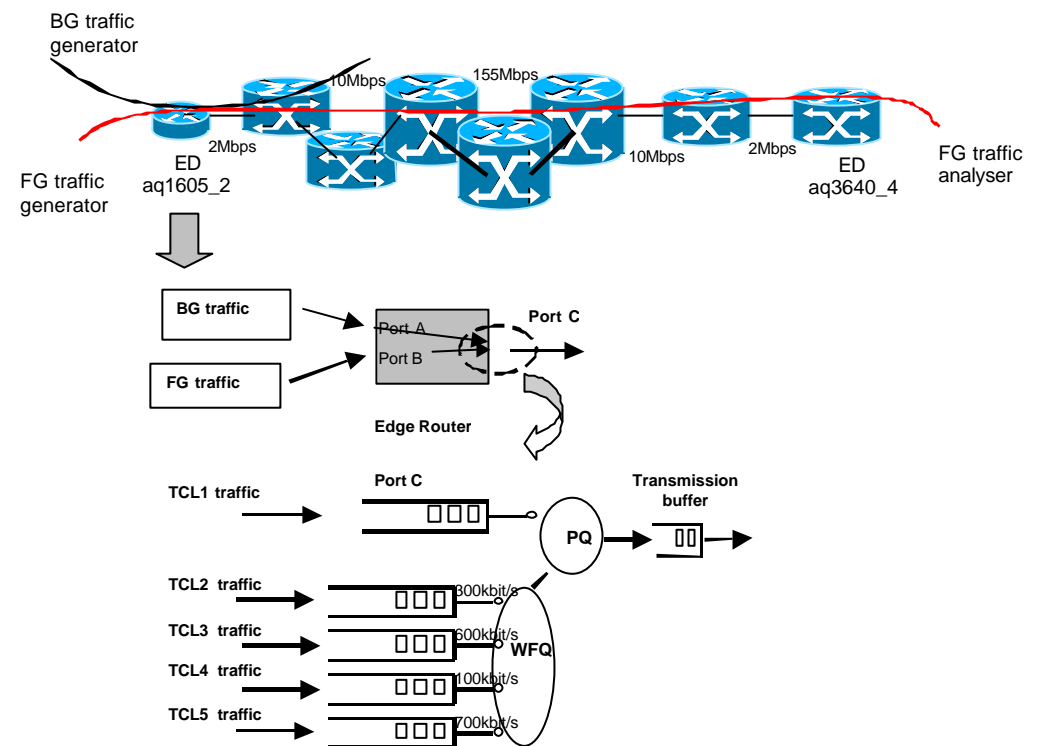
## Mixed services trial objectives

- **Practical verification of the assumptions made for the coexistence of network services with different QoS objectives**
- **Testing areas**
  - Isolation of network services
  - Level of QoS differentiation
- **Traffic in the system**
  - CBR and Poissonian flows in PCBR
  - Greedy TCP flows in PMM
  - Greedy TCP flows in STD
  - Background traffic (CBR traffic submitted for other network services)
- **Measured parameters: throughput, packet loss ratio, delay**

## Scenario

### ■ Measurement equipment

- Foreground TCP flows are generated using the SPU tool
- Foreground CBR flows are generated using HP BSTS
- Background Poissonian flows are generated using the SPU tool
- Background flows in other network services are generated



## Trial #1: Impact of PCBR on PMM

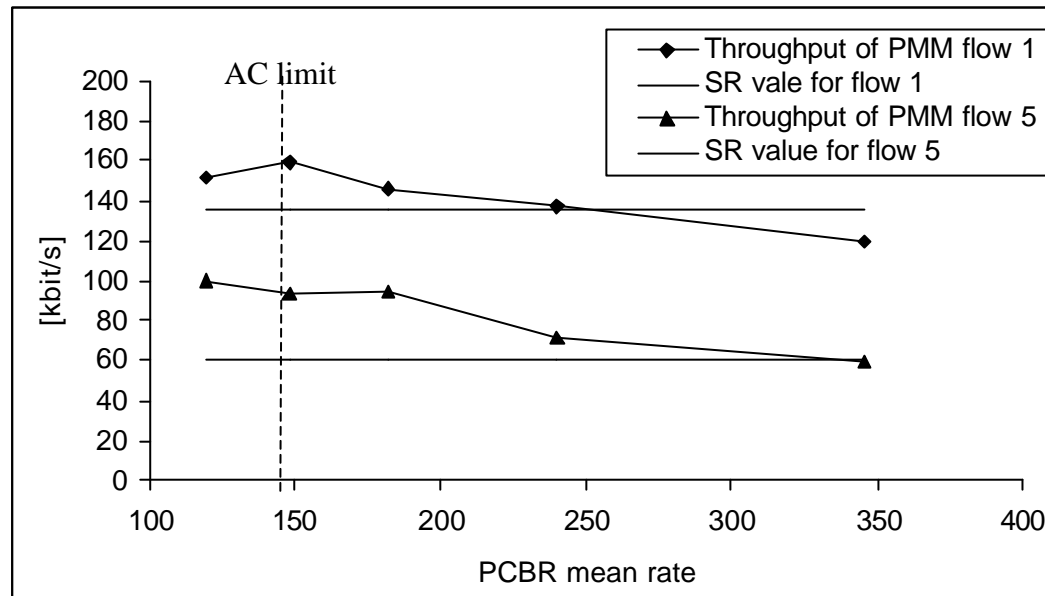
### ■ Purpose

- Observe how the high priority traffic (PCBR) can degrade the traffic inside the PMM network service

### ■ Traffic conditions

- Total link capacity – 2000kbit/s
- Foreground traffic
  - Poissonian stream in TCL1 with mean rate changing from 100 to 350kbit/s (admissible rate=138kbit/s)
  - 5 greedy TCP sources in PMM, reservations set for 4 flows with SR=135kbit/s and for 1 flow with 60kbit/s (Admission limit is not exceeded)
- Background traffic
  - TCL1 – 200kbit/s - TCL2 – 300kbit/s
  - TCL4 – 100kbit/s - TCL5 – 700kbit/s

## Trial #1: Results



- Increased load in PCBR service above AC limit degrades flows submitted in PMM service (as it was expected)
- When load in PCBR is limited by the AC (138kbit/s), QoS of PMM flows is satisfied

## Trial #2: QoS differentiation between TCP flows in PMM and STD

### ■ Purpose

- Assess the possible level of QoS differentiation between the Premium Multimedia and Standard network services

### ■ Traffic conditions

- Total link capacity – 2000kbit/s
- Foreground traffic
  - 4 greedy TCP sources in PMM, reservation set with SR=135kbit/s, BSS=15000B, Admission limit is not exceeded
  - 10 greedy TCP sources in STD
- Background traffic
  - TCL1 – 200kbit/s
  - TCL2 – 300kbit/s
  - TCL4 – 100kbit/s

## Trial #2: Results

Flows served by the PMM network service (4 flows with SR = 135kbit/s)										
PCBR rate = 200kbit/s	158,5	155,6	162,7	153,8						
Flows served by the STD network service (10 flows without QoS guarantees)										
PCBR rate = 200kbit/s	79,6	68,0	74,2	75,8	70,4	81,4	71,5	87,9	70,2	73,4

- In the PMM service AC limits the number of flows and minimum throughput can be guaranteed
- In the STD service there is no limit on the number of flows and minimum throughput cannot be guaranteed

