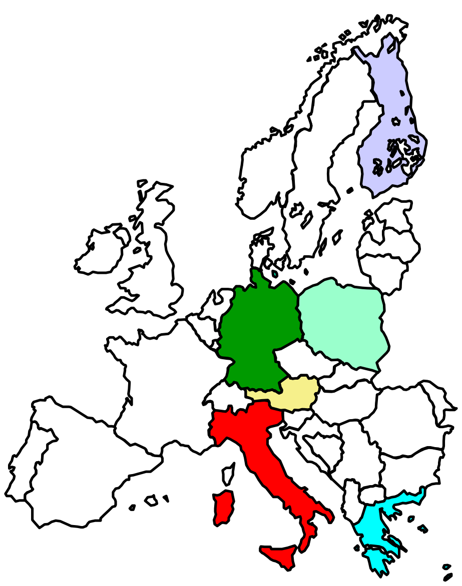
AQUILA (IST-1999-10077)

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



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

Evaluation of the AQUILA Architecture: Trial Results for

- **Signalling Performance,**
- **Network Services and**
- **User Acceptance**

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Outline

- Introduction
- Network Services in a Nutshell
- Signalling Performance Tests
- Network Services Behaviour Tests
- User Acceptance Tests
- Summary
- Demonstration

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• ***Dietmar Katzengruber*** TELEKOM AUSTRIA

• ***Marek Dabrowski***

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

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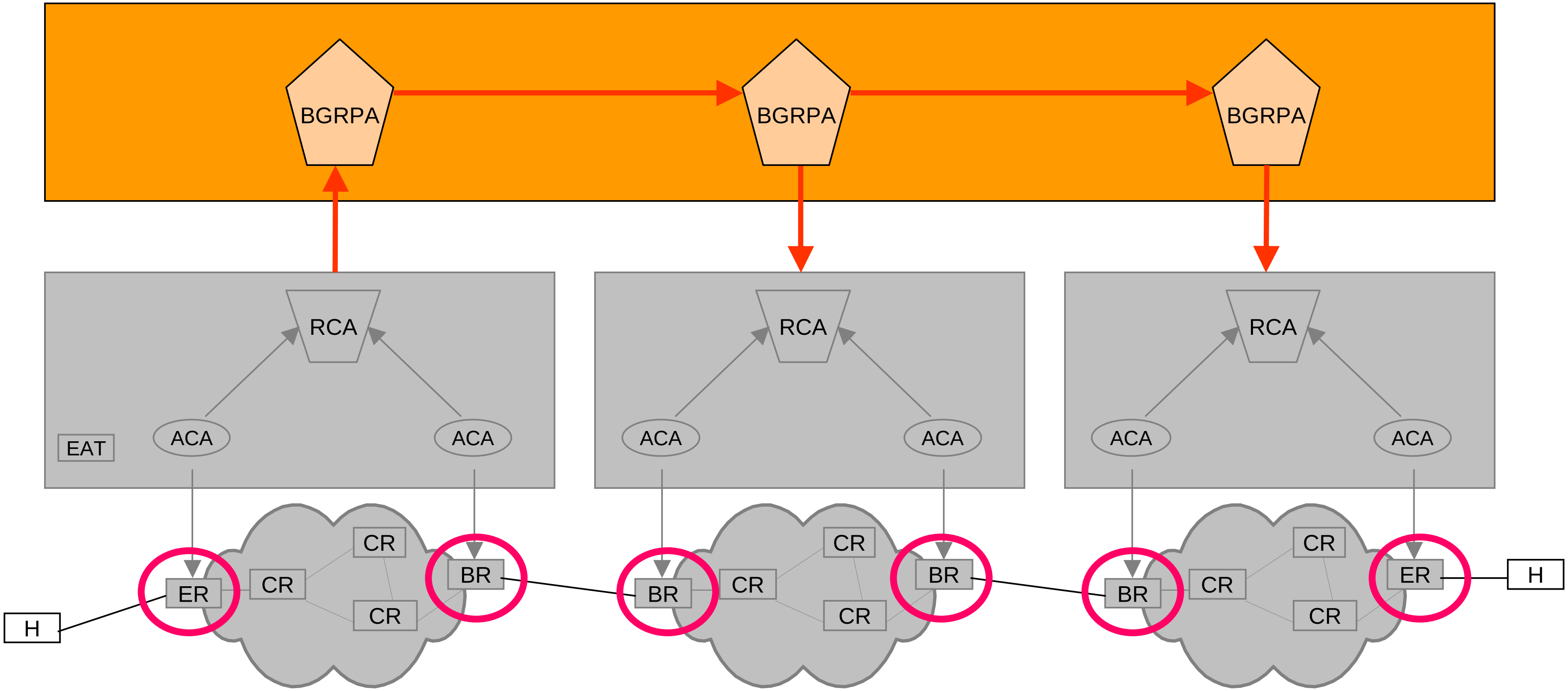
Result Evaluation

