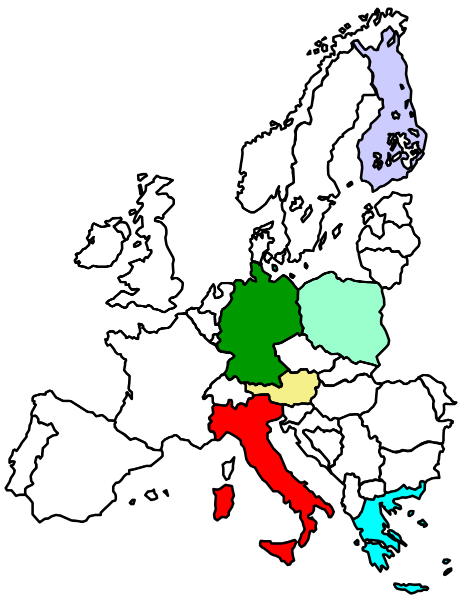
AQUILA (IST-1999-10077)

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



**Project Review No. 3**

*Dresden, Germany*

*November 21 - 23, 2001*

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

# Outline

- Project Overview
  - *Bert F. Koch (Siemens)*
- Measurement Architecture for Development and Operation of DiffServ Networks
  - *Gerald Eichler (T-Systems Nova) Ulrich Hofmann (Salzburg Research)*
- Control Loops
  - *Thomas Engel (Siemens)*
- BGRP Quiet Grafting: An Approach for a Scalable Inter-Domain Resource Control
  - *Martin Winter (Siemens)*

# Consortium

Siemens, Germany

Bertelsmann, Germany

Dresden Univ. of Technology, Germany

Salzburg Research, Austria

T-Systems Nova, Germany

Polish Telecom, Poland

NTUA, Greece

Elisa Communications, Finland

CoRiTeL, Italy

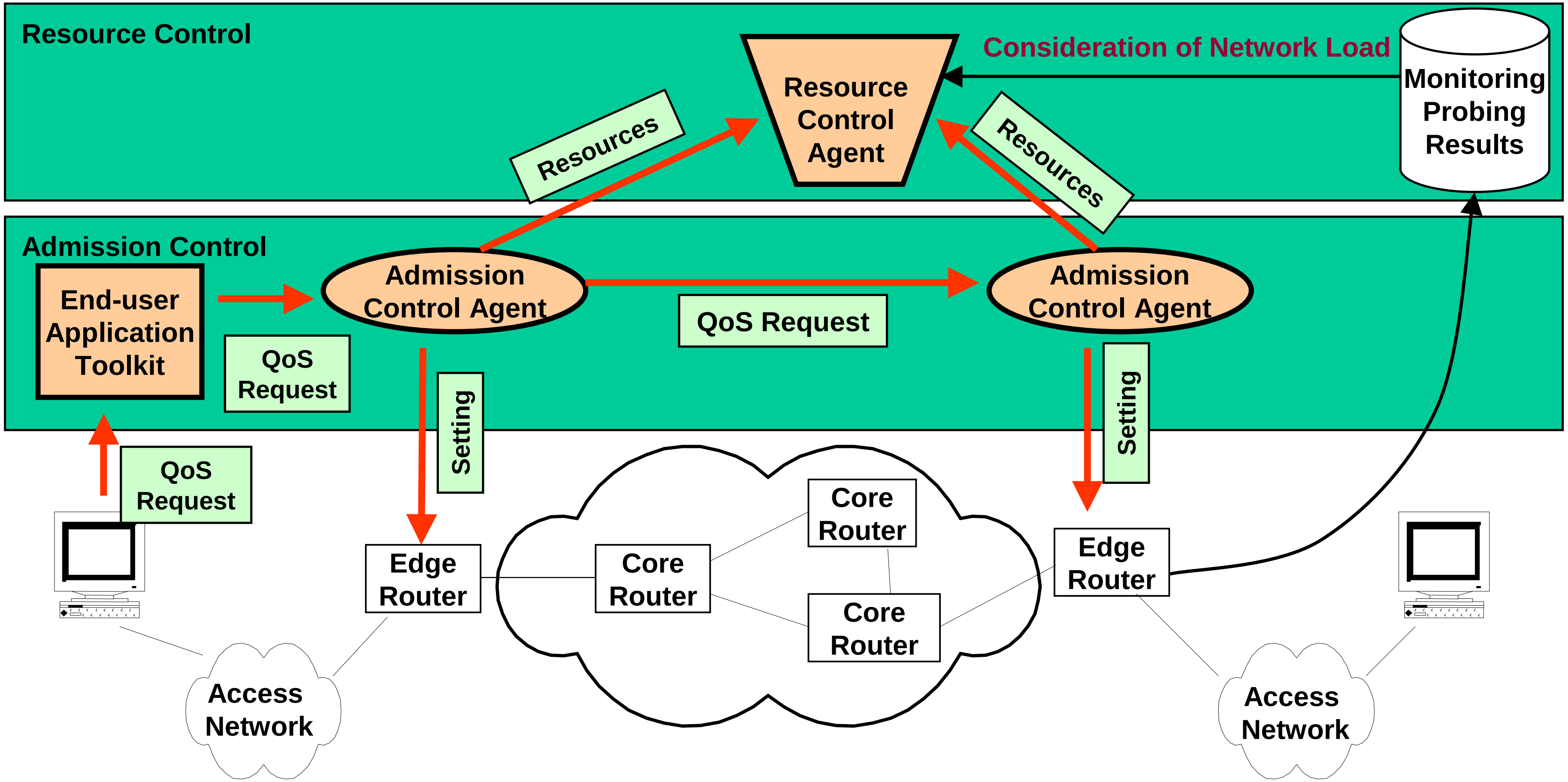
Q-Systems, Greece

Telekom Austria, Austria

Warsaw Univ. of Technology, Poland

# Architecture

Resource Control Layer



# Measurement Architecture for Development and Operation of DiffServ Networks

# Outline

- Measurement architecture
- Measurements within the 1st trial period
- Operator friendly GUI
- Improved load generators
- Passive measurement for MBAC validation
- State of the art, research and development, exploitation

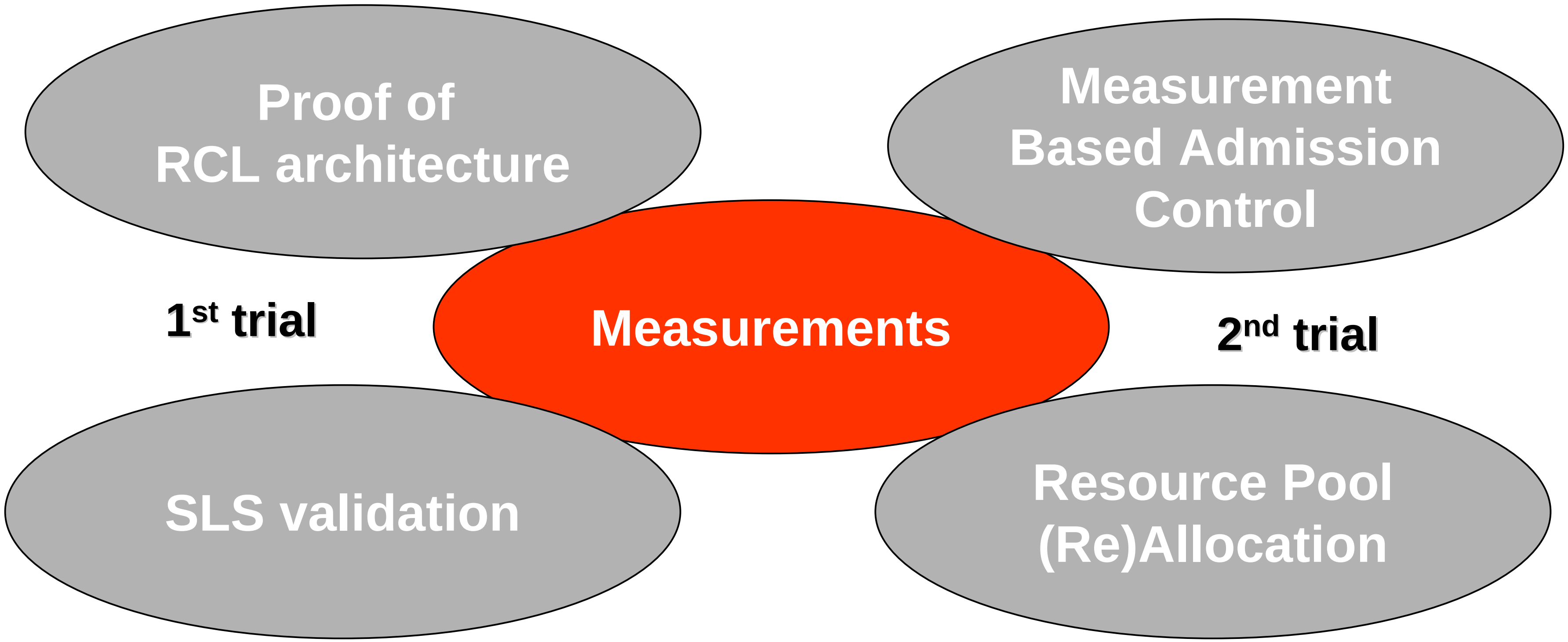
# AQUILA - Why Measurements?

| IntServ Model | | DiffServ Model |
|---|---|---|
| RSVP | Focus | Per hop behaviour |
| end-to-end QoS | QoS | CoS per link |
| Soft state | System view | Stateless |
| Absolute | Guarantees | Relative |

QoS Proven

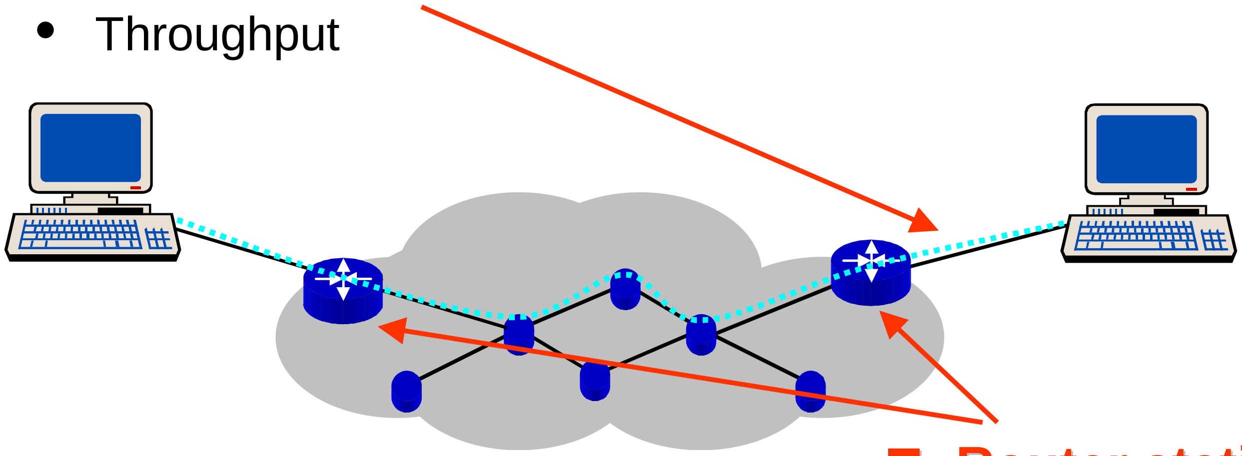
?

# AQUILA - Measurement Focus



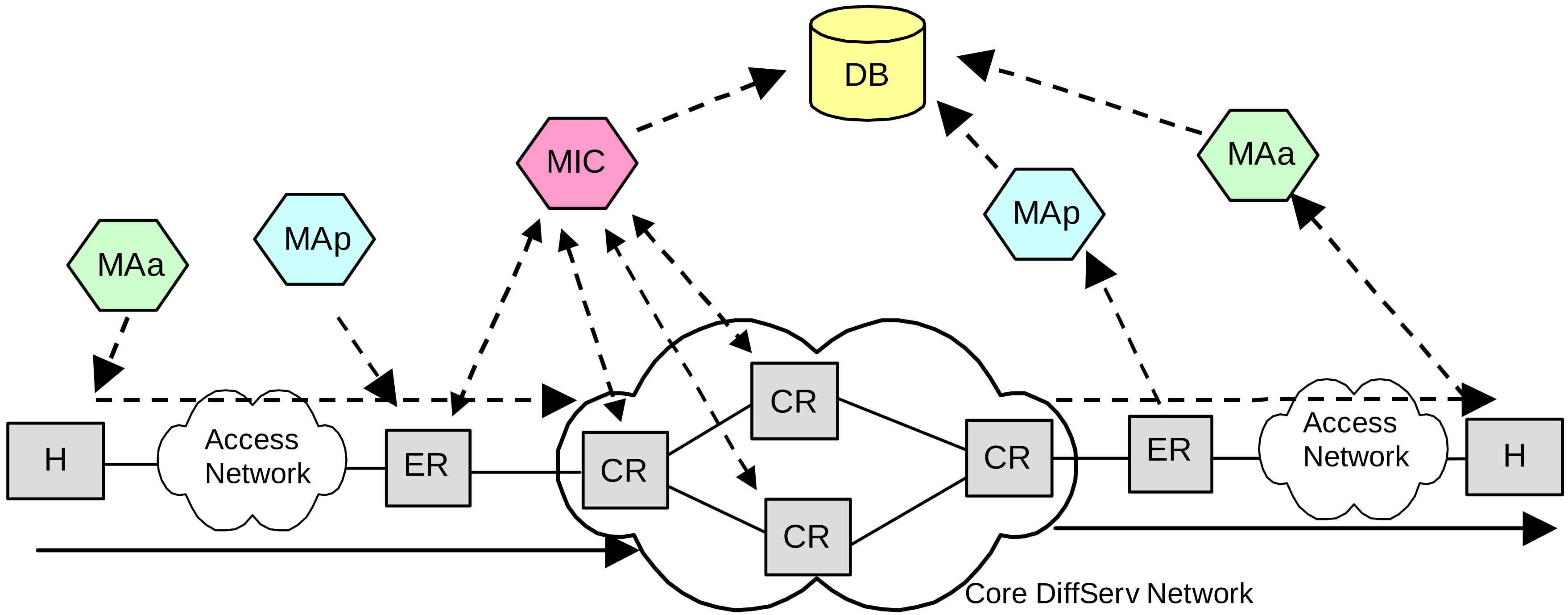
# Measured Parameters

- **Performance parameters**
  - One way delay (OWD) → accuracy 200 µs
  - Instantaneous Packet Delay Variation (IPDV) → accuracy 200 µs
  - Packet loss
  - Throughput



- **Router statistics**
  - Traffic rates
  - Queue lengths
  - Packet drop counters

# Measurement Architecture for the 1st Trial



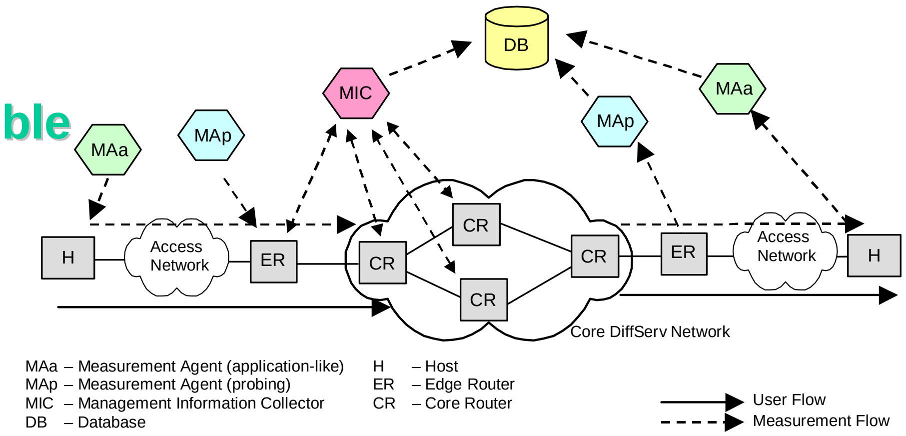

MAa – Measurement Agent (application-like)
MAp – Measurement Agent (probing)
MIC – Management Information Collector
DB – Database

H – Host
ER – Edge Router
CR – Core Router

User Flow
Measurement Flow

# Components of the Distributed Measurement Architecture (DMA)

- **MAa: Measurement agents with traffic generators that produce application-like flows (reproducible experiments as opposed to real applications)**
- **MAp: Measurement agents that perform active network probing (constant monitoring of the whole network)**




- **MIC: Management Information Collectors that supply router statistics (traffic rates, queue lengths, packet drop counters etc.)**
- **DB: Database for configuration data and measurement results**