## Trial #3: QoS differentiation between UDP flows in PCBR and PMM

### ■ Purpose

- Assess the possible level of QoS differentiation between the PCBR and PMM network services

### ■ Traffic conditions

- Total link capacity – 2000kbit/s
- Foreground traffic
  - CBR stream in PCBR with rate 64kbit/s
  - CBR stream in PMM with rate 64kbit/s
- Background traffic
  - TCL1 - Poissonian stream with mean rate 100kbit/s
  - TCL2 - 300kbit/s
  - TCL3 - 4 greedy TCP sources
  - TCL4 - 100kbit/s
  - TCL5 - 700kbit/s

## Trial #3: Results

	Throughput [kbit/s]	Loss ratio	Min latency [ms]	Max latency [ms]	Avg latency [ms]
Flow submitted into the PCBR service	64	0	6,7	27,8	20,1
Flow submitted into the PMM service	63,2	$1,04 \cdot 10^{-2}$	6,4	265,1	108,6

- **Streaming traffic should not be mixed with elastic traffic (QoS for streaming traffic is hard to be satisfied)**
- **At least two QoS network services should be defined: one for streaming traffic and one for elastic traffic**

## Trial #4: QoS differentiation between UDP flows in PCBR and STD

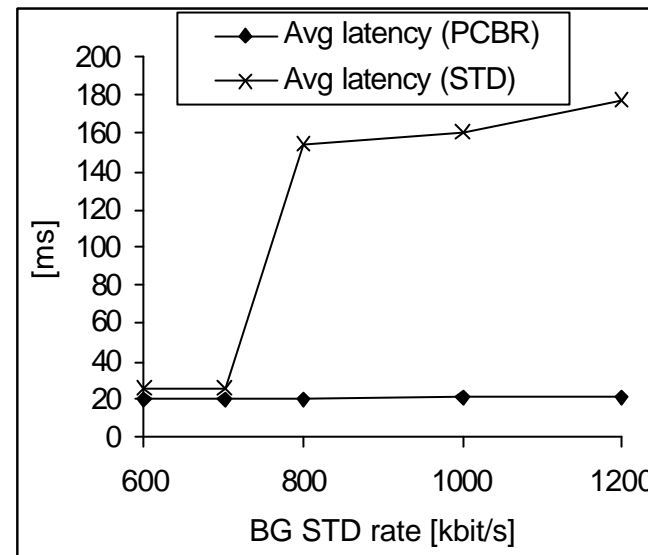
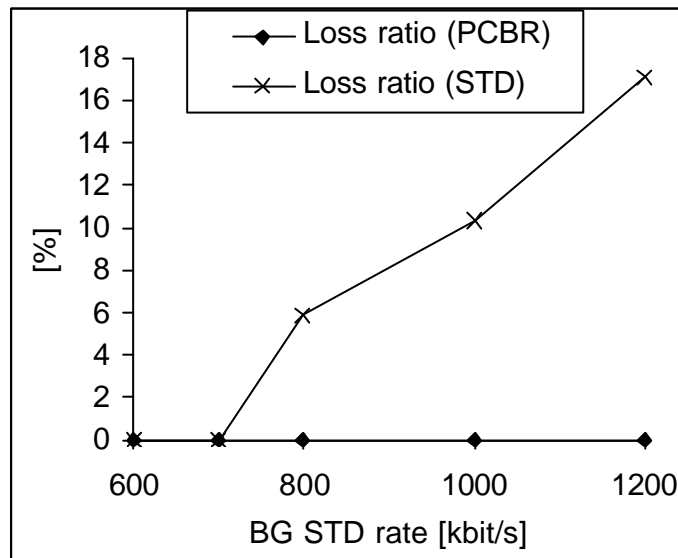
### ■ Purpose

- Assess the level of QoS differentiation between the PCBR and STD

### ■ Traffic conditions

- Total link capacity – 2000kbit/s
- Foreground traffic
  - CBR stream in PCBR with rate 64kbit/s
  - CBR stream in STD with rate 64kbit/s
- Background traffic
  - TCL1 - Poissonian stream with mean rate 100kbit/s
  - TCL2 – 300kbit/s
  - TCL3 - 4 greedy TCP sources
  - TCL4 – 100kbit/s
  - TCL5 – rate changing from 700 to 1200bit/s

## Trial #4: Results



- When the load in the STD network service is low, the performances of both services are similar (underload traffic conditions)
- In the high load conditions the PCBR service can guarantee QoS, while the performance of flows submitted in the STD service is degraded (as expected)

## Summary

- **Between PMM and PCBR services are clearly visible differences**
- **These services co-exist successfully**