- 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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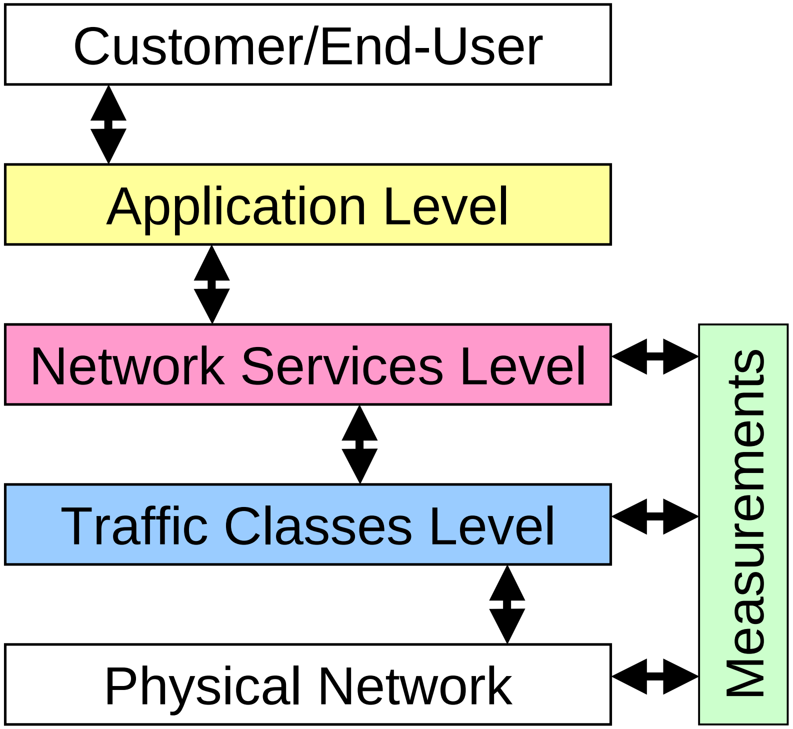
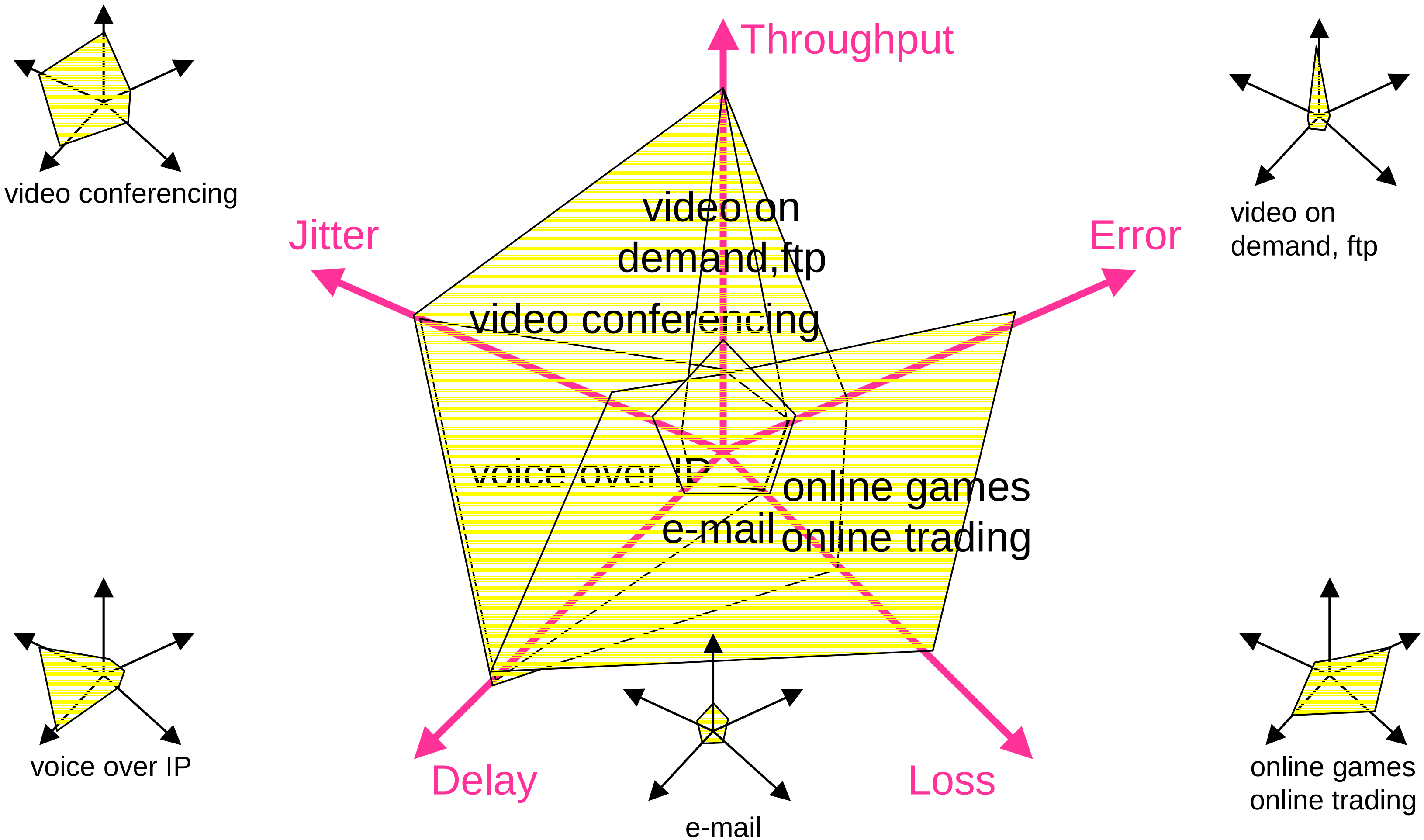
Network Services as Intermediate Level