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- Measurement architecture
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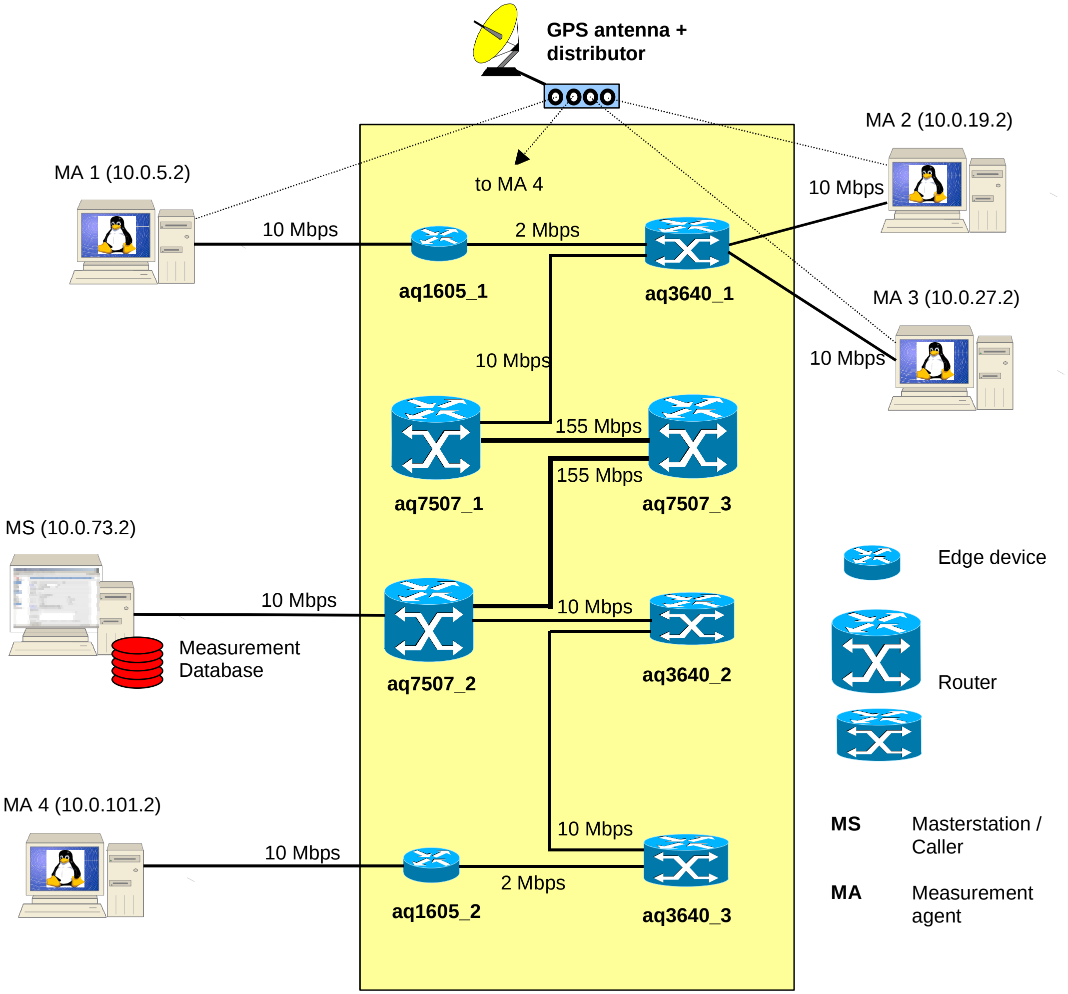
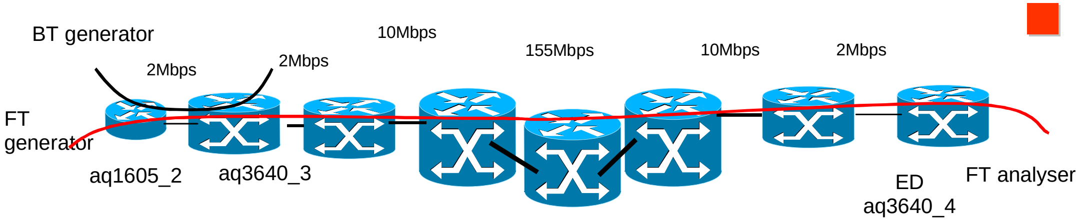
# DMA - Reference Trial Site (Warsaw)

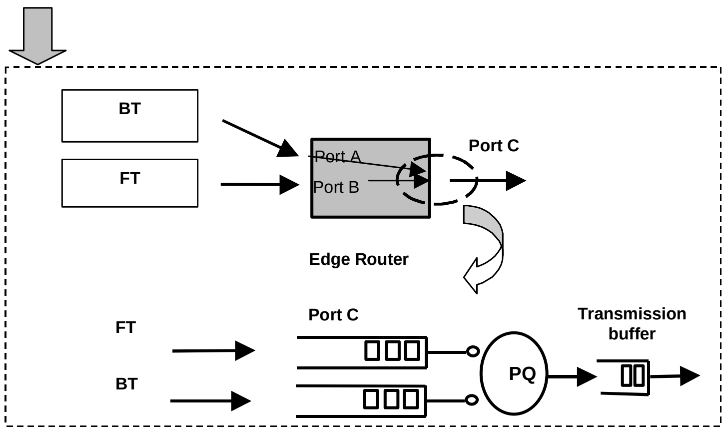


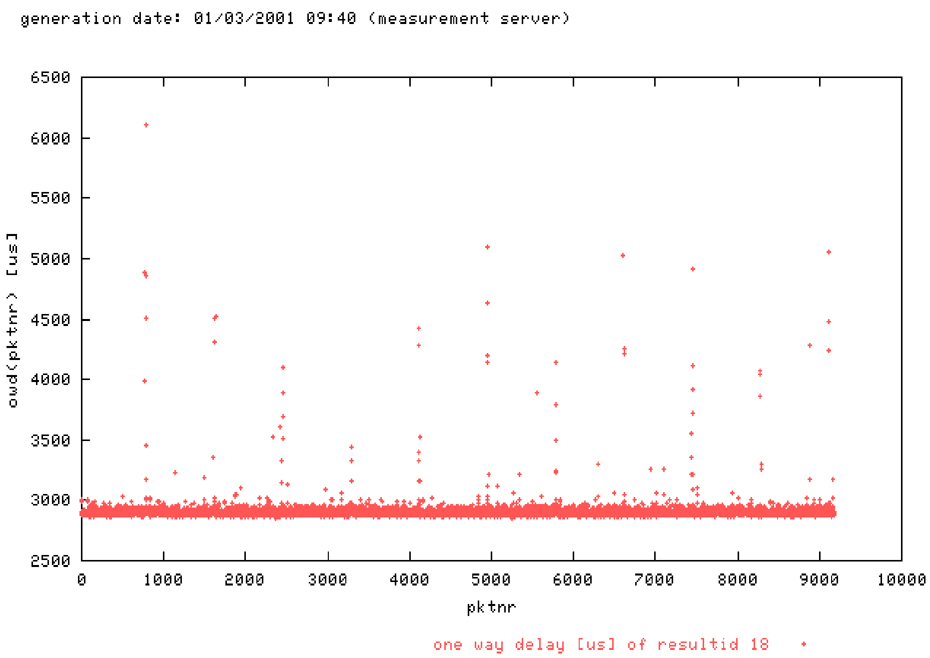

- **4 Measurement Agents (MA 1 - 4)**
  - GPS synchronised
  - MAa and MAp co-located
- **MIC and server components co-located**

# DMA - Example Measurement




- One Way Delay (OWD) as a function of packet number



# DMA - Feedback and Improvements

- **Lessons learnt from 1st trial**
- **New requirements**
  - Navigation ✓
  - DMA configuration ✓
  - Online-monitoring of selected parameters ✓
  - Usability ✓
  - Stand-alone operation

➔ **Implementation in the 1st trial extension and 2nd trial**

# Outline

- Measurements within the 1st trial period
- Operator friendly GUI
- Measurements for MBAC Measurement architecture
- Improved load generators
- Passive measurement for MBAC validation
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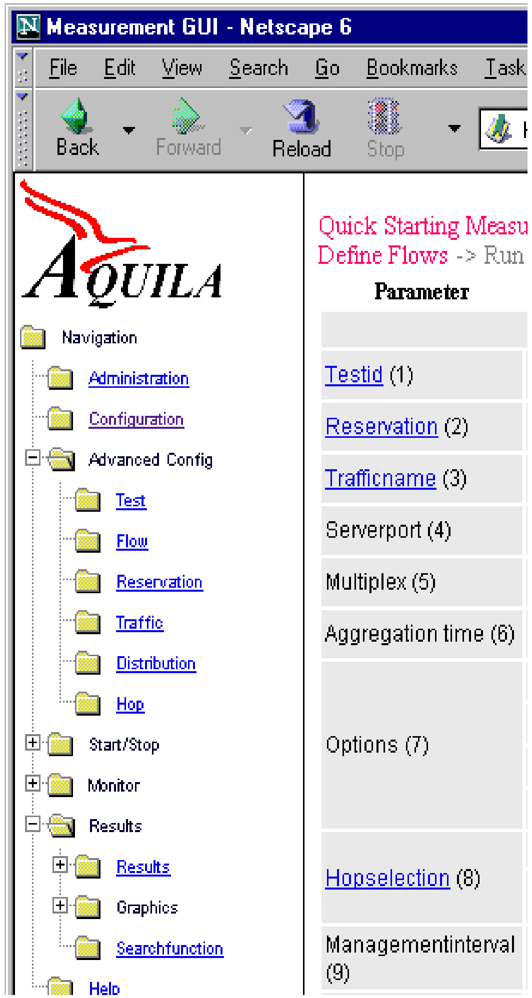
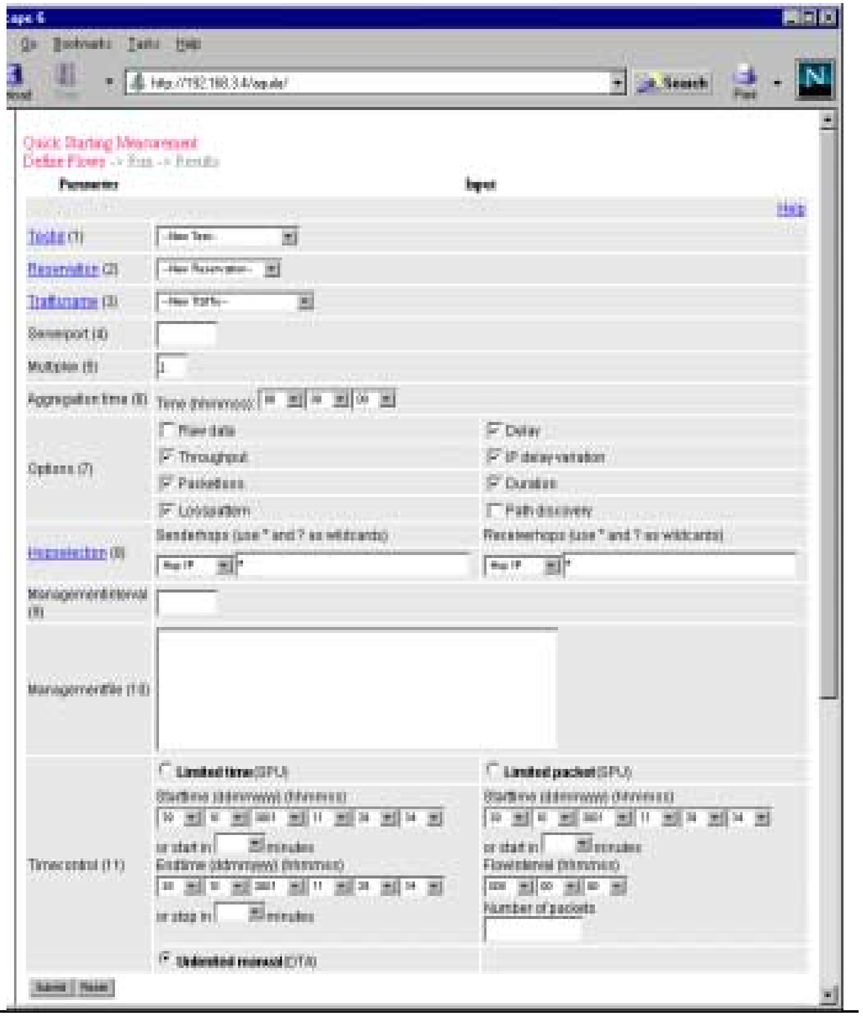
# DMA - Navigation Improvement

- Explorer-like navigation menu
- Re-ordering of the menu items
- Reduced number of menu items



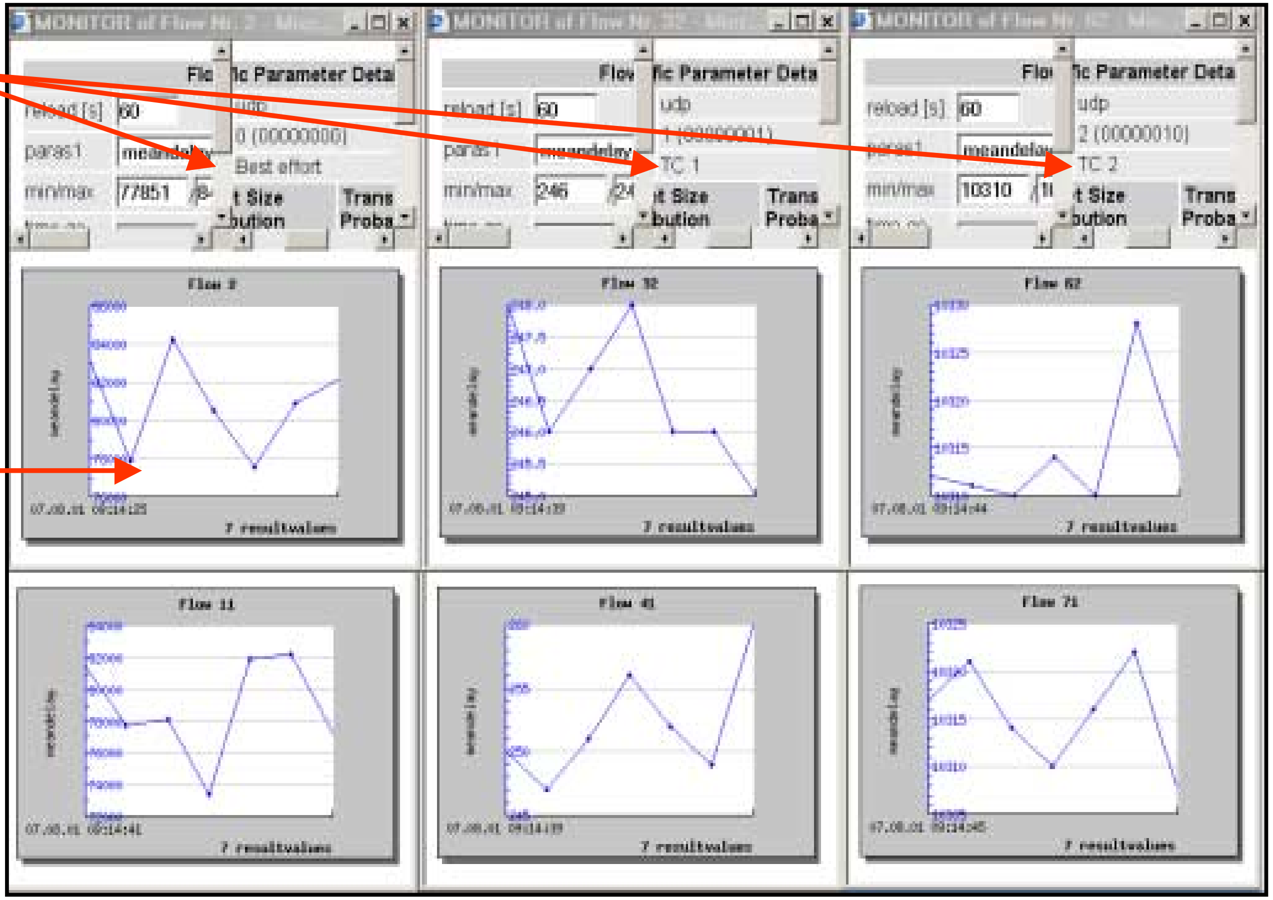
# DMA - Configuration Quickstart

- Configuration assistant
- Leads through the configuration steps
- Easy to configure fully meshed measurement scenarios