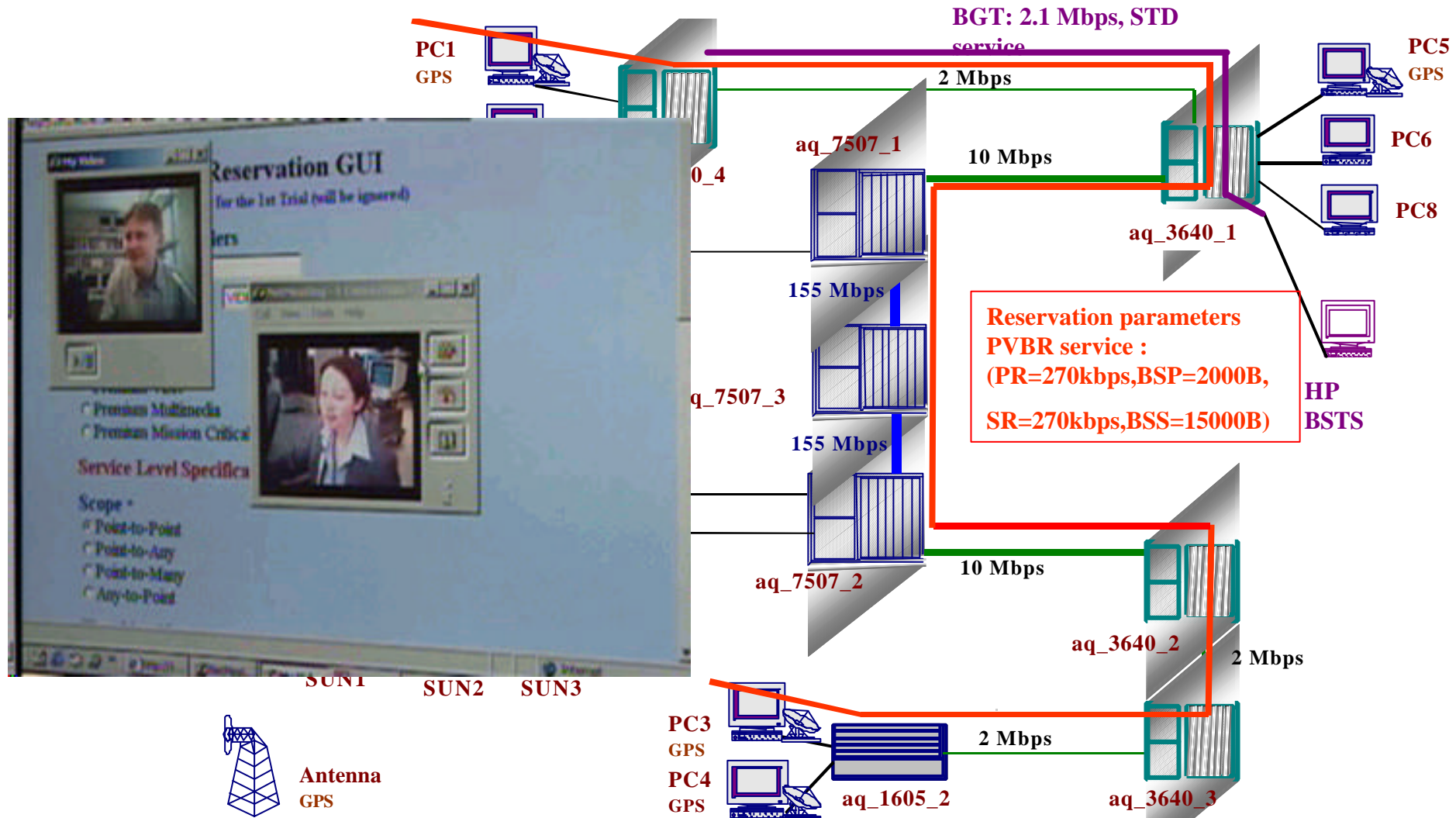
## Outline

- Objectives
- Testbeds
- Exemplary trial results
- **Demonstration**
- Achievements

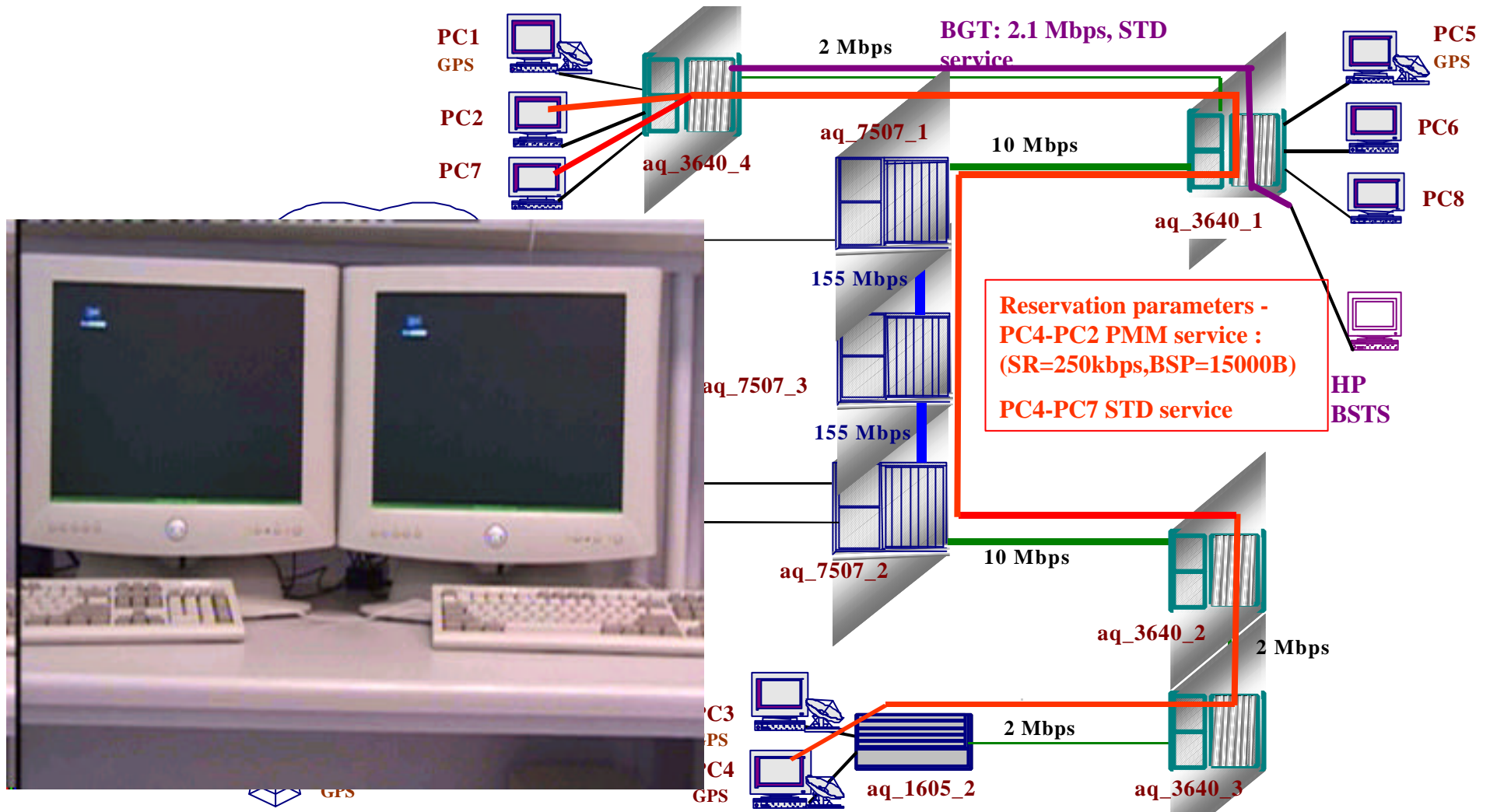
## Demonstration

- **Demonstration of applications and Aquila network services**
  - NetMeeting application (PVBR service)
  - Real Player application (PMM service)

# NetMeeting - PVBR service



# Real Player - PMM service



## Measurement tools - components

### ■ AQUILA tools

- GUI for editing test scenarios and presenting results
- GPS-synchronised clocks
- Load generators
- Database

### ■ Commercial tools

- traffic generator / analyser

## Measurement tools - features

### ■ Generation of different traffic load profiles

- Source types (poissonian, deterministic)
- Number of flows
- Packet length

### ■ User friendly web interface for editing the tests

- remote experiments and administration

### ■ One-way delay measurement

- Accuracy: 30  $\mu$ s ... 100  $\mu$ s

### ■ Test scenarios and results in a common database

## Experiences and Future Plans

- **Well suited measurement tool to prove the AQUILA concept**
- **Further enhancements to measurement tools**
  - More general traffic patterns
  - Editing sequences of flows for a resource pool scenario
  - Discrimination between received QoS for in-profile and out-of-profile packets
  - Support for reading router statistics

## Outline

- Objectives
- Testbeds
- Exemplary trial results
- Demonstration
- **Achievements**

## Achievements of the first trial

- **AQUILA architecture concept is verified**
- **Introduction of different network services for serving streaming and elastic traffic is justified**
- **Correctness of PCBR (for streaming traffic) and PMM (for elastic traffic) network service definition is verified**
- **Need of AC mechanism for providing QoS is justified**
- **Effectiveness of implemented AC mechanism is proven**

# Mediazine

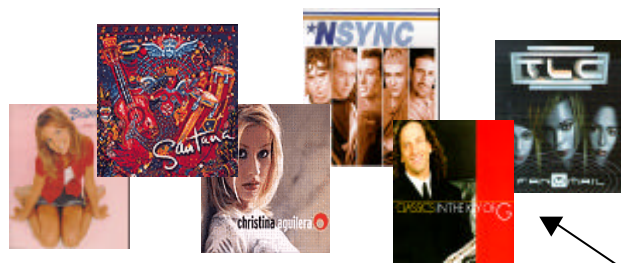
## Complex Internet Service

## Outline

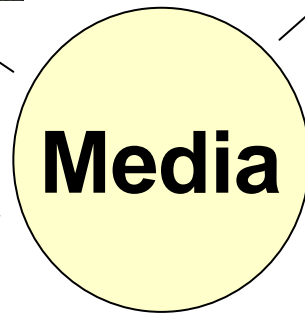
- Bertelsmann's Business / Objectives
- Requirements for Online Services
- Market potential for broadband services
- Complex Internet Service
- AQUILA Mediazine
- Second trial
- Summary