A Level based Approach

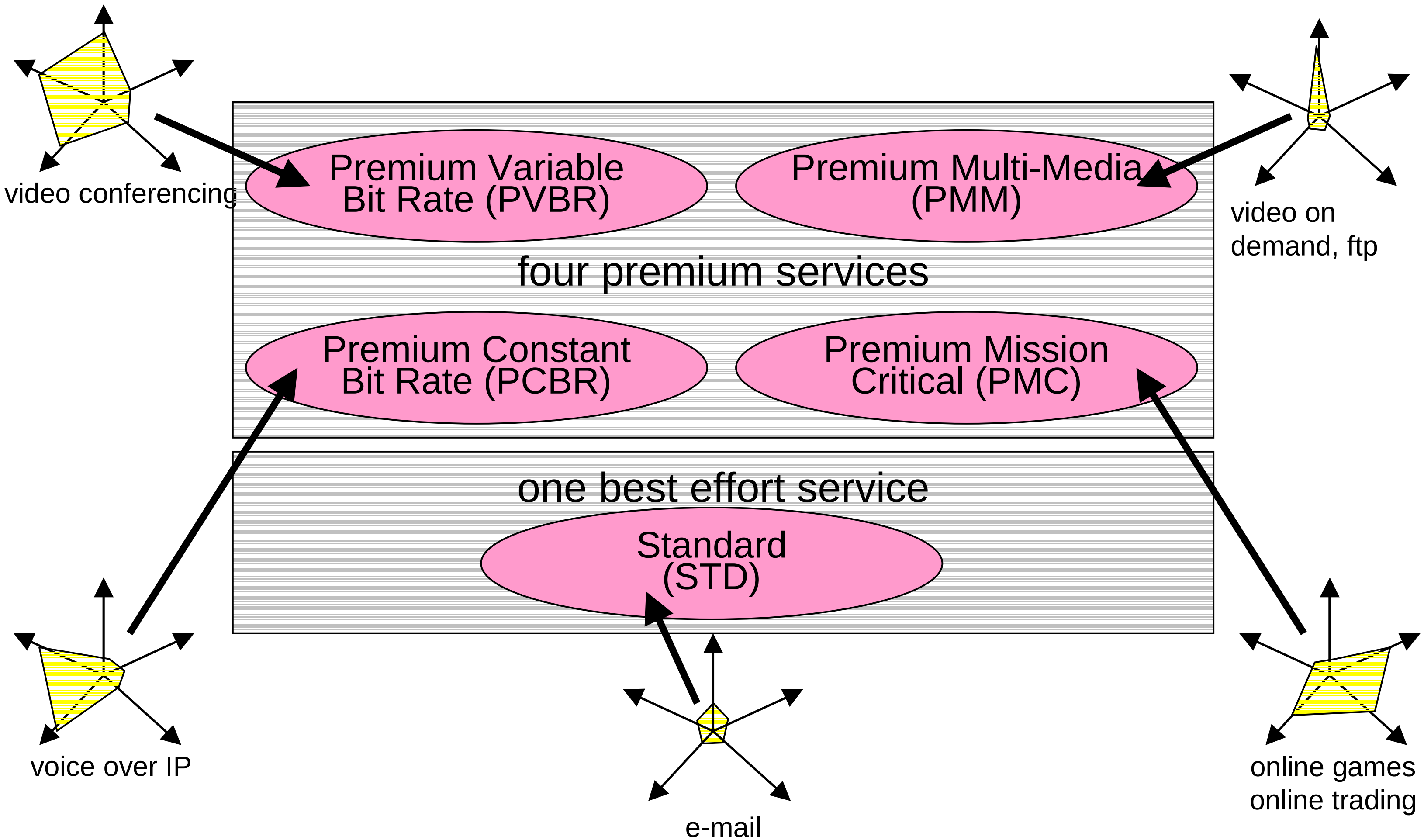
- reflects the innovative chain: customer ⇔ ISP ⇔ operator
- provides predefined services for Internet application support
- allows optimised network entity configuration
- ensures the given guarantees by measurements
- supports a vertical and horizontal system's scalability