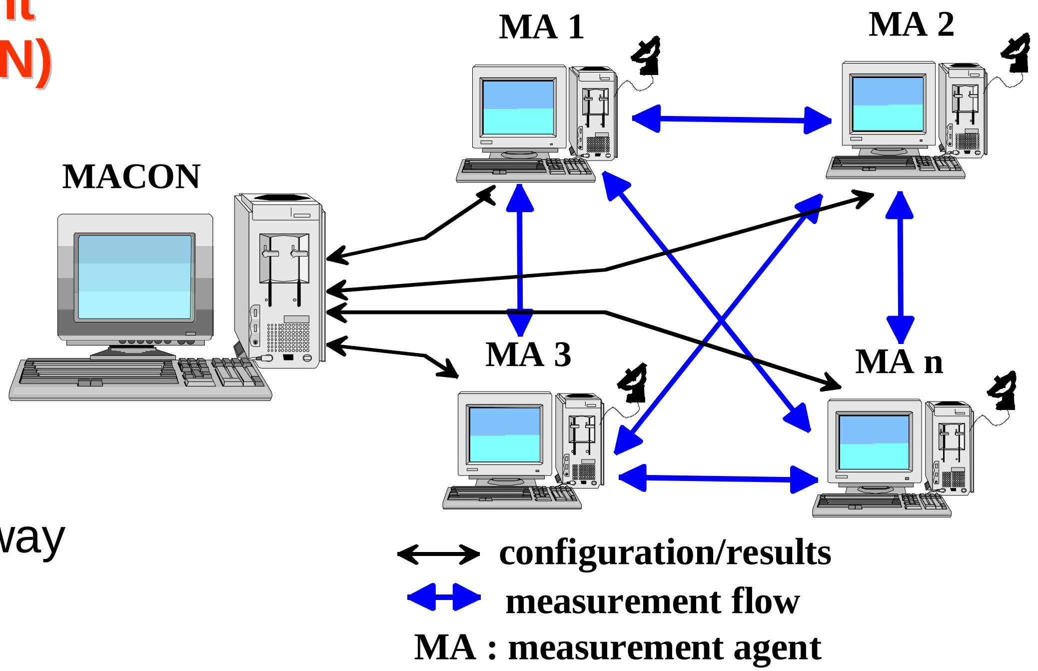
# DMA - Online Monitoring

- **Per traffic class**
- **Graphical display of measurement results during running tests**
  - One Way Delay
  - Delay variation
  - Packet loss
  - Throughput



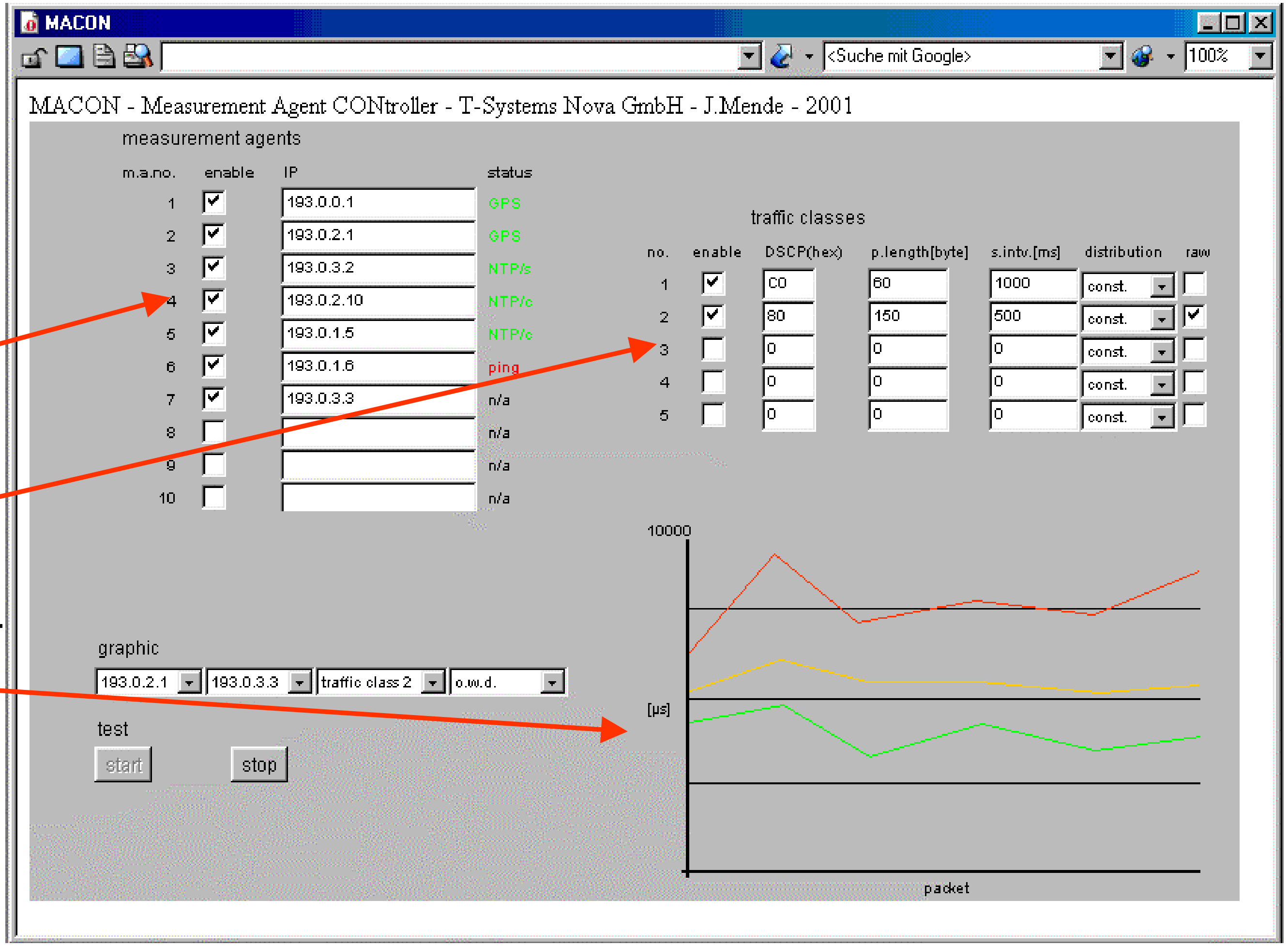
# DMA - Measurement Agent Controller

- **Easy to use Measurement Agent Controller (MACON)**
  - Controls up to 10 measurement agents
  - 5 traffic classes
  - Automatic start of fully meshed measurements
  - Online-monitoring of the system status
  - Online-monitoring of one-way delay, delay variation and packet loss
  - Data export to csv-files



# DMA - Easy to Use GUI

- **Functionality**
  - Easy configuration
  - Database independence
  - Fast agent selection
  - Fast traffic selection
  - Integrated online-monitoring



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- Measurement architecture
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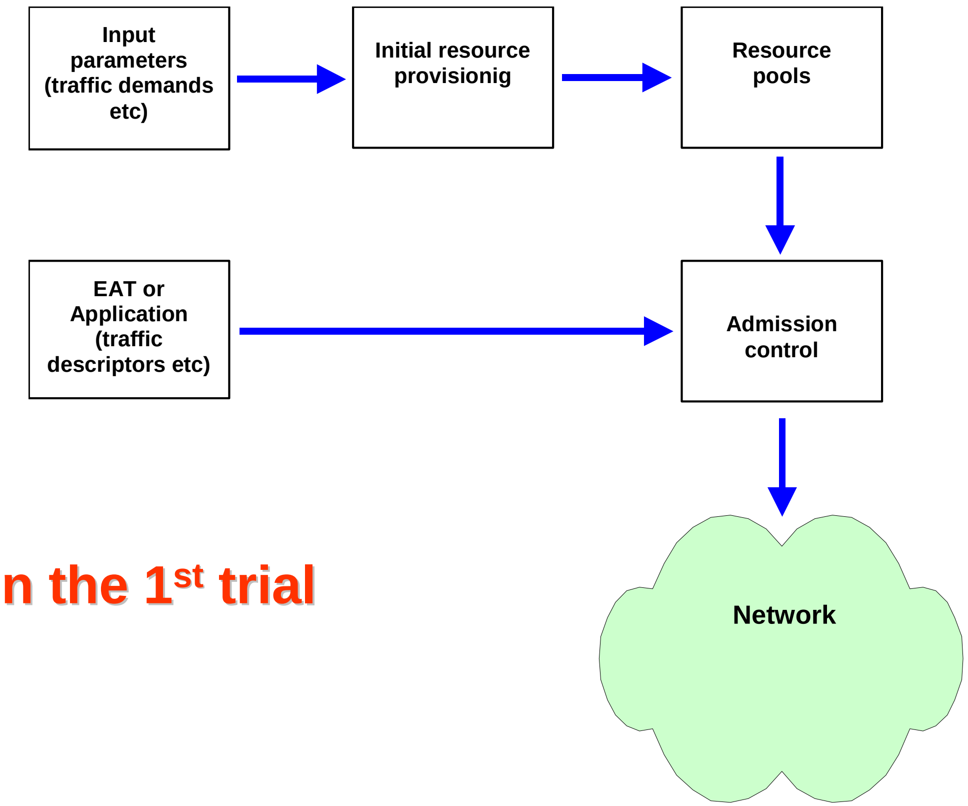
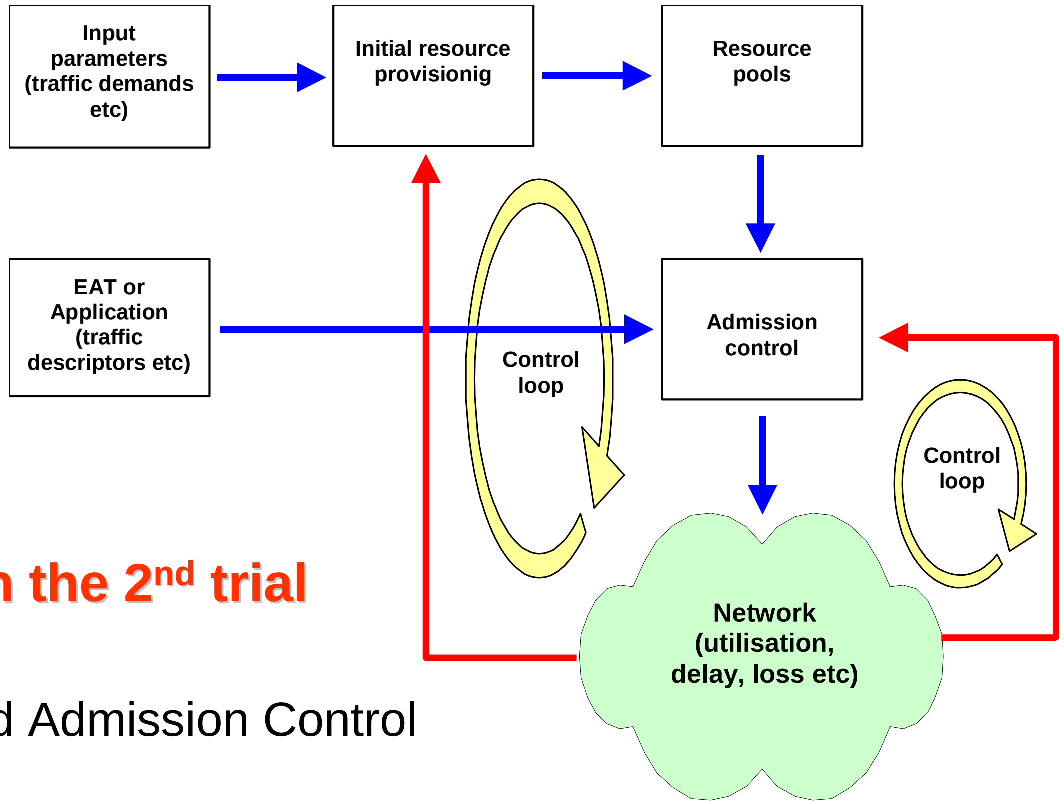
# DMA - Control Loop Support (1)




- Resource control in the 1st trial (open loop)

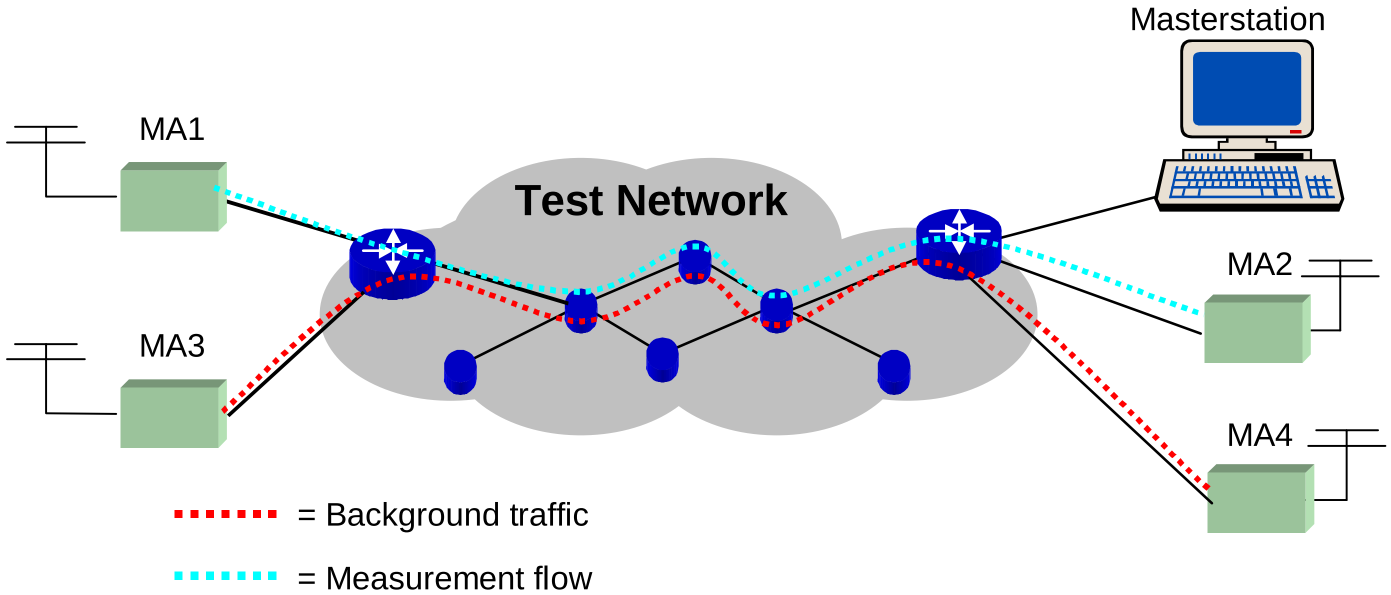
# DMA - Control Loop Support (2)




- **Resource control in the 2nd trial (closed loop)**
  - Measurement Based Admission Control (MBAC)
  - Provisioning Control Loops (PCL)

# DMA - OWD Measurements for MBAC

- **Is the measured One Way Delay suitable for Measurement Based Admission Control (MBAC)?**

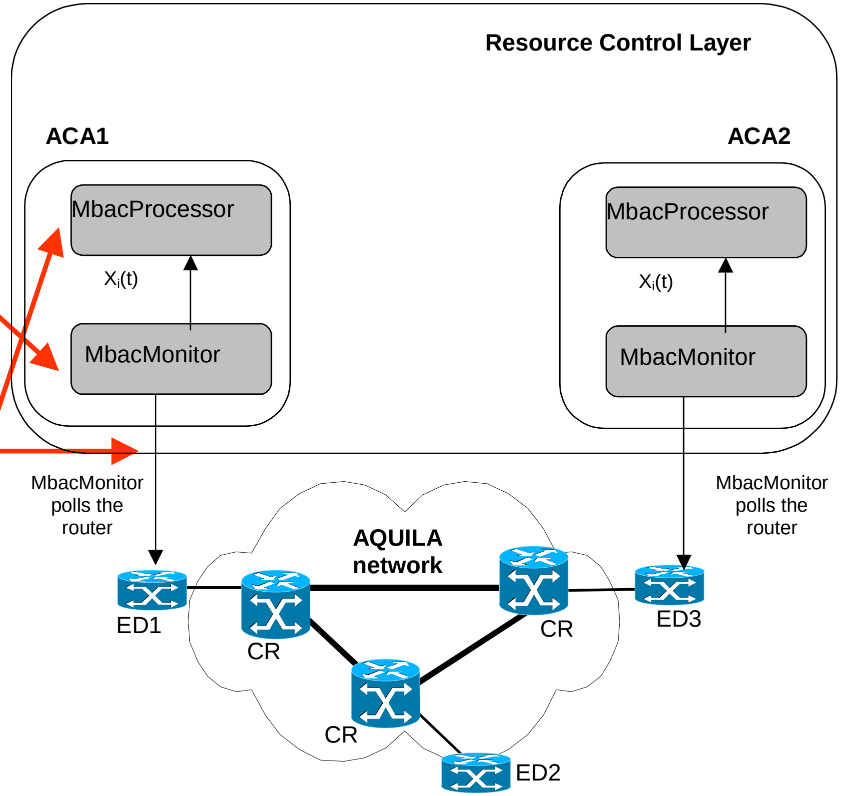


# MBAC Implementation: Function Split

- **MbacMonitor**
  - Measurement agent attached to each ACA
  - Retrieves measurement data $X_{(i)}$ from edge routers
    - manages a list of router interfaces which are to be monitored
    - polls edge router at the end of each measurement interval
    - either monitoring of transmitted bytes on input ports
    - or monitoring of transmitted and dropped bytes on output ports
- **MbacProcessor**
  - Estimates mean load $M_{est(i)}$ from measurement data
  - Keeps state information (mean load, PRs, ...)
    - for each ED, traffic class and direction (ingress, egress)
  - Implements MBAC algorithms
  - AC decision