# Bertelsmann's Business

## Music



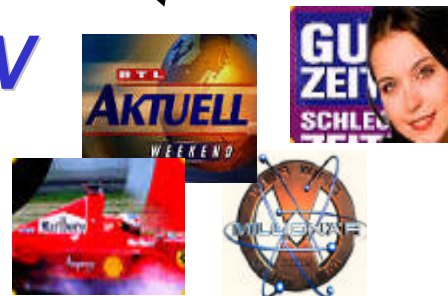
## Magazines



## Books



## TV



## Online World



## Business Objectives

### ■ New distribution channels

- TV over the Internet
- Broadband services over WebPads
- Internet over paddles

### ■ Long term customer loyalty

- Service friendly
- Customer oriented
- Positive shopping and entertainment experiences

## Requirements for Online Services

### ■ Different kind of media types in combination

- Text
- Sound
- Pictures
- Movies

### ■ Streaming tools

- Audio
- Video

### ■ High quality content

## QoS Requirements

### ■ High throughput

- Audio: 64 - 256 kbit/s
- Video: 256 - 1024 kbit/s

### ■ No or low delay

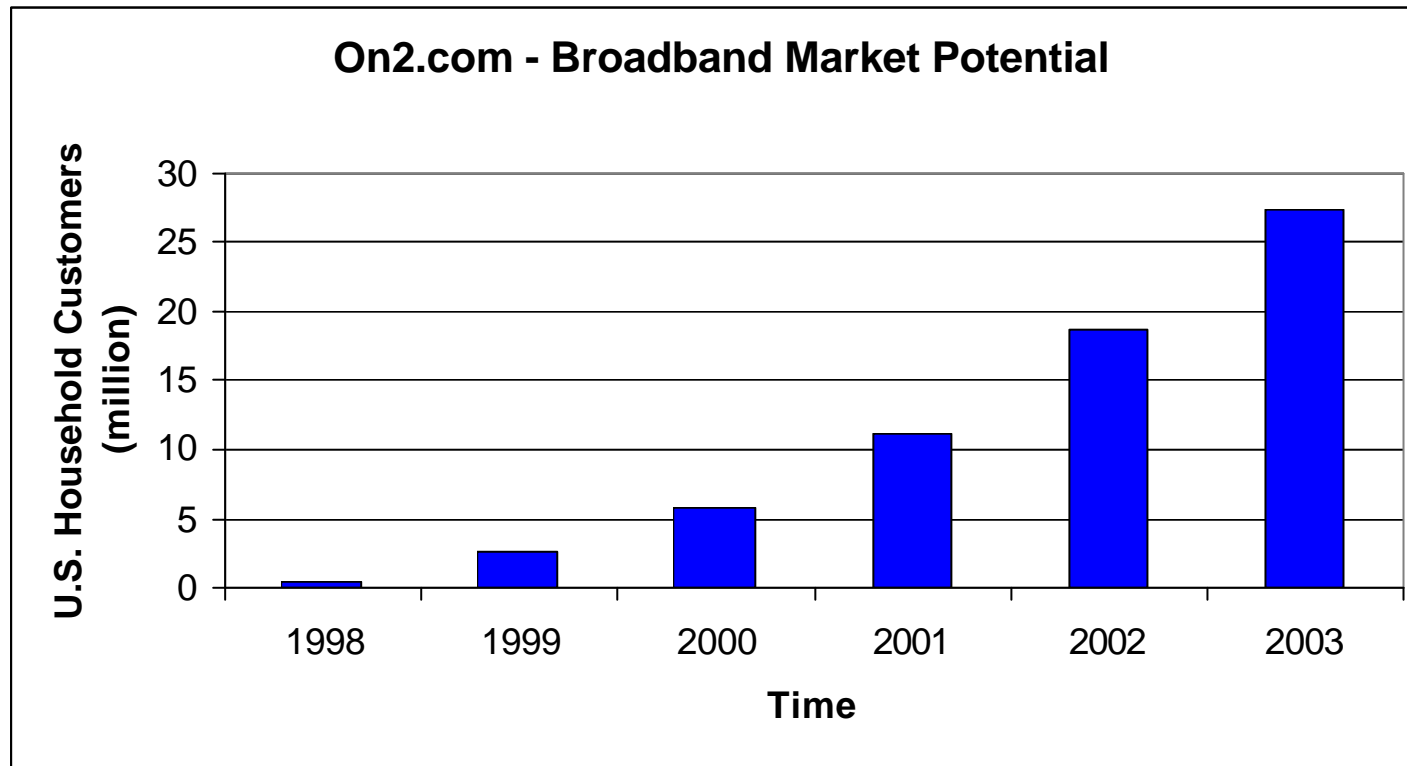
- Audio / Video chat

### ■ No or low jitter

- Audio chat

### ■ Service availability

## Market potential for broadband services



[According to BmS investigations]

Big Brother  streaming powered by 

62. Tag. Noch 43 Tage und 6 Stunden im Haus

- produced by AME
- HOME
- LIVE
- NEWS
- VOTING
- CHAT & FOREN
- AUFGABEN
- GAMES
- AUKTIONEN
- CHRONIK
- GOODIES**
- FACTS
- LINKS
- SHOP
- NEWSLETTER
- SUCHE
- FAQ & HILFE
- ABOUT US

**GOODIES**



**Big Brother Free-SMS**

Hier könnt ihr kostenlos SMS-Nachrichten versenden. Mit wenigen Klicks, kinderleicht und in alle Handy-Netze! Mit Big Brother ist auch dein Handy nicht allein.

[...zu FreeSMS](#)



**Downloads!**

Kein PC bleibt allein! Maus-Cursor und Bildschirm-Hintergründe für deinen Computer.

[...zu den Downloads](#)



**Big Brother-Funcards**

Verschickt echte Postkarten mit euren Lieblingsstars.

[...zu den Funcards](#)



**SMS News**

Coming soon!



**Das persönliche Autogramm**



**Das Big Brother-Logo auf deinem Handy-Display.**

BB von A bis Z



ANZEIGE  **Die Reality-Talk-Soap!** 



## Complex Internet Service

### ■ Uses Basic Internet Services in the form of

- Applications
- Tools
- PlugIns

### ■ Combines them to a value added service

- “Higher” quality of service
- “Higher” quality of information

### ■ Developed via Web technologies

- Web programming languages: HTML, PHP4, Java ...
- Internet protocols: TCP, UDP, HTTP, ...