QoS Parameters affecting Applications



Limited Set of Network Services



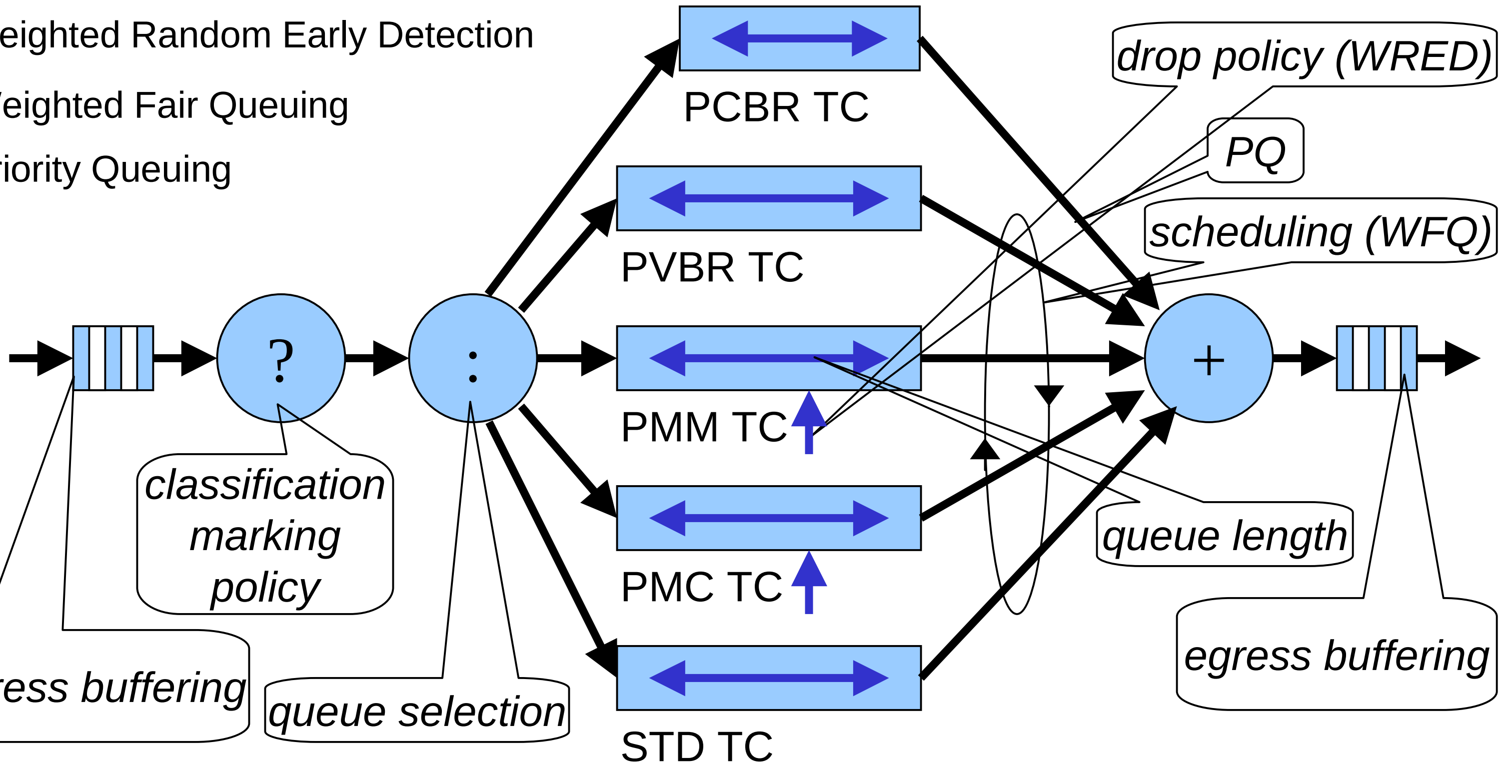
Traffic Classes Level - Router Capabilities

TC Traffic Class

WRED Weighted Random Early Detection

WFQ Weighted Fair Queuing

PQ Priority Queuing



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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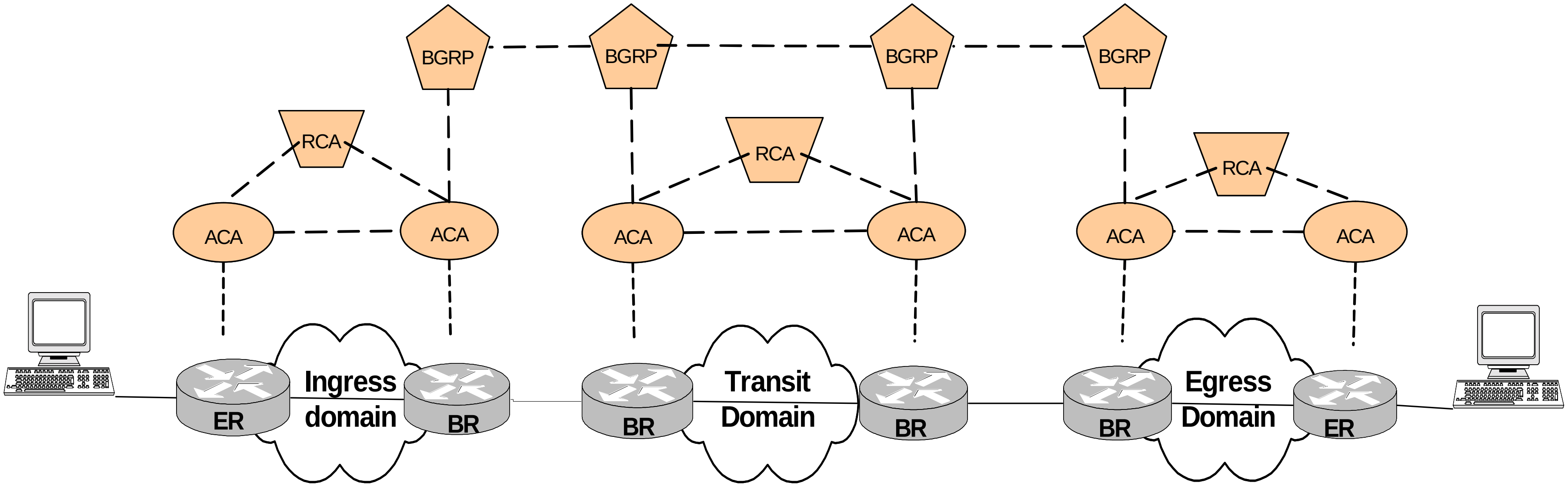
Resource Control Test Setup