# DMA - Router Statistics for MBAC

- **Admission control loop using statistics data from routers**
  - Monitor real traffic load on edge link(s) to perform MBAC
  - Retrieve traffic rates for both outgoing and incoming traffic from the router
  - Store traffic rates for MBAC algorithm processing



# DMA - Router Statistics

- **Management Information Collector enhancements for 2nd trial**
  - Distributed design
    - agent controller and DMA database interface
    - Edge Router monitoring integrated with corresponding Admission Control Agents
      - » less interference to network traffic due to monitoring
      - » agents store results to ACA for MBAC and optionally to the DMA database
    - core router monitoring agents stay co-located with the measurement server
  - Easier configuration of router measurements

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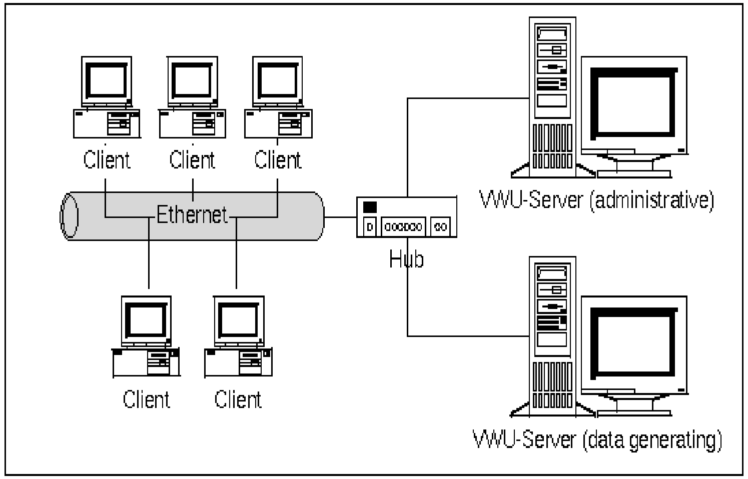
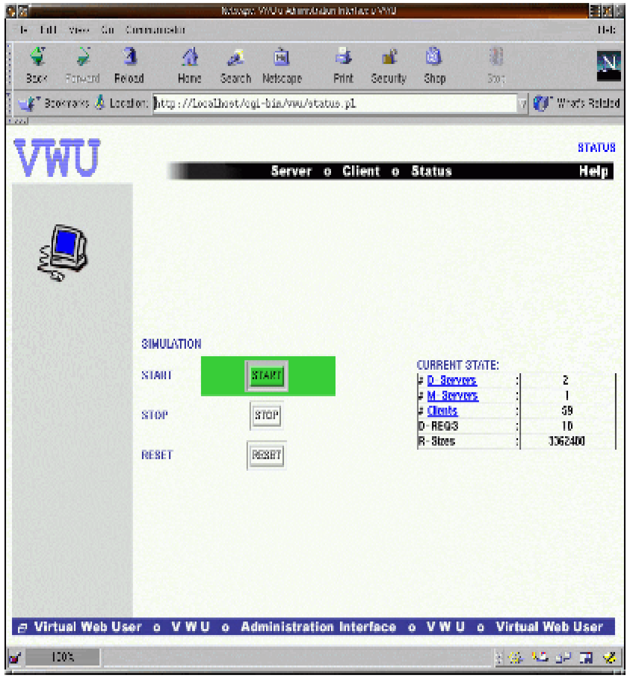
# Virtual WEB User (VWU)

- **3 components**
  - WEB Proxy ➔ traces {object_size, think_time, ...}
  - Statistical models for objects, think_times
  - Load generator: models, traces
- **AQUILA: trial integration of VWU (3/02)**



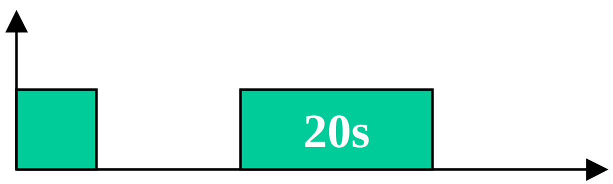



# Virtual WEB User Testing

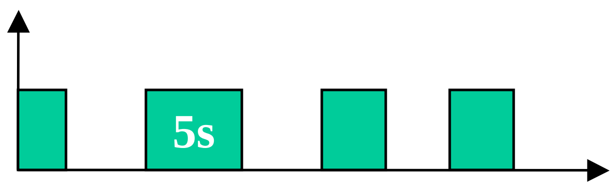
## WEB tests with more realistic load generators

- Derived from different application and network scenarios
- Self-adaptive to network conditions (traces of 64 kbps link users are different from 2 Mbps link users)
- New load generator objects

## QoS-test  for different user characteristics



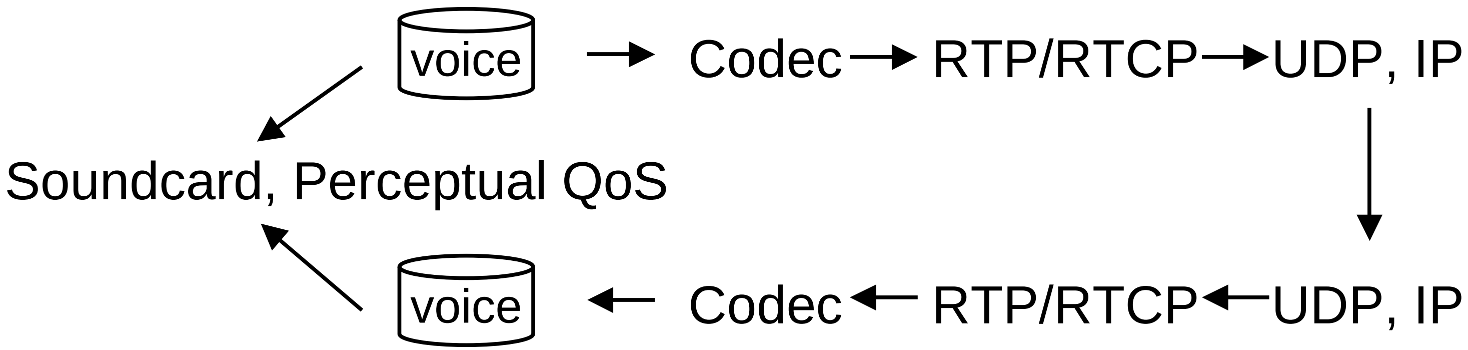

user1: long active/inactive intervals




user2: short active/inactive intervals

# Perceptual VoIP QoS Measurement (1)

- **From „end-to-end“ to „mouth-to-ear“**
- **Perceptual VoIP QoS measurements**
  - e2e IP-QoS ⇒ e2e application QoS (PCBR, TCL1)
    IP {one_way_delay, jitter, loss} ⇒ mouth_to_ear QoS
  - Generation of voice samples (e.g. *.wav-files)
  - Transmission, Perceptual QoS; IPQoS ⇔ Perceptual QoS



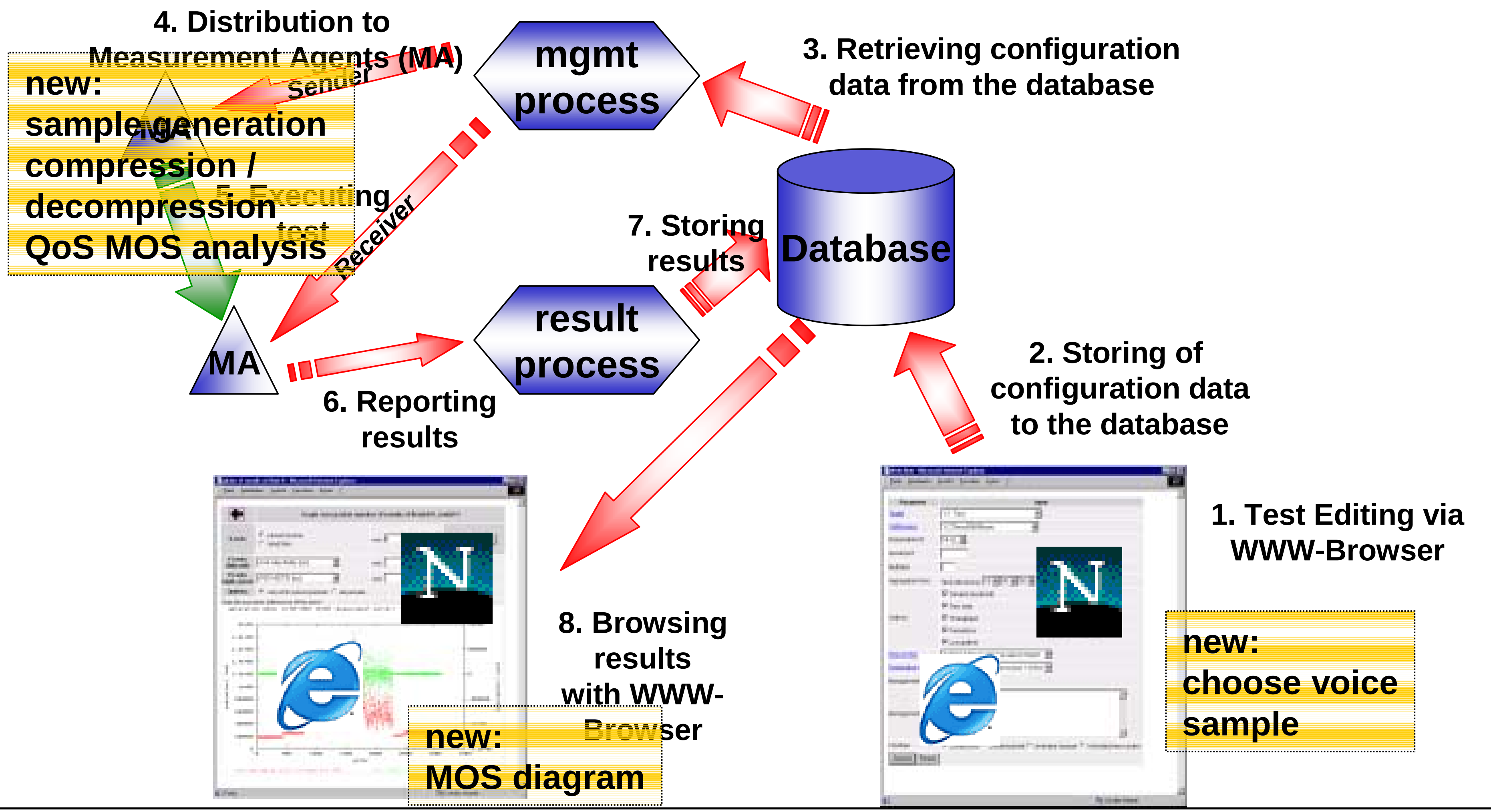
# Perceptual VoIP QoS Measurement (2)

- **Implementations:**
  - PAMS Perceptual Analysis Measurement System (BT 1998)
  - PSQM, PSQM+ Perceptive Speech Quality Measurement (BT, KPN)
  - TOSQA Telecommunications Objective Speech Quality Assessment (DT)
  - Products HP: Agilent Telegra VQT100, $39.000, monitoring of alternative routing for IP telephony
- **Standards:**
  - ITU-T Rec. P.57: Artificial Ear
  - ITU-T Rec. P.862: Perceptual Evaluation of Speech Quality, an Objective Method for end-to-end Speech Quality Assessment of Narrow Band Telephone Networks and Speech Codecs

# Perceptual VoIP QoS Measurement (3)

- **QoS = MOS (Mean Opinion Score)**
  - 5 = Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Bad; 0 = ----
  - Test scenario:
    - VoIP-TCL1-Admission (e.g. BW = 10 kbps)
    - transmission
    - results:
      - » IP-QoS: Delay, Loss
      - » MOS
- **Research project: correlation IP-QoS ⇔ MOS**

# Measurement Process



# Outline

- Measurement architecture
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- **Passive measurement for MBAC validation**
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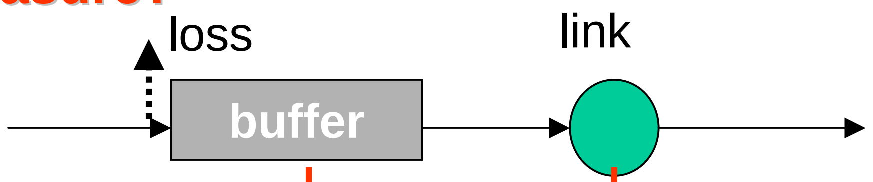
# Approaches for MBAC Measurements

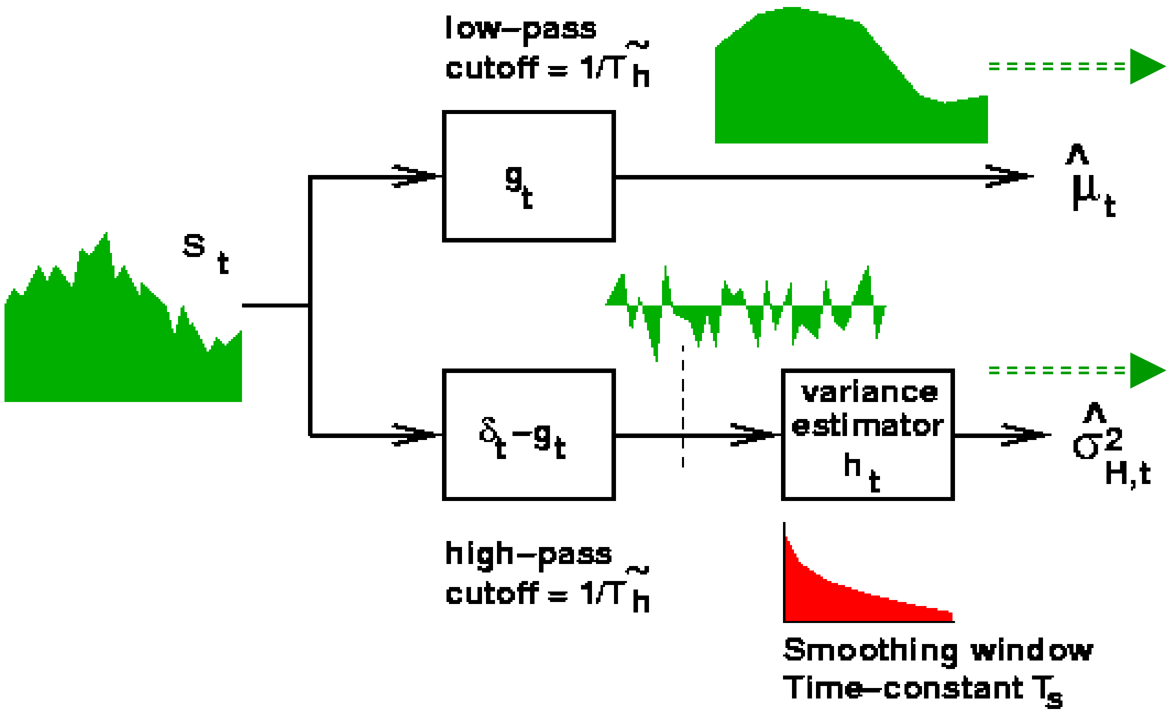
- **AQUILA QoS target: loss rate < $10^{-4..-6}$ | max #flows**
- **Why don‘t we measure loss? Rare events!**
  - Difficult to measure for operational purposes
- **What to measure?**




| M. Siler, J. Walrand, IWQoS98 | AQUILA |
| --- | --- |
| 1st step: measurement based estimation of buffer occupancy | 1st step: measurement based estimation of link load |
| model: buffer occupancy ⇔ loss | model: link load ⇔ loss |