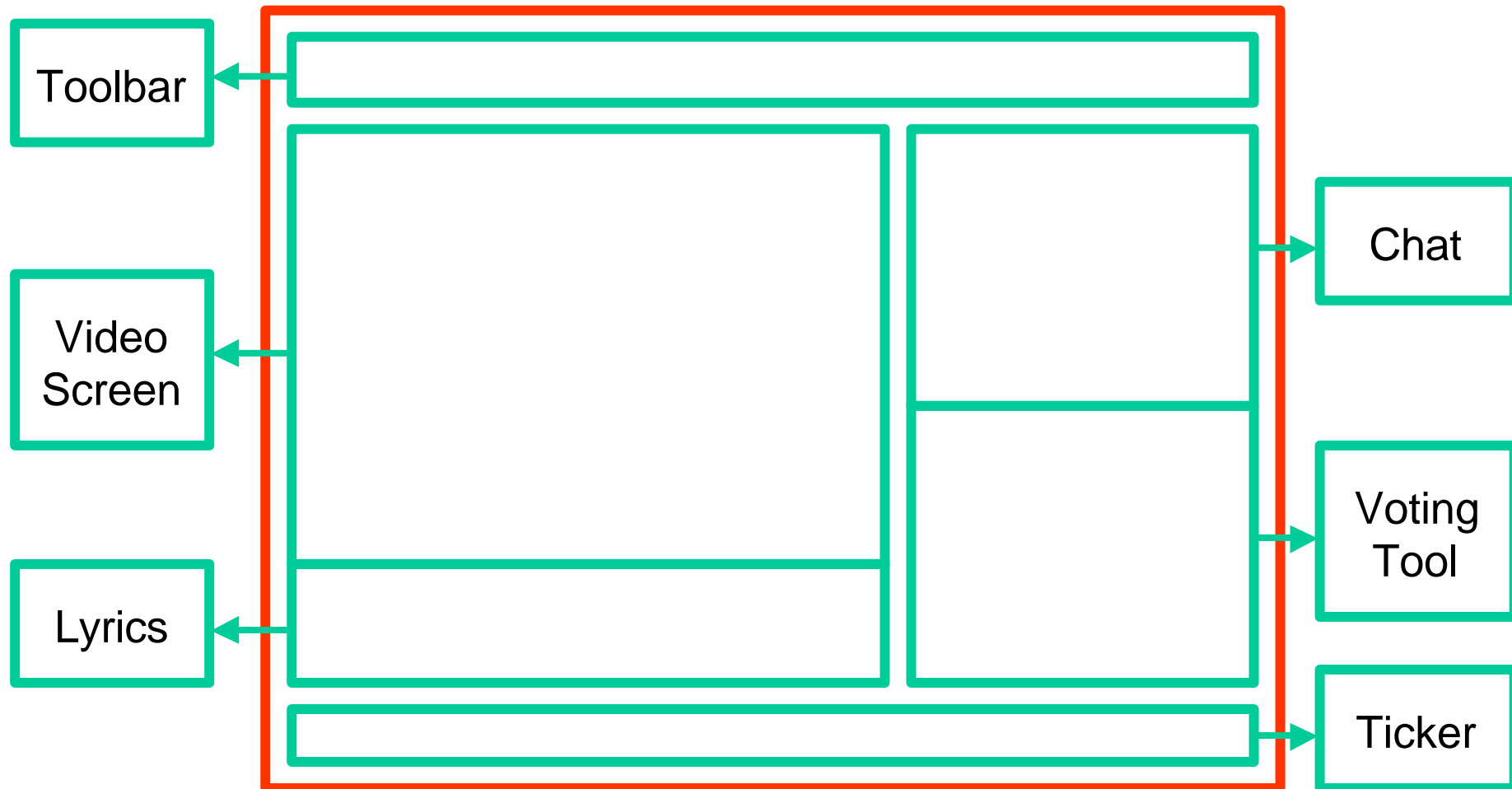
## Idea for such a service: Mediazine

### ■ Platform for music fans

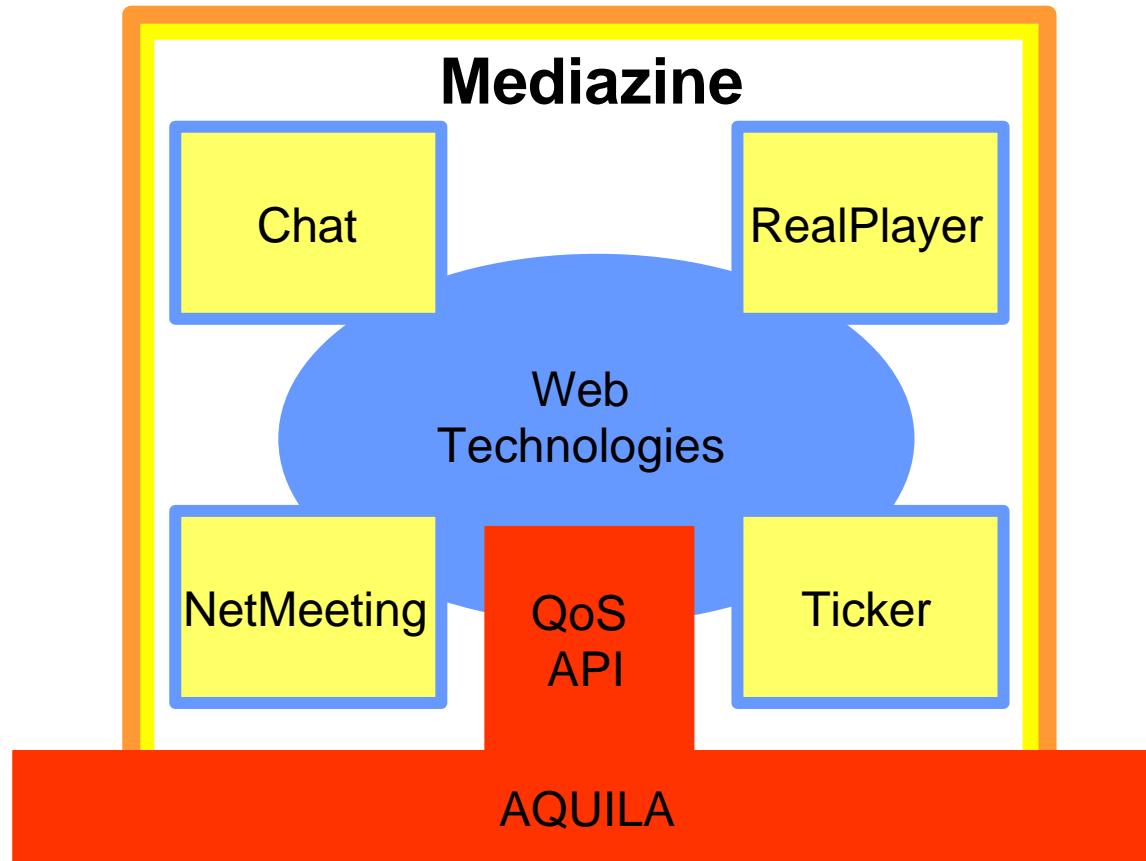
### ■ Features

- Audio / video streaming
- Text / voice / video chat
- Lyrics
- News ticker
- Background information
- Music voting
- E-commerce

## Scheme for the Mediazine



# An Integrated and Complex Internet Service: AQUILA + Mediazine



## AQUILA Mediazine - Technical Features

- **Integrating various content types and Basic Internet Services**
- **Requirements for low- and high-bandwidth services**
- **Parallel presentation of different content types, simultaneously**
- **Binding together different streaming tools (audio, video)**
- **Adequate presentation form for satisfying the end-users**
- **Multilevel, high quality content**