- **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

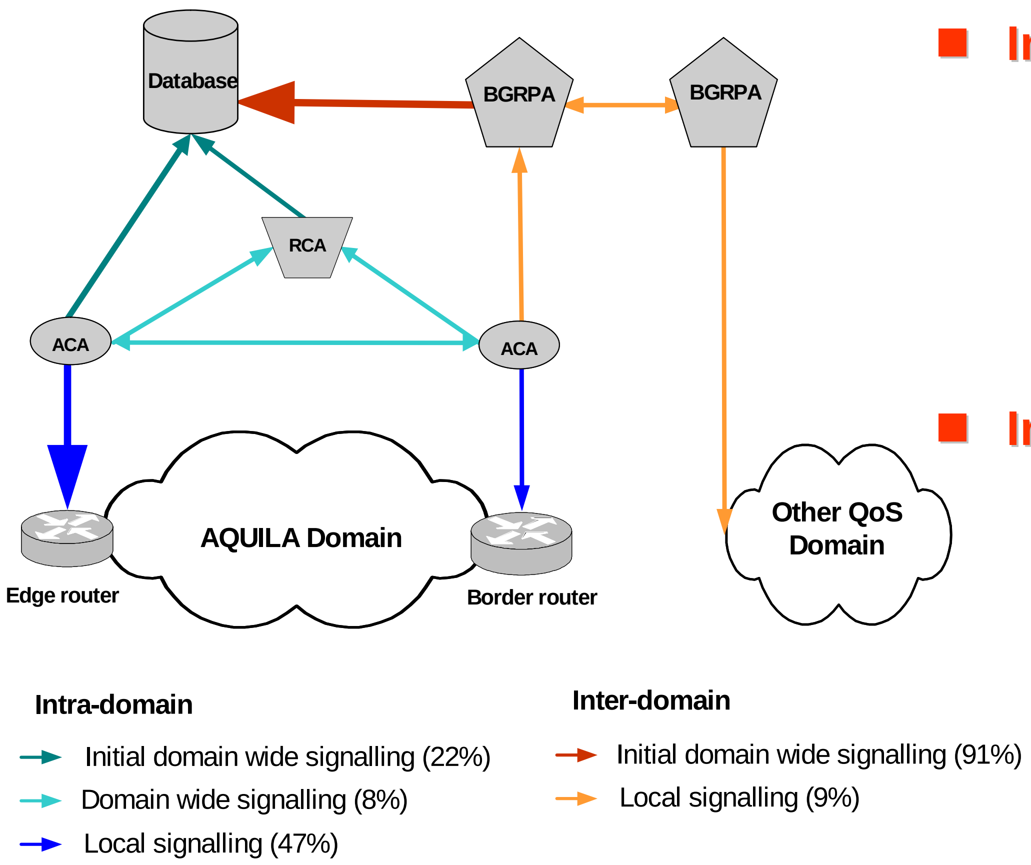


Resource Control – Reservation Times

- **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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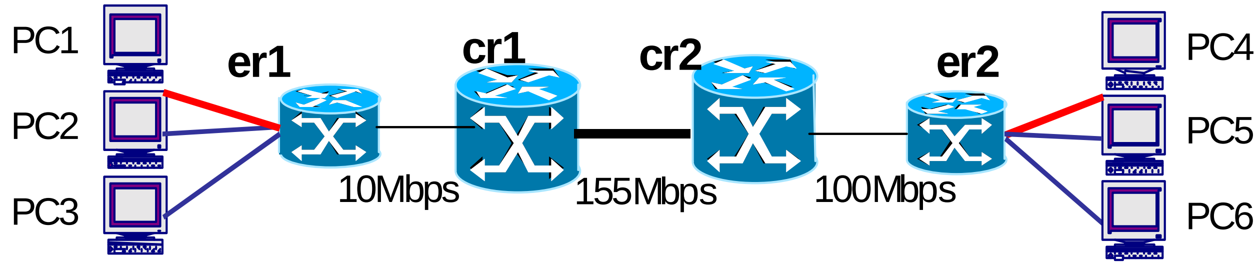
Network Services Behaviour Tests

	QoS objectives	Admission Control
PCBR	▪Very low packet loss ratio ▪Low delay	▪Peak rate allocation ▪Single Token Bucket
PVBR	▪Very low packet loss ratio ▪Low delay	▪Measurement Based Admission Control ▪Single Token Bucket
PMM	▪TCP throughput guarantees	▪(1) Token Bucket Marking (TBM) ▪(2) Advertised TCP window setting ▪Singe Token Bucket
PMC	▪Very low packet loss ratio	▪Rate Sharing Multiplexing ▪Dual Token Bucket

Evaluation of PCBR Service (1)