**2nd step: derivation of loss probabilities**

# Measurement Interval (1)



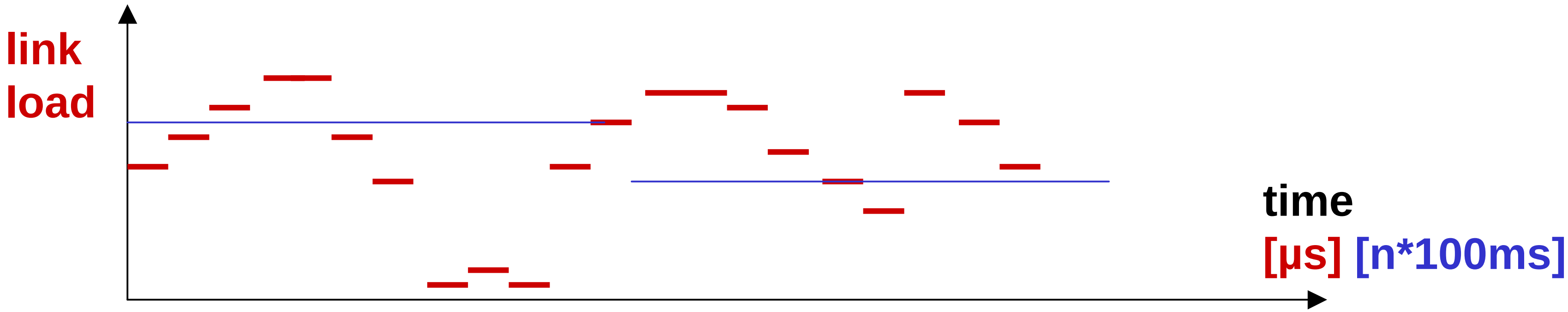

**long term variations:**
**low → new flow accepted**
**high → new flow rejected**

**short term variations:**
**compensated by**
**BW over-provisioning**

- **Open questions: what to measure measurement intervals [µs ... s ... min]**

# Measurement Interval (2)

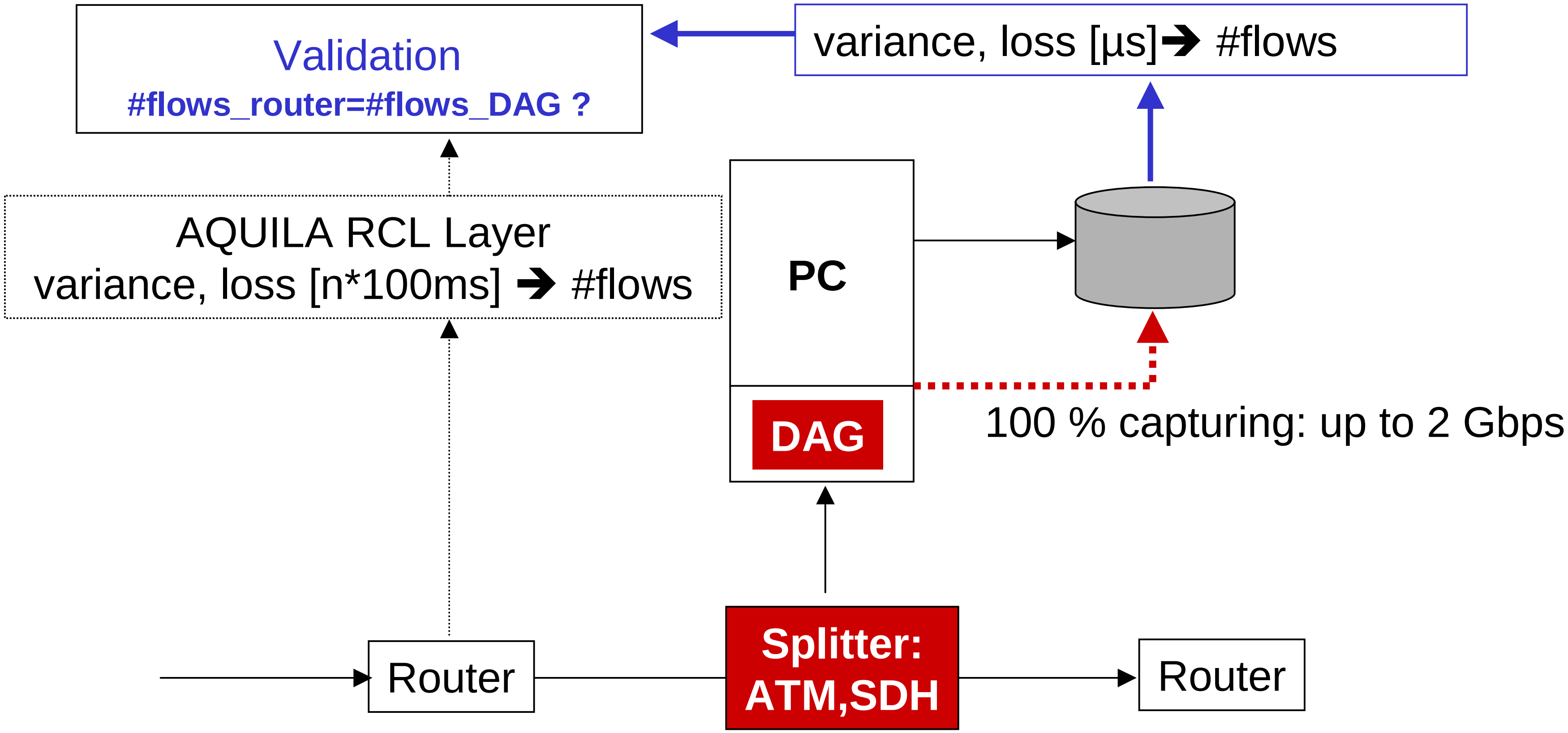
- **Validation necessary**
  - Measurement interval small enough?




  - No: high load values smoothed ⇔ loss intervals not detected
  - Yes:
    - – bucket parameters = worst case variation
    - – long term variations can be measured
      - » validation of the AQUILA MBAC by passive and active measurements

# Validation Architecture

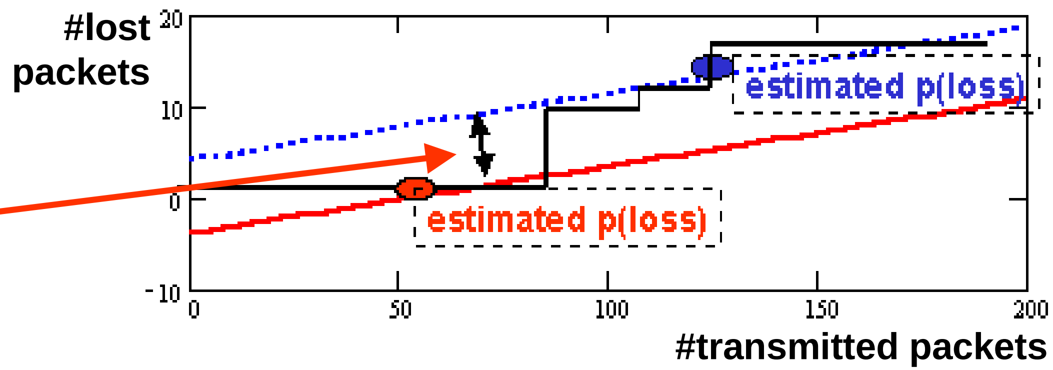
- **Accurate variance estimation: Passive measurements**



# Loss Rate Estimation

**Sequential testing [Wald]**

- Hypothesis 1: p(loss) = p1
- Hypothesis 2: p(loss) = p2
- $\alpha$: type1 error

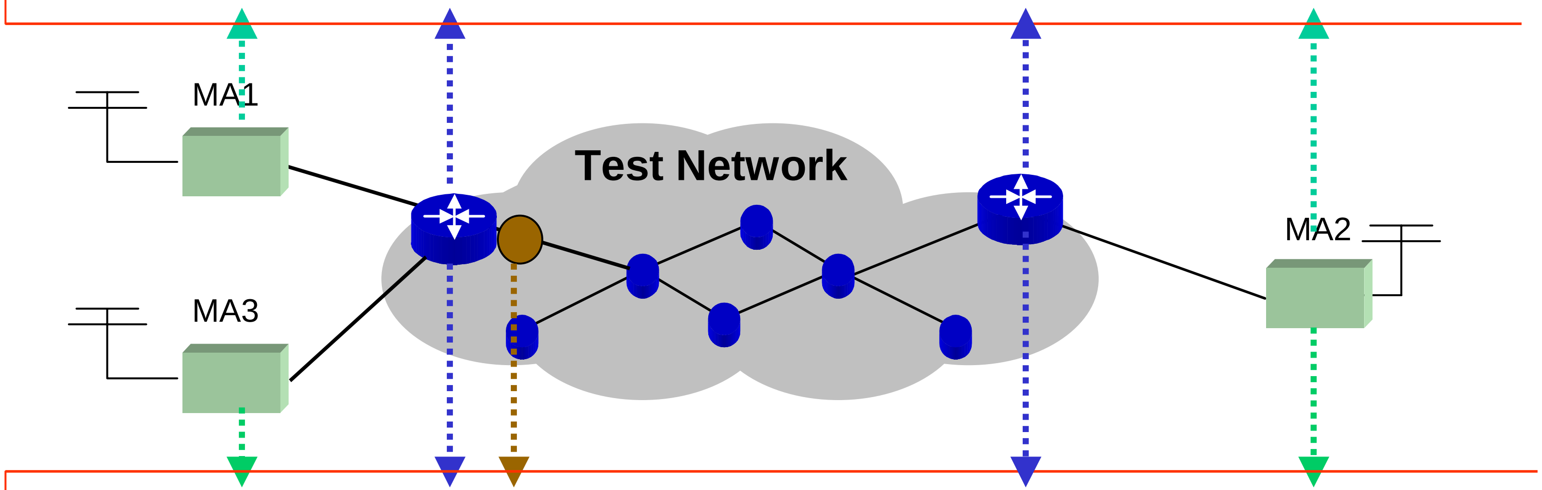



## Result for $10^{-3}$

- Mean = 1000 packets ➔ take 2000 packets
- $\alpha$-accurate loss estimation for passive and active measurements
- Estimation of test run length (new feature DMA edit GUI 2nd trial)

# DMA Status and Plans

- **Operational measurements (Control Loop)**
  - **Router statistics (load, future R&D: loss)**
  - **Probing**




- **Validation measurements**
  - **Application-like flow generators**
  - **Passive measurements with DAG card (load, loss)**
  - **Router monitoring (load, loss)**
- **Continuously enhanced GUI, DataBase**

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- Measurement architecture
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# State of the Art - IETF (1)

- **Traffic flow measurement architecture**
  - RFC2722 [N. Brownlee, C. Mills, G. Ruth, October 1999]
  - Today's measurement architectures: how, what?
- **Next steps for the IP QoS architecture**
  - RFC2990 [G. Huston, Nov. 2000]
  - QoS discovery
    - no mechanisms exist to query the network for the potential to support a specific service profile
  - QoS Routing and Resource Management
    - spreading the load across a broader collection of network links
  - Calculate per-path dynamic load metrics
  - Metric: path's potential to carry additional traffic

# State of the Art - IETF (2)

- **A Migration Path to provide End-to-End QoS over Stateless Networks by Means of a Probing-driven Admission Control**
  - *draft-bianchi-blefari-end-to-end-qos-01.txt*, 7/2001
  - Implicit signalling paradigm GRIP (Gauge&Gate Reservation with Independent Probing)
  - Probes and Information packets different labels (DS codepoint) service priority to Information packets
- **Transport Performance Metrics MIB**
  - *draft-ietf-rmonmib-tpm-mib-03.txt*, R. Dietz, R. Cole 7/2001
  - General framework for the collection and reporting of performance related metrics on traffic flows in a network

# State of the Art - Conferences (1)

- **PAM (Passive and Active Measurement): 2001 Amsterdam**
  - Telcordia RONDO: Real-Time Measurement → MPLS re-routing
  - SPRINT: Passive Measurement DAG → 5µs accuracy;16 LINUX-Cluster
  - RIPE: Active Measurements, Infrastructure
  - N. Brownlee: Stream/Flow-Statistics, Simple Rule Language (SRL)

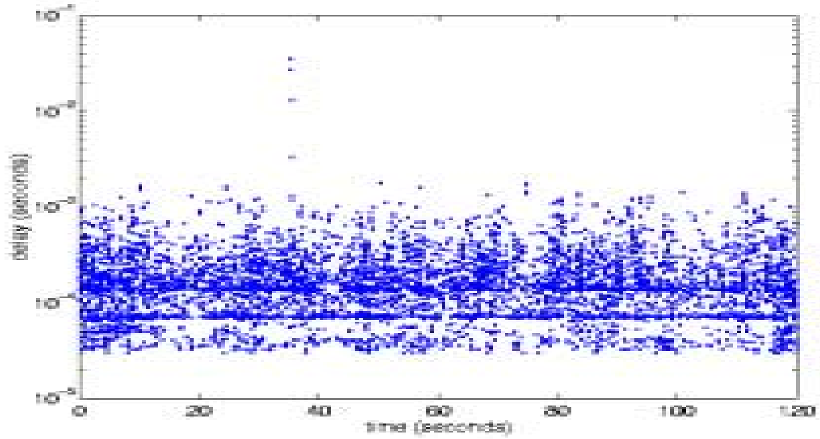



Fig. 13. Delay from *web-in* to *peer-out*

30 s pathological behaviour: difficult to detect without monitoring

# State of the Art - Conferences (2)

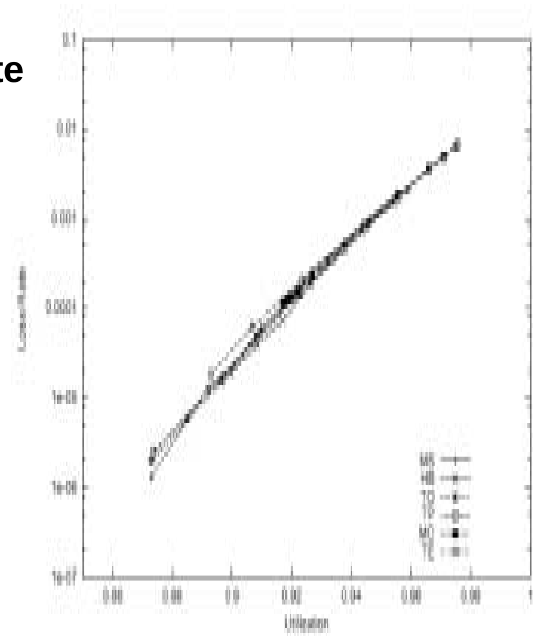
## SIGCOM IMW2001

- J.Micheel, S. Donelly, I. Graham: Precision Timestamping of Network Packets
- G. Iannaccone, C. Diot, I. Graham, N. McKeown: Monitoring very high speed links
- M.J. Luckie, A.J. McGregor, H.W. Braun: Towards Improving Packet Probing Techniques IPMP IP Measurement Protocol

# State of the Art - Conferences (3)

- **Shenker et al.**
  - No difference between the different MBAC algorithms
  - Network operators will need to monitor actual performance in order to learn appropriate parameter setting for prediction, smoothing, ...