---

## **AQUILA Mediazine - Business Features**

- **Complex Internet Service**
- **Covers a wide range of Basic Internet Services**
- **Meets our strategy for commercial exploitation**
- **Implementation of the project's results will be immediate and sound**

## AQUILA Mediazine within the second trial

### ■ Technical aspects

- Apply AQUILA architecture on a real-life Complex Internet Service
- Demonstrate the importance of using the AQUILA QoS architecture
- Validate the functionality of the involved AQUILA system features

### ■ Business aspects

- Real-life Complex Internet Service, in order to verify the potential of supporting a realistic business scenario
- User-friendliness

## Enhancement from 1st to 2nd trial

### ■ 1st trial

- Basic Internet Services
- One QoS characteristic for one service
- Test of the AQUILA architecture with test persons

### ■ 2nd trial

- Complex Internet Service
- Different QoS characteristics in one enhanced service
- Test of the AQUILA architecture with real-life customers coming from a Bertelsmann Internet portal
- Includes the tested trial 1 services

## AQUILA Mediazine: Summary

- **Prototype of a Complex Internet Service for interactive broadband technologies**
- **Tested by Bertelsmann customers**
- **Provides video and/or audio streaming tools, in terms of**
  - Movies (MPEG4)
  - Music (MP3)
- **Audio/video – conferencing**
- **E-commerce facilities**

## Conclusions

In order to be able to follow the **latest market's developments** and to provide a **real world service** test-bed, we need to use a **Complex Internet Service** for validating the project's results.

**AQUILA Mediazine** can be used for such a purpose, as it is possible to **validate the involved project's system features** and to create a **commercially exploitable market case**.

AQUILA Mediazine will become a real service

# AQUILA Inter-Domain Architecture

## Future AQUILA architecture

### ■ Major enhancements in several areas

- Service for web traffic
- Network architectures including MPLS
- Comparison of several resource distribution algorithms
- Inter-domain resource allocation
- Application interfaces and protocol gateways
- Management and security
- Service verification

## Role of inter-domain resource control

### ■ Currently, operators look at intra-domain solutions

- Customers demand for QoS
- Intra-domain resource control is the first key to QoS

### ■ Future customer demands

- When customers take a fancy to QoS, they demand for these services world-wide
- Inter-domain resource control will be the next logical step

### ■ AQUILA's phased approach

- For the first trial, intra-domain resource control was established
- For the second trial, AQUILA will provide a scalable QoS architecture for the Internet

## Intra-domain architecture

### ■ Coarse view of topology

- Don't look too deep into the topology details

### ■ Reservation aggregation using resource pools

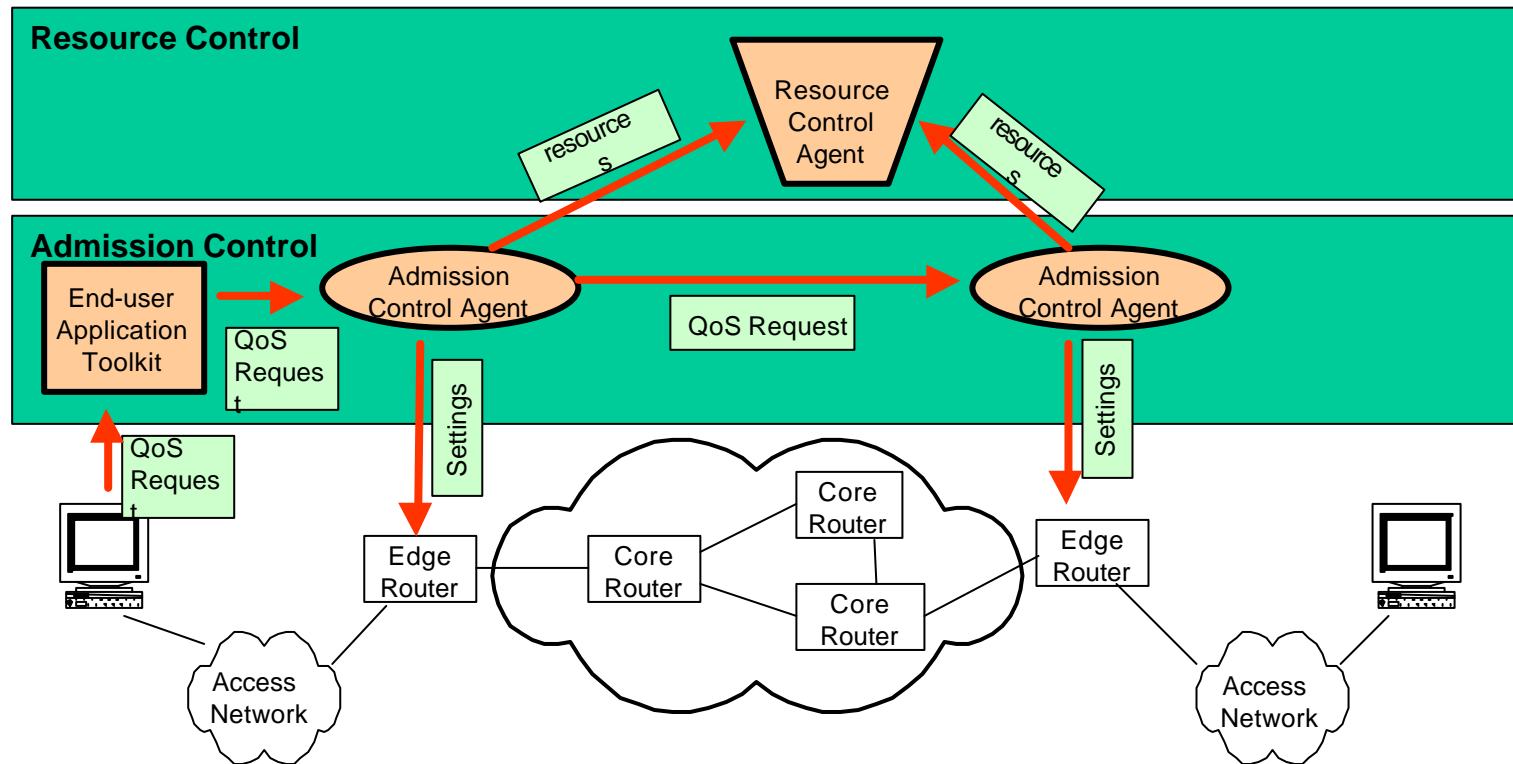
- Scalable hierarchical resource control architecture (scales even better than  $O(\text{hosts})$ )
- Dynamic redistribution of resources
- Allows an efficient utilisation of network resources