Test-bed topology



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

B_1 [Mbps]	PCBR traffic load [Mbps]	Lower priority background traffic load [Mbps]	P_{loss} of PCBR stream	Delay [ms]			IPDV [ms]	
				min	max	avg	avg	max
1	0.58	11.42	0	0.60	19.76	4.70	0.70	17.74
5	2.90	9.10	0	0.60	22.87	3.89	1.08	18.41
7	4.06	7.94	0	0.59	22.23	3.71	1.10	19.96
9	5.22	6.78	$4.5*10^{-5}$	0.59	24.59	3.60	1.09	22.26
10	5.80	6.20	$9.0*10^{-5}$	0.59	19.32	3.57	1.09	14.96

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

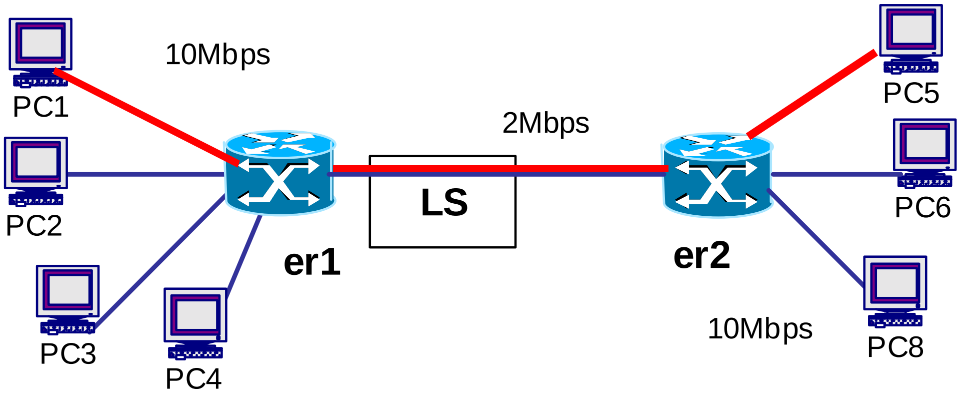
B_1 [Mbps]	PCBR traffic load [Mbps]	B_2 [Mbps]	N_{PVBR}	PVBR traffic load [Mbps]	P_{loss} of PVBR stream	Delay [ms]			IPDV [ms]	
						min	max	avg	avg	max
0	0	8.945	23	3.45	$1.26 \cdot 10^{-4}$	2.84	17.50	3.95	0.49	12.99
0	0	4.238	7	1.05	$1.30 \cdot 10^{-4}$	2.95	17.37	4.01	0.52	13.04
4	2.32	5.243	10	1.50	$1.36 \cdot 10^{-4}$	2.87	23.34	4.16	0.70	19.13
4	2.32	2.658	3	0.45	$1.00 \cdot 10^{-4}$	2.23	14.88	4.15	0.63	11.44
7	4.06	2.658	3	0.45	$1.18 \cdot 10^{-4}$	2.43	21.70	4.41	1.00	17.86

Conclusions

- The impact of higher priority PCBR traffic on PVBR service is effectively regulated by the applied AC rules
- Measured P_{loss} is close to assumed target value (10^{-4})
- The packet delays are acceptable

Evaluation of PMM Service (1)

Test-bed topology



LS: Link Simulator

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 Buket Marking (TBM) heterogeneous case**

Test	#1	#2
Sustained Rate (kbps)	40	392
Bucket Size (bytes)	60000	60000
No. Flows	2	2
Requested Rate (kbps)	250	500
Throughput (kbps)	385 ± 110	473 ± 16

- **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)

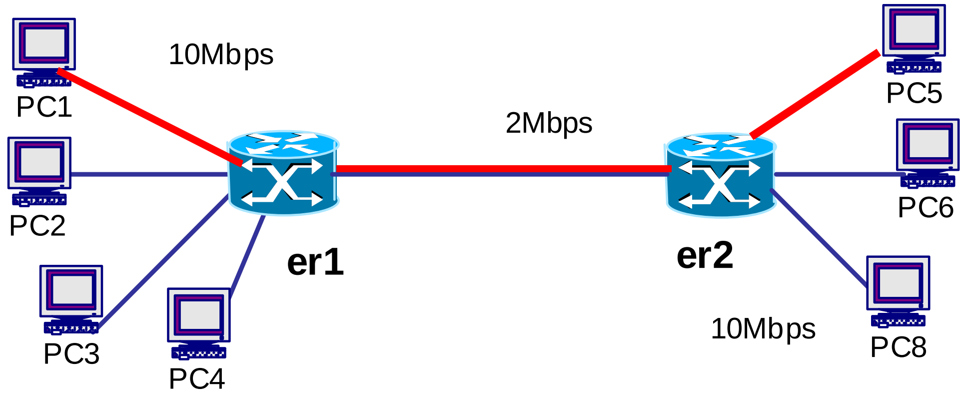
- **Results for AC based on advertised window setting heterogeneous case**

Test	#1	#2
Sustainded Rate (kbps)	328	672
Advertised Window (bytes)	4274	8688
Bucket Size (bytes)	4283	8463
Number of Flows	2	2
Rrequested Rate (kbps)	232	521.7
Throughput (kbps)	275 ± 2	567.6 ± 2.5

- **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

Test	#1	#2
Number of Flows	2	2
File size [bytes]	36200	73848
Peak Rate [Mbps]	10	10
Bucket Size [bytes]	15000	30000
Sustained Rate [kbps]	340	170
Packet Loss Ratio	0	0

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)