**loss rate**



**link utilisation**

**exploitation**

AQUILA

# Exploitation

Bilateral projects with AQUILA partners Siemens, TA, DT

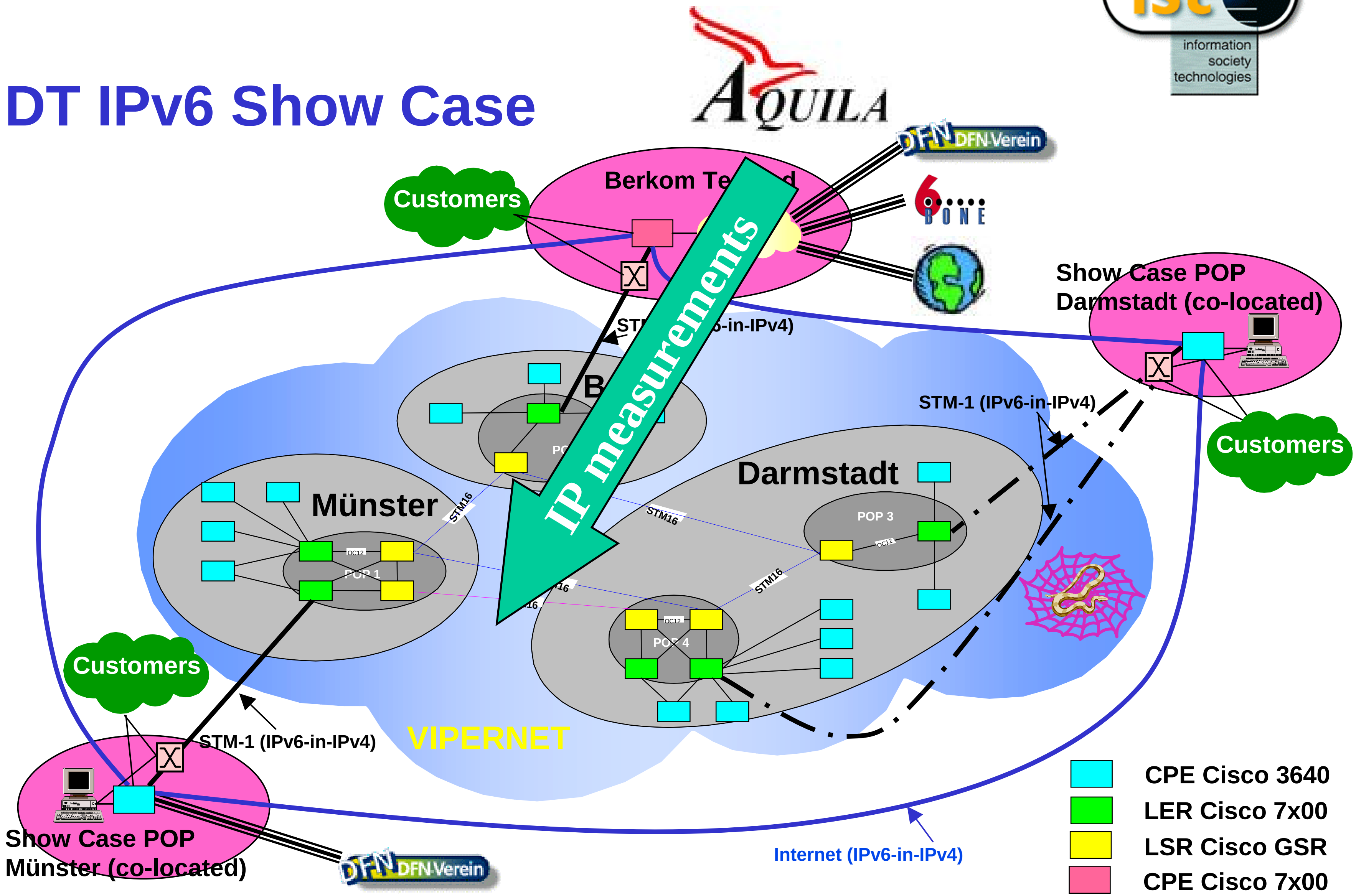
Courses at FH Salzburg (Internet-Technologies)

AQUILA

Interdisciplinary research: Telemedicine

New EU IST proposal

# DT IPv6 Show Case



# CeBIT 2002

- **13.-20.3. 2002 Hall 11**
  **FH Salzburg & SalzburgResearch**
- **AQUILA demo (1st concept)**
  - 3 „real" applications:
    PCBR, PVBR, STD
  - Increase background load
  - Show  QoS stability for
    PCBR, PVBR
- **AQUILA documentation**

# Control Loops

# Outline

- Overview
- Measurement Based Admission Control (MBAC)
- Provisioning Control Loops (PCL)

# Resource Management in 1st Trial

traffic forecasts → **Provisioning**

↓

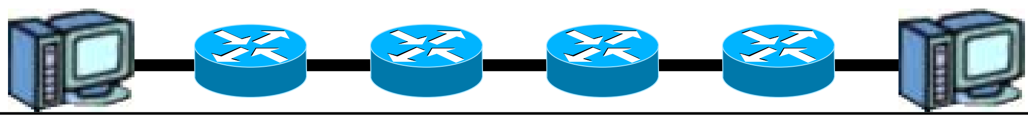
measurements → **Resource Pool**

↓

traffic models → **Admission Control**

↓

traffic descriptor → **Individual Flow**



**View:**

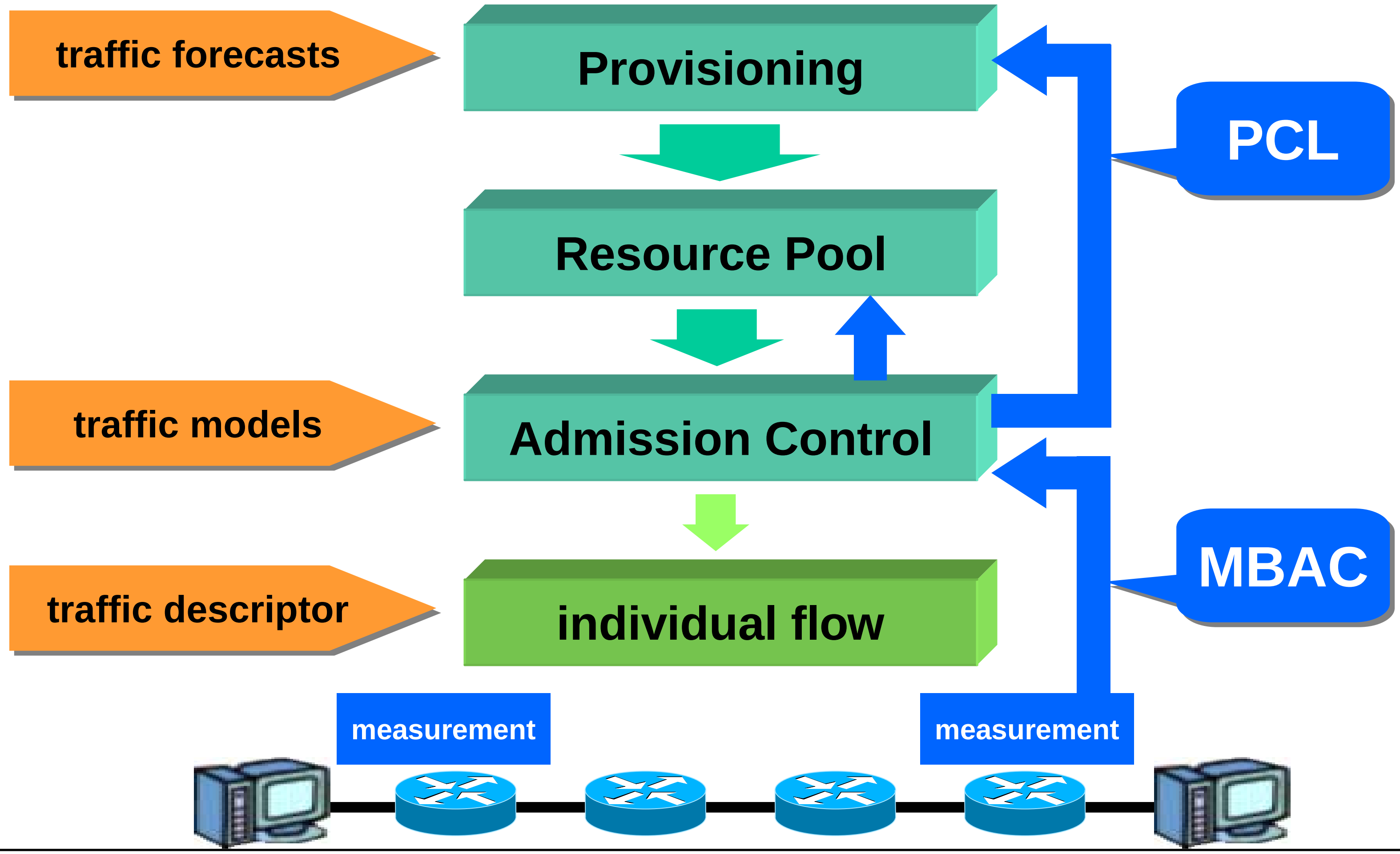
- Global network
- Traffic collection / distribution area near network border
- Available bandwidth at edge router
- Perceived QoS

# Control Loops (1)

## Idea

- Use feedback from measurements
  - traffic load
  - QoS
- Adapt resource management to real situation
- Instead of blind following assumptions
  - traffic forecasts
  - traffic models

# Control Loops (2)



# Outline

- Overview
- **Measurement Based Admission Control (MBAC)**
- Provisioning Control Loops (PCL)

# MBAC Approaches

## Aggregate stream measurement

- Estimation of mean rate
  - simple implementation
- Estimation of mean rate and variance
  - variability of traffic is difficult to capture
  - some self-similar traffic models show unlimited variance
  - requires special measurement functions
  - requires very small measurement intervals,
    if variance has to be determined from mean rate measurements
  - better performance in terms of achieving QoS targets

## Per flow measurement

- Complex implementation

# MBAC Approaches

- **Aggregate stream measurement**
  - Estimation of mean rate
    - simple implementation
  - Estimation of mean rate and variance
    - variability of traffic is difficult to capture
    - some self-similar traffic models show unlimited variance
    - requires special measurement functions
    - requires very small measurement intervals, if variance has to be determined from mean rate measurements
    - better performance in terms of achieving QoS targets
- **Per flow measurement**
  - Complex implementation

# Estimation of Mean Rates

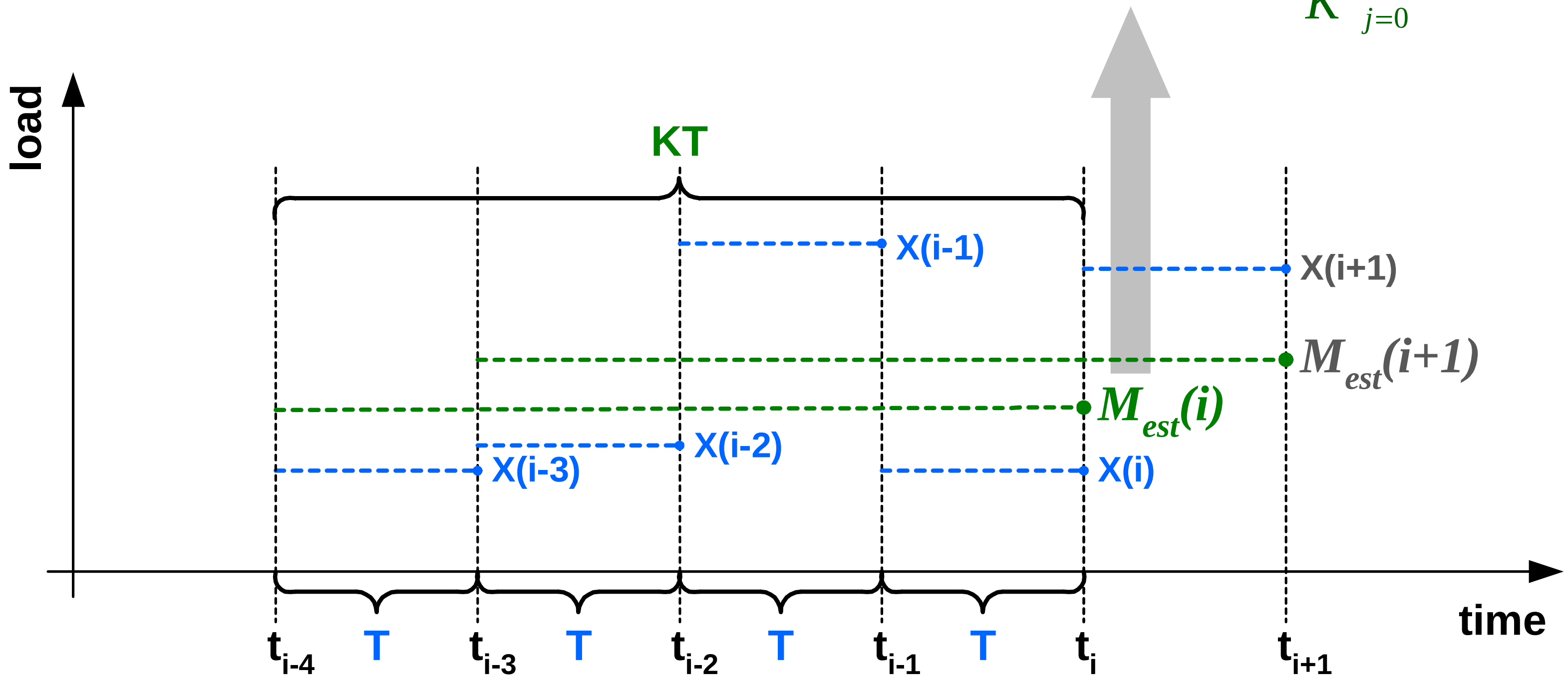
- **Sampling**
  - Sampling intervals with fix length T
  - X(i) - measured mean rate in sampling interval i
- **Estimation**
  - Moving average (window based mean rate estimation – moving window)
  - Fix window size K (number of sampling intervals)
  - Mean of measurement values of K sampling intervals

$$M_{est}(i) = \frac{1}{K} \sum_{j=0}^{K-1} X(i-j)$$

  - After each sampling interval a new $M_{est}$ is calculated

# Measurement Scheme

$$M_{est}(i) = \frac{1}{K}\sum_{j=0}^{K-1} X(i-j)$$

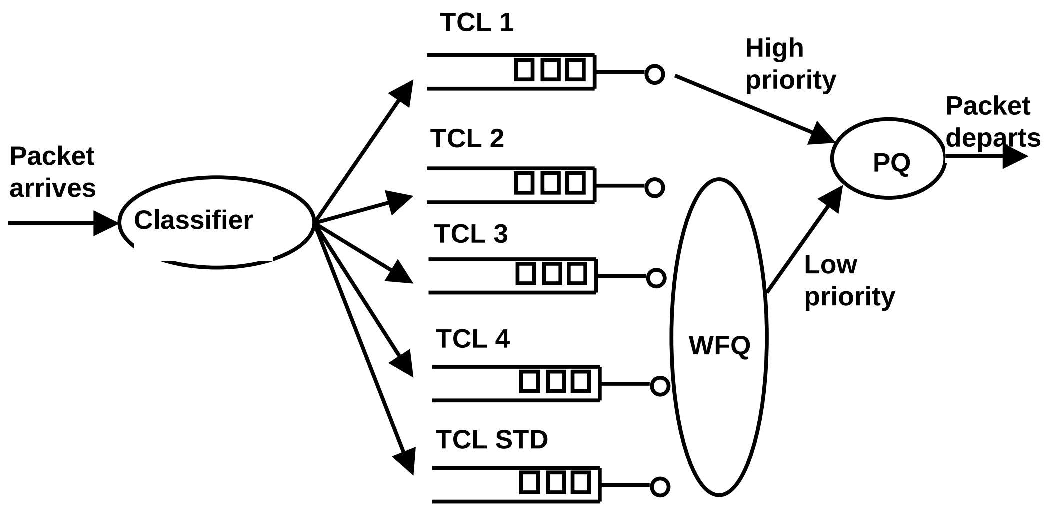


# Traffic Classes

- **Five Traffic Classes have been specified**

| **Network service** | Premium CBR | Premium VBR | Premium MultiMedia | Premium Mission Critical | Standard |
|---|---|---|---|---|---|
| **Traffic class** | TCL 1 | TCL 2 | TCL 3 | TCL 4 | TCL STD |

- **… as well as the related Traffic Control Mechanisms in the Routers**



# MBAC for TCL1
## Basic Scheme

$$PR_{new} + M_{est} \leq \rho C_1$$

- Aggregate sum
- $PR_{new}$ peak rate of new flow
- $M_{est}$ estimation of aggregate mean rate
- $\rho$ utilisation target (tuneable parameter)
- $C_1$ resources available for TCL1 (e.g. AC limit)

# MBAC for TCL1
# Peak Rate Reservation Refinement

$$\boldsymbol{PR + M_{est} \le \rho C_1}$$

$$PR = PR_{new} + \sum_{i=1}^{A} w_i \; PR_i^{aggr} \qquad \boldsymbol{PR_i^{aggr} = \sum_{j=1}^{n_i} PR_{ij}} \qquad w_i = e^{-i/\tau}$$

- **Takes peak rates of previously accepted flows into account**
  - recently admitted flows are reflected in measurements after some delay only
  - avoids accepting more flows than fit into the available bandwidth
- **$PR_i^{aggr}$** **sum of PR of flows accepted in measurement interval i**
- **A** **aging window**
- **$PR_{ij}$** **PR of $j^{th}$ reservation in measurement interval i**

# MBAC for TCL2

$$PR_{new} + M_{est} + \sqrt{\frac{\gamma}{2}\sum_{i=1}^{N_2} PR_i^2} \leq C_2 \qquad \gamma = -\ln(P_{loss})$$

- **Hoeffding bound**
- **$PR_{new}$** peak rate of new flow
- **$M_{est}$** estimation of aggregate mean rate
- **$C_2$** resources available for TCL2 (e.g. AC limit)
- **$N_2$** number of reservations in TCL2
- **$PR_i$** peak rate of $i^{th}$ still active reservation
- **$P_{loss}$** target packet loss ratio