### ■ Single reservations still visible at the edges

- Ingress and egress edge router knows about each flow

# Scalable Architecture for RCL

## Resource Control Layer



# Resource Pools

## ■ Resource Limits

- Limit amount of QoS traffic from each edge router

## ■ Group neighboured Routers

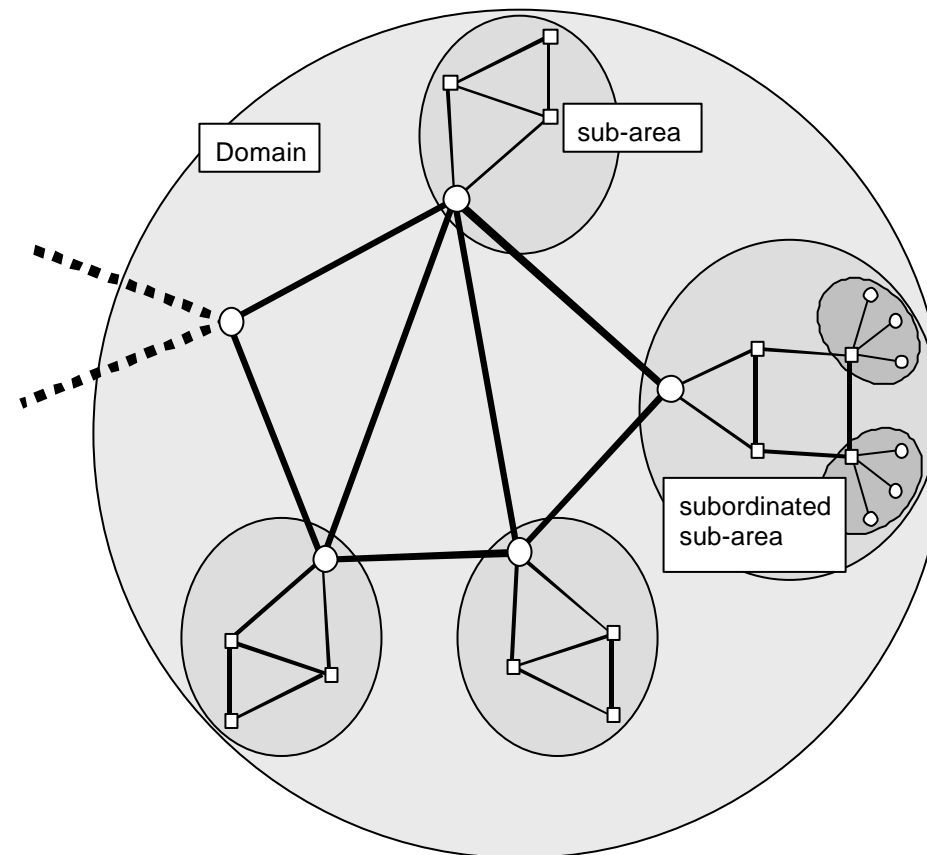
- Limit amount of QoS traffic from each group

## ■ Dynamic Distribution

- Dynamically shift resources within group

## ■ Hierarchical Structure

- “Groups of groups”



## Internet domain architecture

### ■ Domains, autonomous systems (AS)

- Currently, the Internet consists of about 10.000 AS
- Each AS is operated and managed by a network operator

### ■ Internet routing

- Internally, each AS may use any routing protocol
- For routing between AS, BGP (Border Gateway Protocol) is used world-wide

### ■ Independent, but co-operating routing mechanisms

- Same is required for resource allocation
- Inter-domain resource control architecture must not depend on any particular resource control mechanism within the AS

# Looking for a matching inter-domain solution

## ■ Possible candidates

- **SIBBS** (Simple Inter-domain Bandwidth Broker Signalling)
  - *QBone Bandwidth Broker Architecture, work in Progress, <http://qbone.internet2.edu/bb/bboutline2.html>*
- **BGRP** (Border Gateway Reservation Protocol)
  - *P. Pan, E. Hahne, and H. Schulzrinne, “BGRP: A Tree-Based Aggregation Protocol for Inter-domain Reservations”, *Journal of Communications and Networks*, Vol. 2, No. 2, June 2000, pp. 157-167. <http://www.cs.columbia.edu/~pingpan/papers/bgrp.pdf>*

## ■ Further reservation aggregation proposal

- RSVP aggregation
  - *draft-ietf-issll-rsvp-aggr-03.txt*

## Short discussion: SIBBS

- **Initiated by the QBone initiative of the Internet 2**
- **Focus on “Bandwidth Broker Signalling”**
  - Defines messages to exchange reservation information between domains
- **Scalability “to be added later”**
  - Scalability still an unsolved problem
  - Proposed aggregation using “core tunnels”: still unclear, how and when to establish and use core tunnels
  - Main problem may be, that the number of signalling messages grows  $O(N^2)$  with the number of autonomous systems.

## Short discussion: BGRP framework

- **Specially designed for inter-domain reservations**
  - Does not rely on any specific mechanism within the domains
  
- **Sink-tree-based**
  - Aggregates reservations along the sink trees formed by BGP
  - No e2e signalling of single reservations
  
- **Scalable**
  - Number of signalling messages grows  $O(N)$  with the number of autonomous systems.

## Short discussion: RSVP aggregation

### ■ Enhancement to the RSVP protocol

- Assumes a complete e2e RSVP architecture in the underlying network
- Reduces signalling by forming aggregation regions

### ■ More focussed on intra-domain

- Not specially designed for inter-domain
- Has many open issues, if used inter-domain

## Comparing the approaches

### ■ SIBBS

- Strong doubts on scalability
- No clear solution available



### ■ BGRP

- Specially designed for inter-domain reservations
- Designed to be scalable



### ■ RSVP aggregation

- Requires e2e RSVP infrastructure
- Many open issues for inter-domain application



## BGRP: Tackling the scalability problem

### ■ Microflow reservation

- At a core router, there might be more than 1 Mio individual flows at the same time

### ■ AS (autonomous system) pair reservation

- We could aggregate reservations starting and ending at the same AS pair into one inter-domain reservation
- This would still yield in the order of 10.000 reservations on a core router at the same time
- In general, the problem remains, that the number of reservations grows  $O(N^2)$  with the number of AS in the internet

## BGRP: Sink tree based aggregation

### ■ Sink tree: definition of term

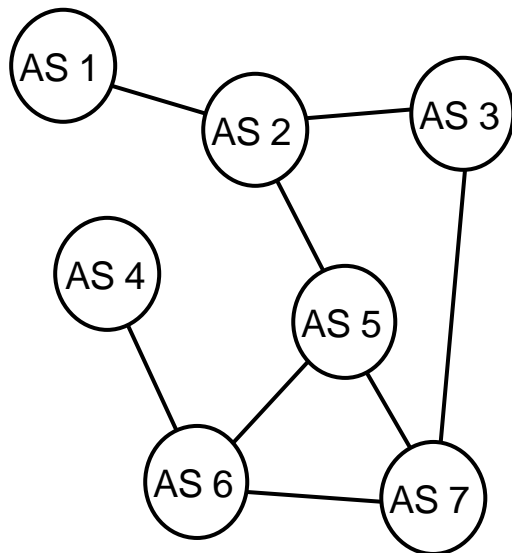
- An BGP router sends all traffic for the same destination AS to the same next hop AS (property of the BGP routing protocol)
- This guarantees the construction of a so called sink tree for a destination AS
- The root of the sink tree is the destination AS
- The traffic from all other AS travels along the links of this sink tree to the destination AS

### ■ Aggregation

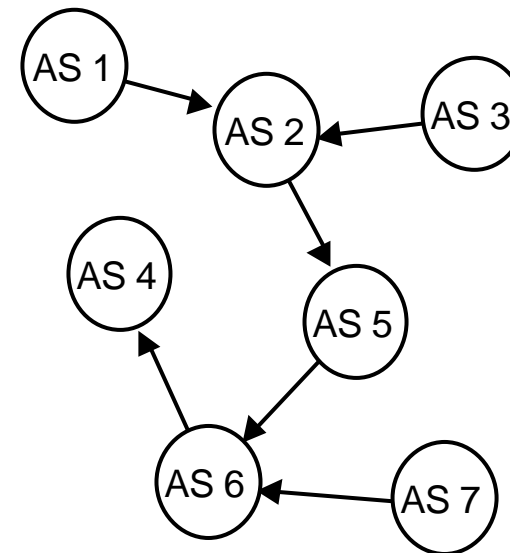
- Reservations from various AS to a common destination AS can be aggregated, as they merge along the sink tree