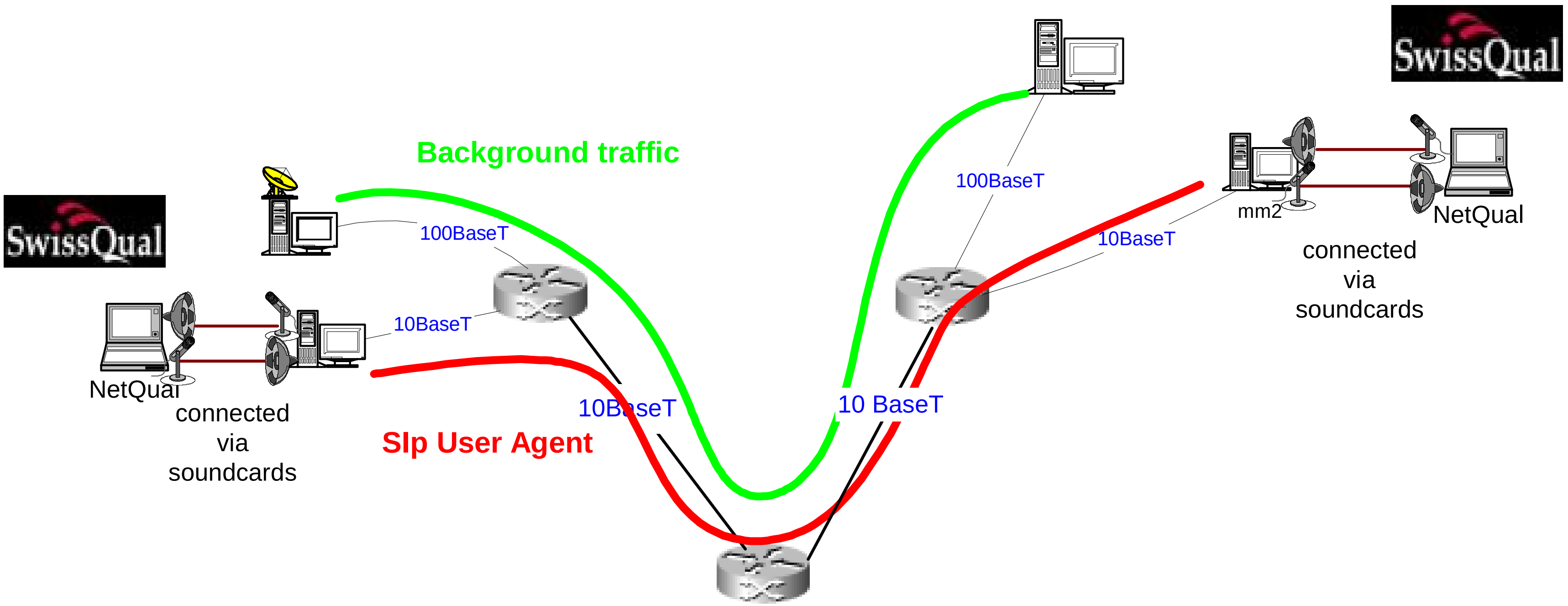
Test results

Test scenarios	Average logatom articulation (W_L)	Mean square deviation (S)	MOS
Scenario #1: reference	74.1 %	7.1 %	4.0
Scenario #2: VoIP using PCBR	71.9 %	9.8 %	3.8
Scenario #3: VoIP using STD	46.1 %	9.6 %	1.9

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

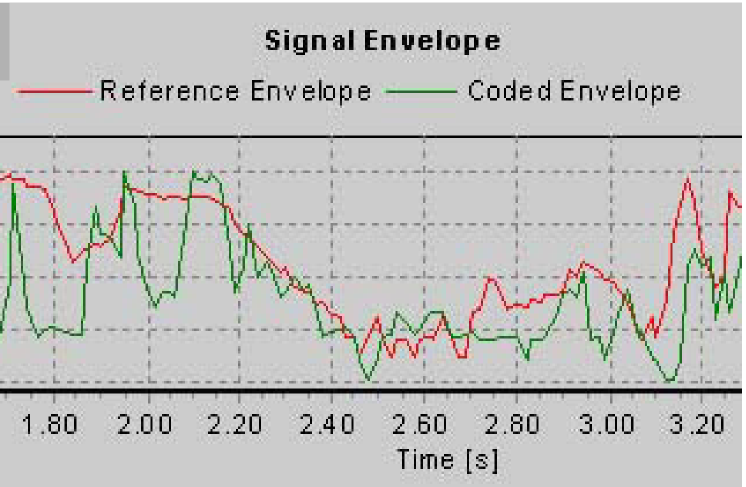
Test Environment for Voice Tests



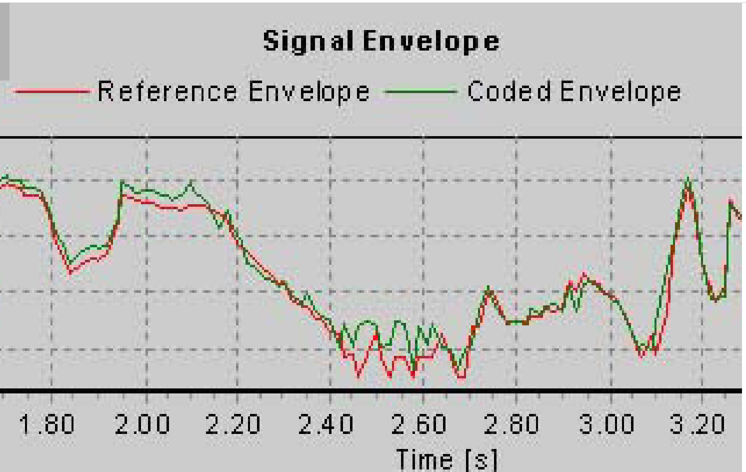
- Standardised (ETSI) reference wave sample files were injected
- Reference- and recorded file were compared
- MOS values were calculated