# MBAC for TCL3

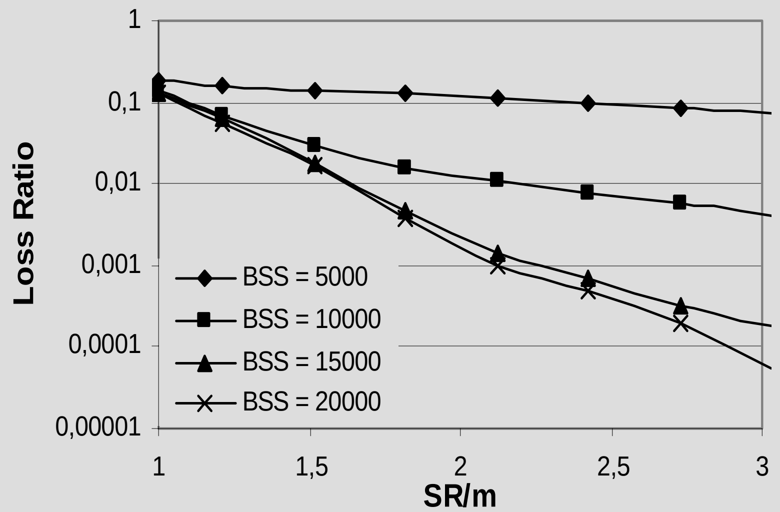
$$( SR_{new} + \sum_{k} SR_k \leq \rho_{3_1} C_3 ) \quad or \quad ( SR + M_{est} \leq \rho_{3_2} C_3 )$$

$$SR = SR_{new} + \sum_{i=1}^{A} w_i \, SR_i^{aggr} \qquad \boldsymbol{SR_i^{aggr} = \sum_{j=1}^{n_i} SR_{ij}} \qquad w_i = e^{-i/\tau}$$

- **EITHER:** **sum of SRs has to be below the available capacity**
- **OR:** **similar MBAC method as used for TCL1 base on**
  - sustainable rate
  - estimation of mean rate of „in-profile" packets
- **The sum of declared SR parameters cannot over-allocate the available capacity more than n-times (protection against measurement error)**
- **$SR_i^{aggr}$** **sum of SR of flows accepted in interval i**
- **A** **aging window**

# Potential Benefits of MBAC (1)

- **Token bucket characterisation requires significant over-allocation of token rate in case of real traffic sources**
- **Required SR is significantly larger than mean rate**
  - 3 times for $P_{loss}=10^{-4}$

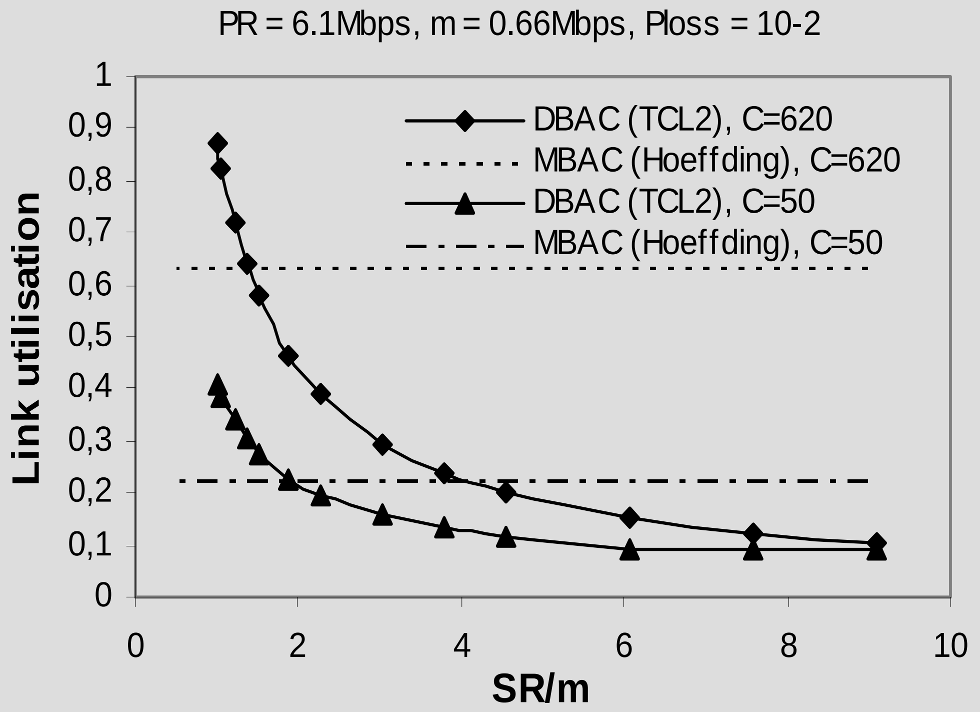



**Packet Loss**

- **due to Policing**
- **MPEG trace**
- **different token bucket parameter**
  - **token rate**
  - **bucket size**

# Potential Benefits of MBAC (2)

- **MBAC is more efficient than DBAC (Declaration Based Admission Control) when SR/m is > 2**



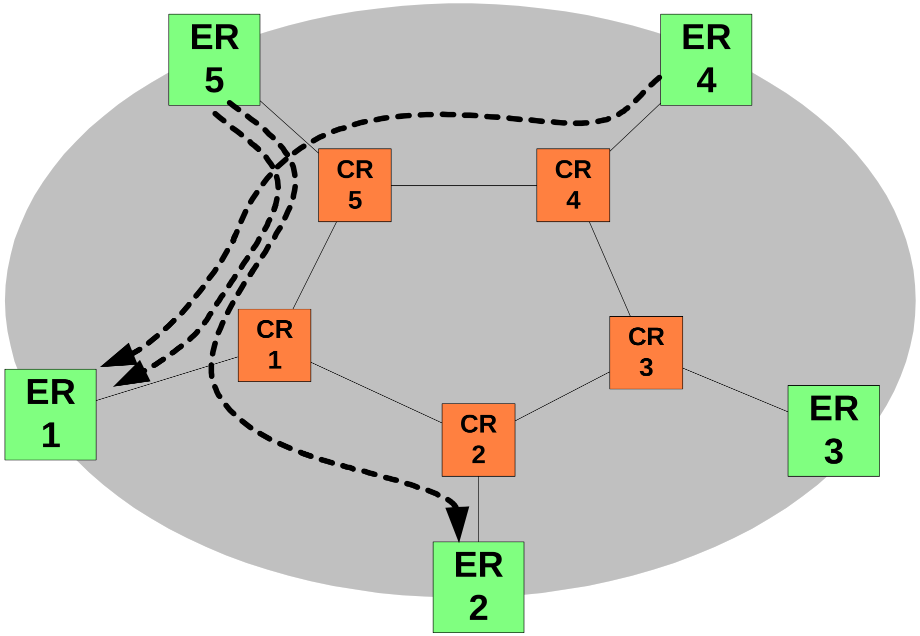

## Link Utilisation

- **MPEG trace**
- **different token bucket parameter**
  - **token rate**

# Outline

- Control Loops
- Measurement Based Admission Control (MBAC)
- Provisioning Control Loops (PCL)

# Does AQUILA need a PCL?

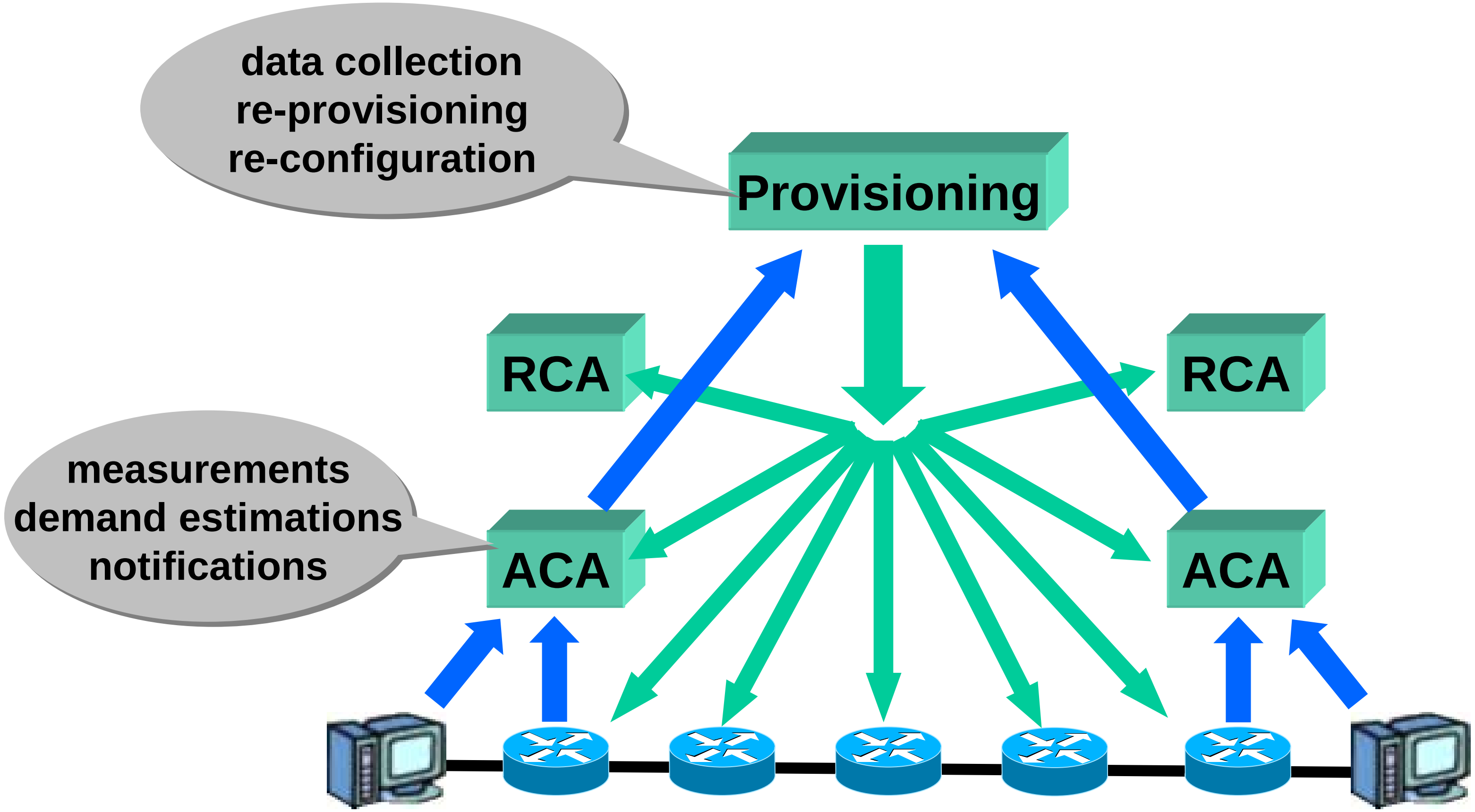



- **What bandwidth is needed between CR5 and CR1?**
  - Routing minimises hop count
  - All AC limits are 1 Mbps
  - Equal traffic distribution: 0,6 Mbps
  - Worst case: 2 Mbps
- **How is blocking probability?**

# PCL Aims

- **Dynamic control of**
  - Scheduling (WFQ weights)
  - AC limits
  - RP limits
- **Goals**
  - Optimised resource utilisation
  - Assure QoS targets
- **Constraints**
  - There is sufficient BW
  - Adapt BW partition for traffic classes only

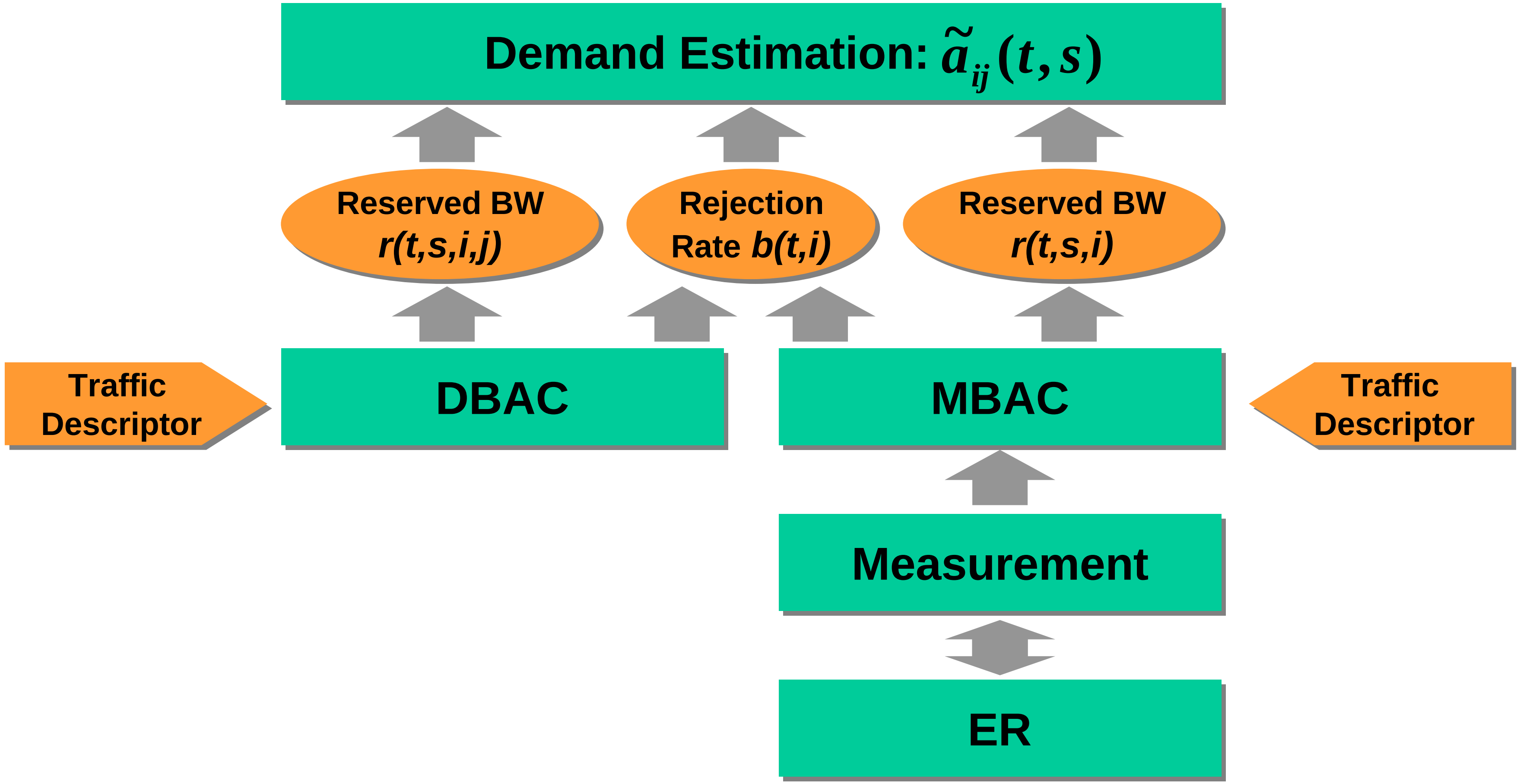
# PCL Architecture



# PCL Sequence of Events

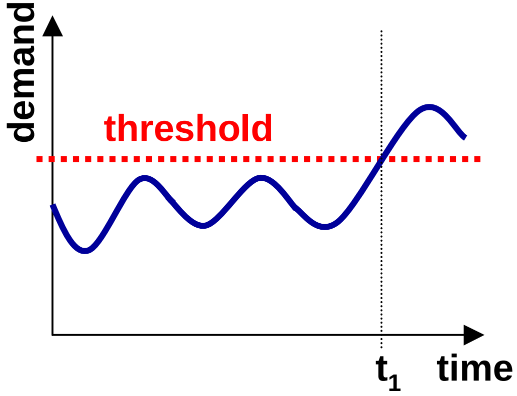
- **Measurement of blocking frequency**
  - At each ACA for each (TCL, ER)
- **Estimation of BW demand**
  - DBAC: at each ACA for each (TCL, ingress ER, egress ER)
  - MBAC: at each ER for each (TCL, interface)
- **Problem detection**
  - Notification triggers re-provisioning
- **BW partition**
  - For each (TCL, link)
- **Computation provisioning parameter**
  - WFQ weights for ER, CR
  - AC limits for each (TCL, ER)
  - RP limits for each RP