# BGRP: Example of a sink tree

## ■ Internetwork topology



## ■ Sink tree rooted at AS 4



## BGRP: Relation to intra-domain reservations

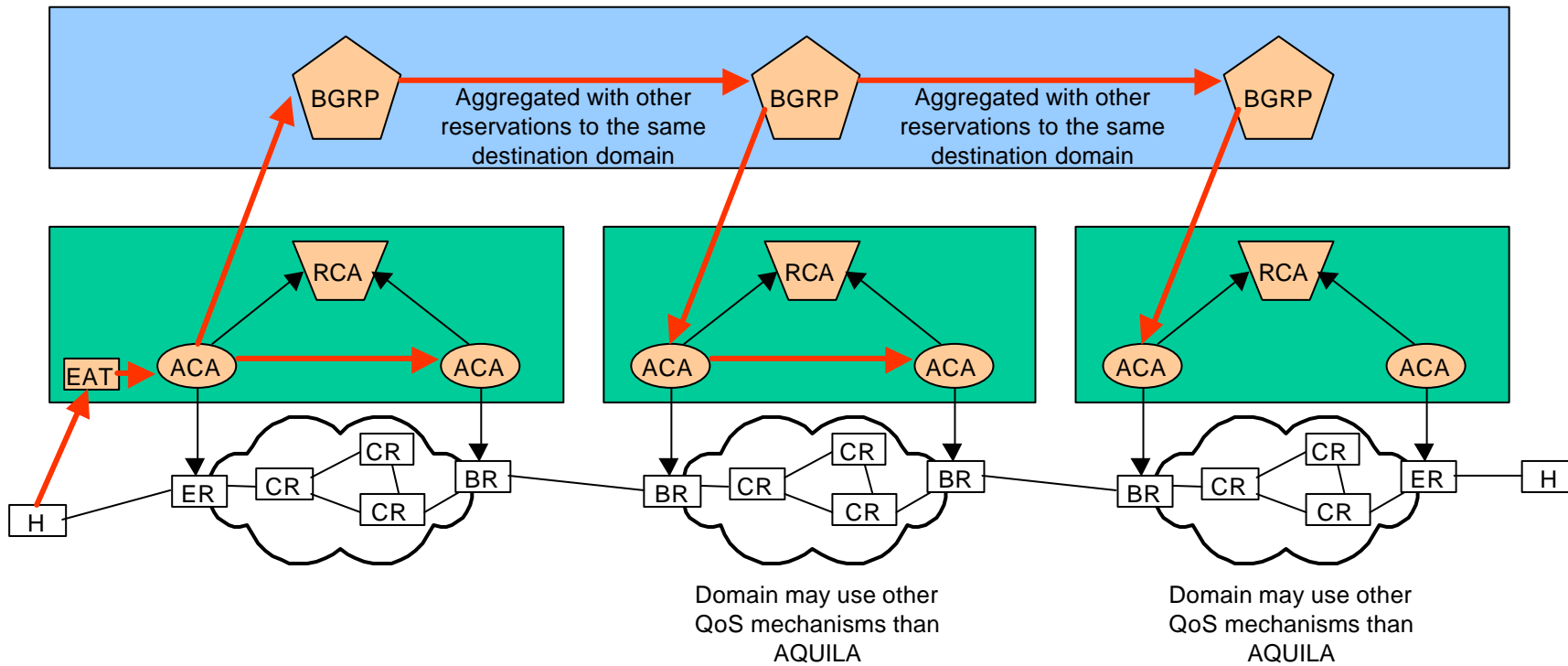
### ■ Operates on the boundaries between ISPs

- Each ISP is free to operate its own domain independently
- Additional layer above the intra-domain resource control

### ■ Relation to AQUILA phase 1

- AQUILA phase 1 ACA requests inter-domain resources from the BGRP bandwidth broker at the initiating domain
- BGRP bandwidth broker requests intra-domain resources from the AQUILA phase 1 architecture at subsequent domains

# Example: Inter-domain signalling



## Comparison: Sink trees vs. resource pools

### ■ Intra-domain advantages of resource pools

- Resource pools can be used for ingress and egress admission control
- Resource pools scale for networks with many sources and sinks (Scales better than  $O(\text{hosts})$ )
- Configuration and administration based on an overall picture of the domain.

### ■ Inter-domain advantages of BGRP sink trees

- BGRP considers the full network topology at the AS level
- BGRP can be independently configured and administered at each AS

**→ Both approaches are well positioned within an overall AQUILA architecture**

# AQUILA implementation of BGRP framework

## ■ BGRP is a framework, not a running protocol

- BGRP provides basic mechanisms for scalable inter-domain resource reservation

## ■ AQUILA inter-domain architecture

- Based on the BGRP framework
- Will address topics not solved within the current BGRP framework (e.g. reservation in the last domain)
- Resource pool algorithms and experiences from the first trial are re-used for inter-domain mechanism

## Summary

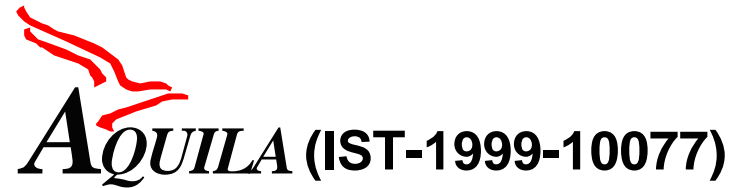
### ■ Interoperable inter-domain architecture

- Each domain may use its own QoS architecture
- AQUILA intra-domain architecture is just one possible choice

### ■ Scalable solution

- Scales to the current internet and more, even if each flow would use a resource request

### ■ Fits to the AQUILA intra-domain architecture

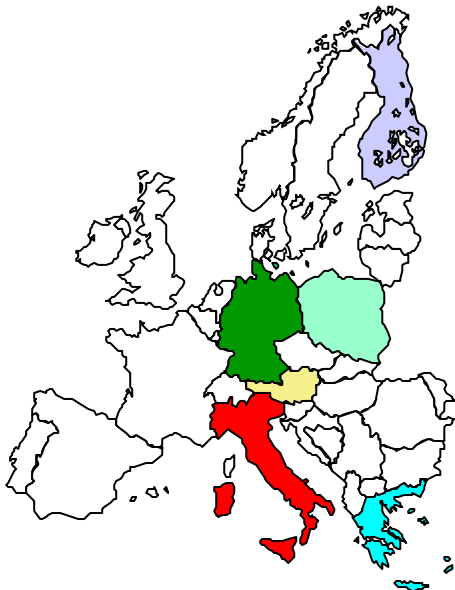


**Adaptive Resource Control for QoS  
Using an IP-based Layered Architecture**

**Project Review No. 2**

*Anacapri, Italy*

*April 3 - 4, 2001*



**Thank you for  
your attention !**

<http://www-st.inf.tu-dresden.de/aquila/>