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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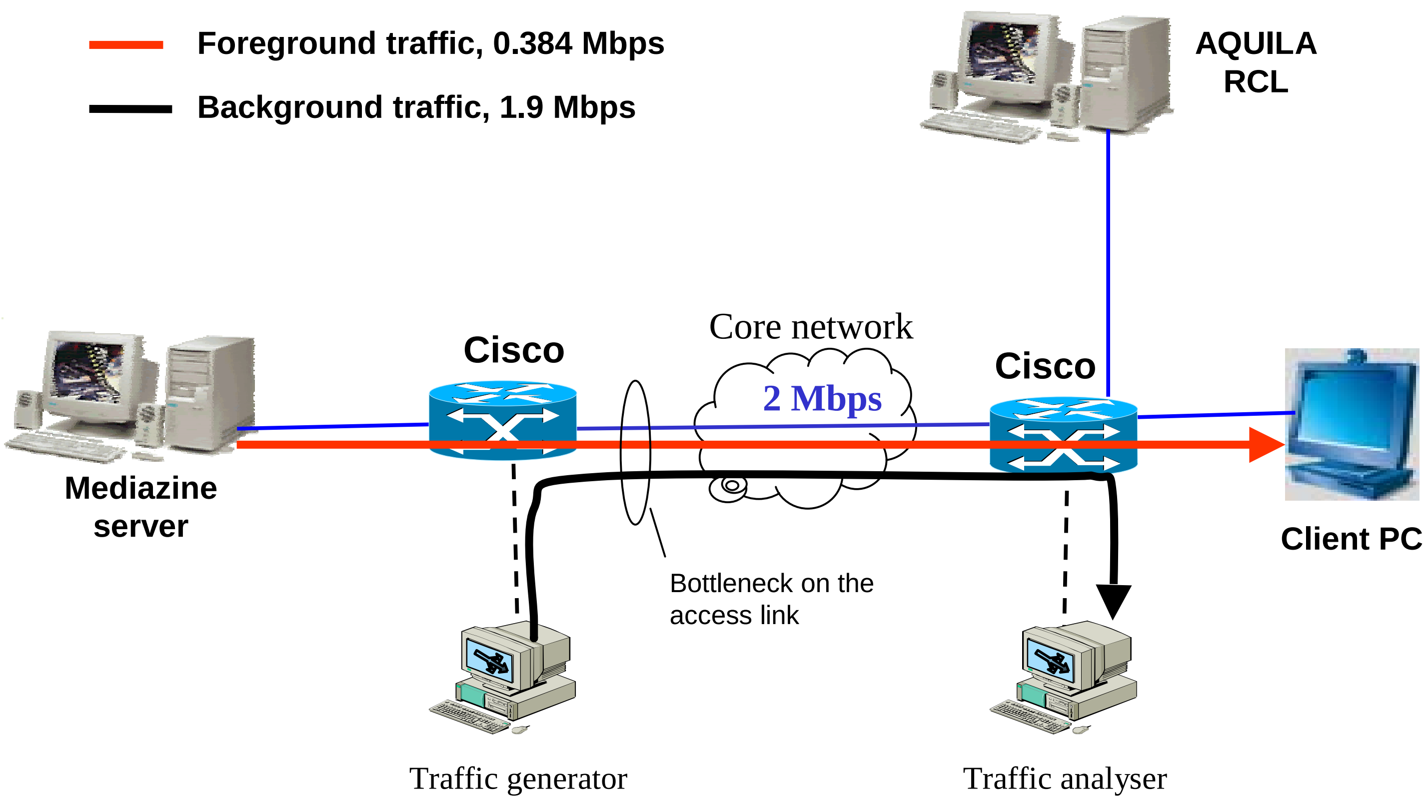
Demonstation of the AQUILA Testbed

- **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



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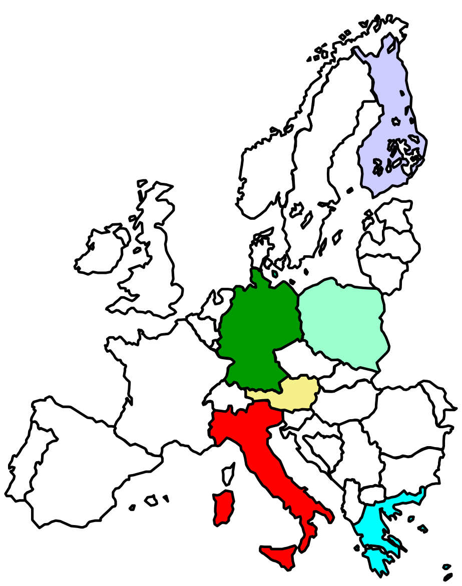

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