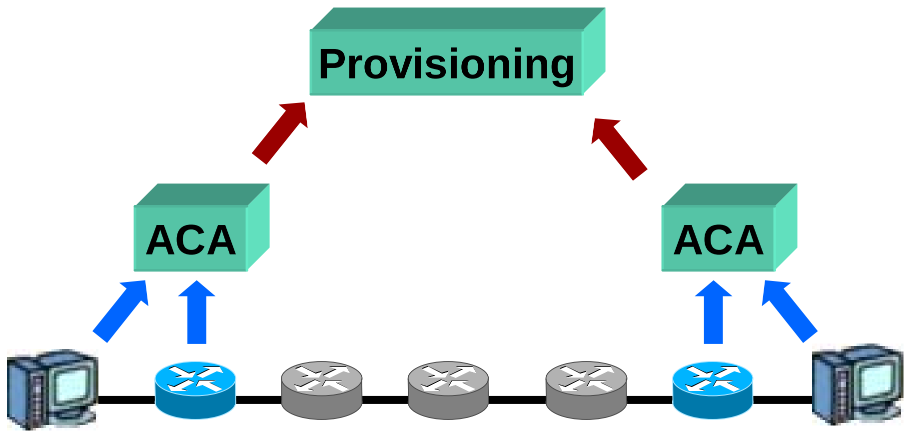
# Demand Measurement and Estimation



# DBAC Based Re-Provisioning

- **Event triggered**



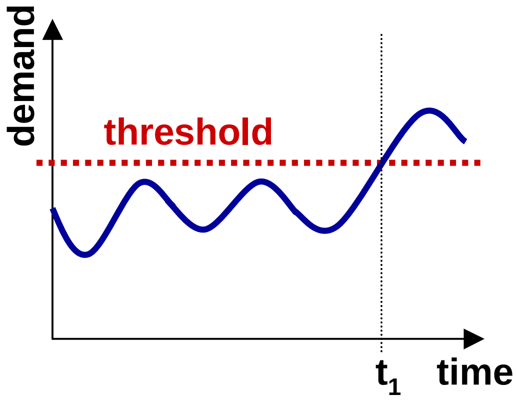



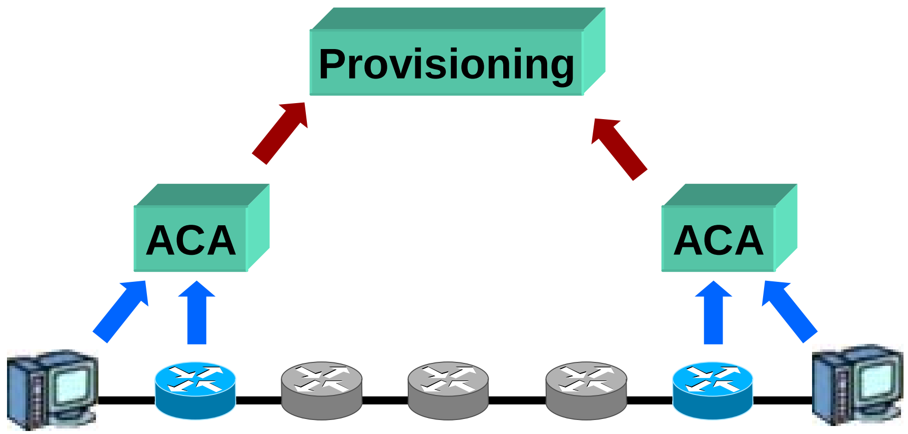

- **Local observation of demand matrix at network border**

$$\begin{pmatrix} \tilde{a}_{11}(t,s) & \tilde{a}_{12}(t,s) & \dots & \tilde{a}_{1N}(t,s) \\ \tilde{a}_{21}(t,s) & \tilde{a}_{22}(t,s) & \dots & \tilde{a}_{2N}(t,s) \\ \dots & & & \dots \\ \tilde{a}_{N1}(t,s) & \tilde{a}_{N2}(t,s) & \dots & \tilde{a}_{NN}(t,s) \end{pmatrix} \leq \begin{pmatrix} a_{11}(s) & a_{12}(s) & \dots & a_{1N}(s) \\ a_{21}(s) & a_{22}(s) & \dots & a_{2N}(s) \\ \dots & & & \dots \\ a_{N1}(s) & a_{N2}(s) & \dots & a_{NN}(s) \end{pmatrix}$$

# MBAC Based Re-Provisioning

- **Event triggered**




- **Local observation of demand vector at network border**

$$\begin{pmatrix} \tilde{A}_1(t,s) \\ \tilde{A}_2(t,s) \\ \dots \\ \tilde{A}_N(t,s) \end{pmatrix} \leq \begin{pmatrix} A_1(s) \\ A_2(s) \\ \dots \\ A_N(s) \end{pmatrix}$$

## Summary

- **Assumptions are replaced by measurements**
  - Improved resource utilisation / QoS
- **Local measurements at the network edge**
  - Window based mean rate estimations at edge router interfaces
  - Demand and blocking in ACAs
- **Local processing of measurement data at the network edge**
  - ACA
- **Different MBAC algorithms for TCL1, TCL2 and TCL3**
  - Adapted to specific requirements of each traffic class
- **Next steps**
  - Implementation and test of control loops in second phase
  - Performance studies
  - Validation by passive measurements

# BGRP Quiet Grafting

# An Approach for a Scalable Inter-Domain Resource Control

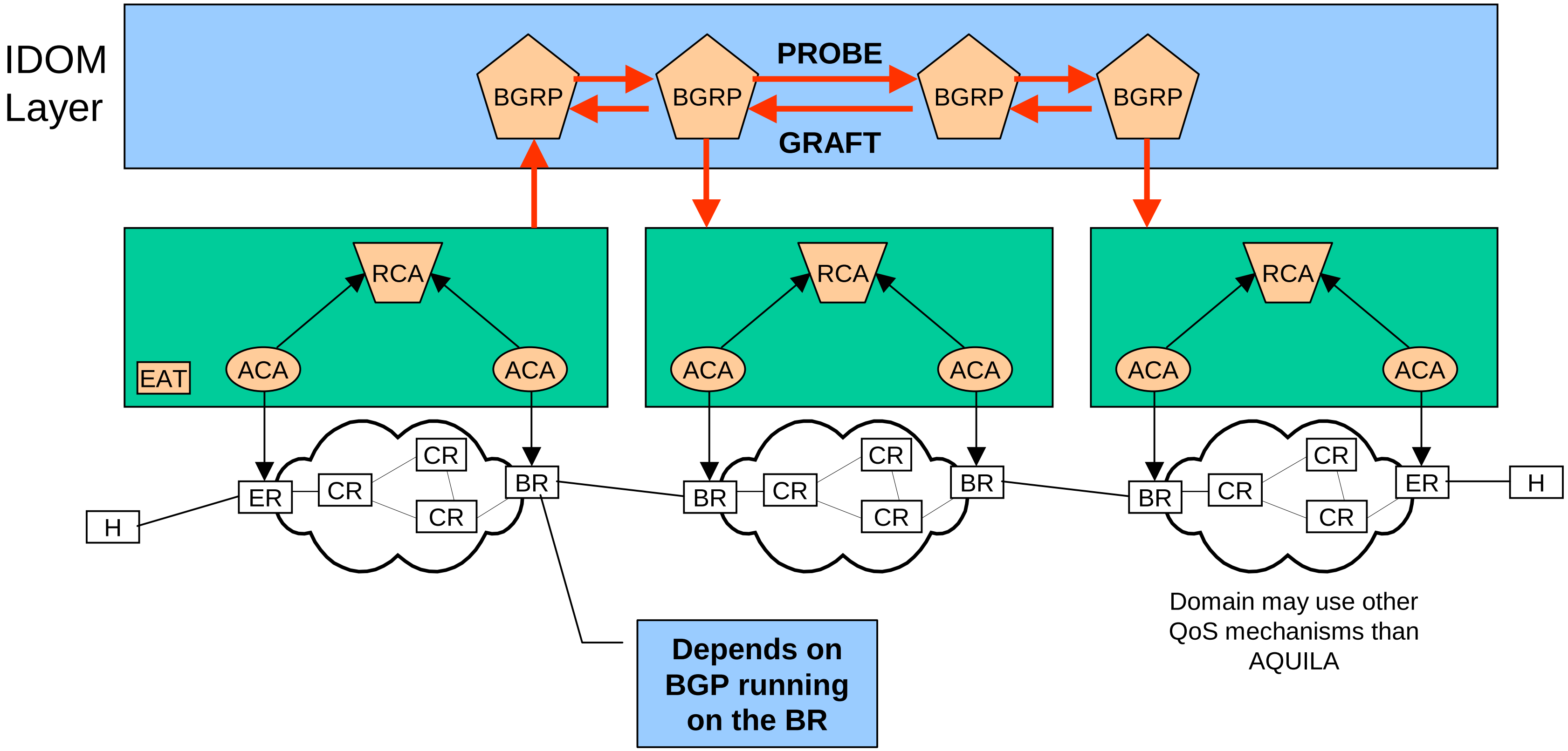
# Outline

- Short Review of BGRP
- BGRP and scalability: problems and solutions
- Simulation results

# Short Review of BGRP

- **Inter-domain resource reservation protocol**
  - Additional layer on top of intra-domain resource control
- **BGRP agents associated with border routers**
  - May run co-located or on other associated device
- **Depends on BGP running on the BRs**
  - Uses the BGP sink trees for reservation aggregation
- **Simple soft-state messages**
  - Downstream: PROBE message identifies sink tree and checks policy
  - Upstream: GRAFT message makes reservation

# Short Review of BGRP

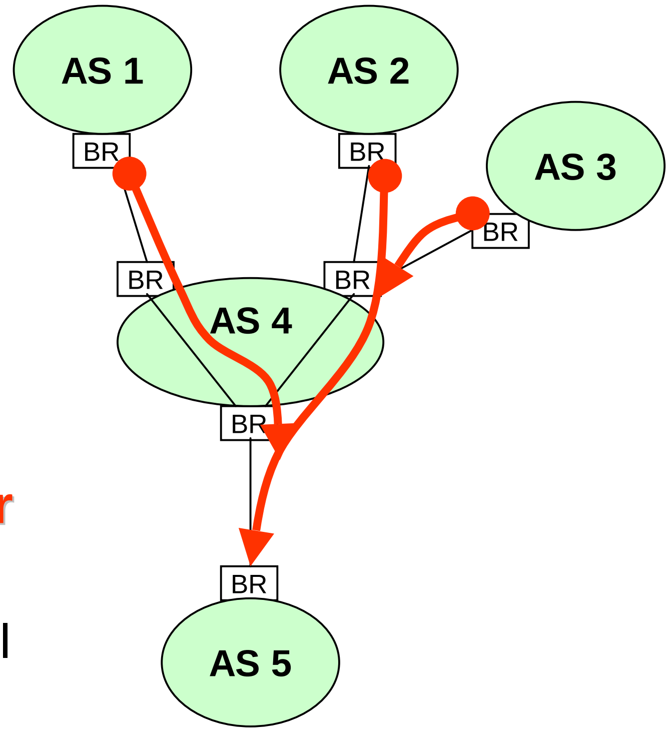


# Outline

- Short Review of BGRP
- BGRP and scalability: problems and solutions
- Simulation results

# BGRP and Scalability

- **BGRP aggregates reservations along BGP sink trees**
- **BGRP limits the number of active reservations at each node**
  - Maximum: number of Autonomous Systems (AS) in the Internet
  - BGRP limits memory usage in BGRP agents
- **BGRP does not reduce the number of signalling messages**
  - PROBE and GRAFT messages travel end-to-end
  - BGRP does not limit the necessary processing power in BGRP agents



# Quiet Grafting

- **How can we reduce the number of signalling messages?**
  - Shorten the path of the messages
  - Answer PROBE messages as early as possible before the destination AS
- **What is necessary for quiet grafting? Three problems!**
  - Identify the sink tree before the destination AS
  - Use pre-reserved resources on the sink tree
  - Establish mechanisms for reservation of resources within the destination domain

# Problem 1: Identification of Sink Tree

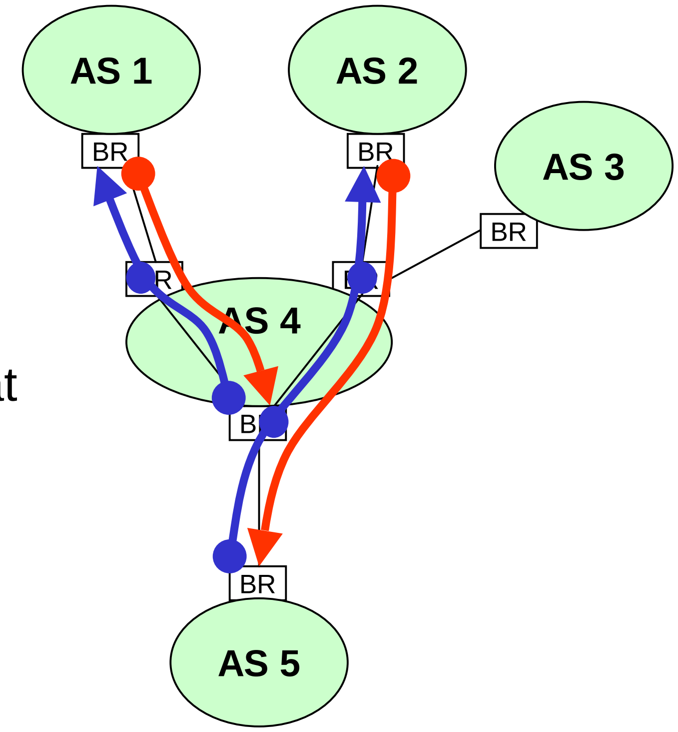
- **Sink tree identification**
  - Sink trees are identified by their root: the destination AS number and an identification of the border router in the destination AS (entry point)
  - Sink trees collect all traffic identified by the Network Layer Reachability Information (NLRI) announced by that root
- **Sink trees are not BGP routes**
  - BGP may aggregate several routes
  - However, multiple BGRP sink trees must not be aggregated
  - So BGP routing information is not sufficient to identify a sink tree

# Solution 1: BGRP Sink Tree Identification

- **Install sink tree identification information**
  - Return sink tree identification information with GRAFT messages
    - AS, BR id
    - NLRI
  - Store this information at every BGRP agent, which handles the GRAFT message
- **Use information for early sink tree identification**
  - Match further requests with the stored NLRI to identify the sink tree as early as possible
  - Sink tree may be identified at the point, when a PROBE message hits an already existing reservation for that sink tree
  - Use REFRESH messages to validate the NLRI information

# BGRP Sink Tree Identification

- **Installing the NLRI information**
  - First PROBE sent from AS2 to AS5
  - GRAFT installs AS5 NLRI in intermediate BGRP agents
- **Use NLRI for quiet grafting**
  - PROBE from AS1 hits the sink tree at the egress BR of AS4
  - AS4 may already return a GRAFT message without forwarding the message to AS5

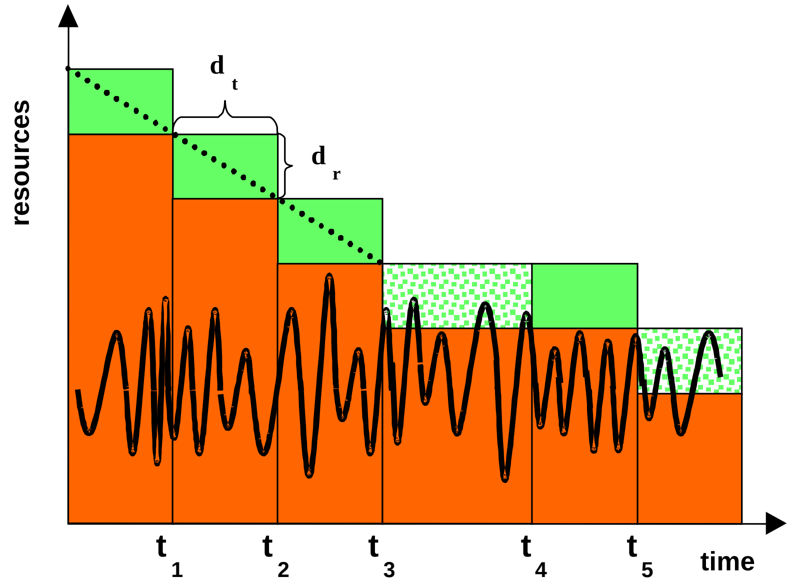


# Problem 2: Pre-Reserved Resources

- **Need for resource cushions**
  - A GRAFT message can only be generated, when pre-reserved resources are available within the network
- **Trade-off between network utilisation and signalling load reduction**
  - It is a crucial point for network utilisation to find a proper algorithm

# Solution 2: Delayed Resource Release

- **Regular checks**
  - Check resource utilisation at regular intervals
- **Return policy**
  - Return fixed size block of resources, if it was unused during the complete Retain Period (RP)
  - Return Block Size (RBS) and Retain Period are configurable and determines performance of algorithm



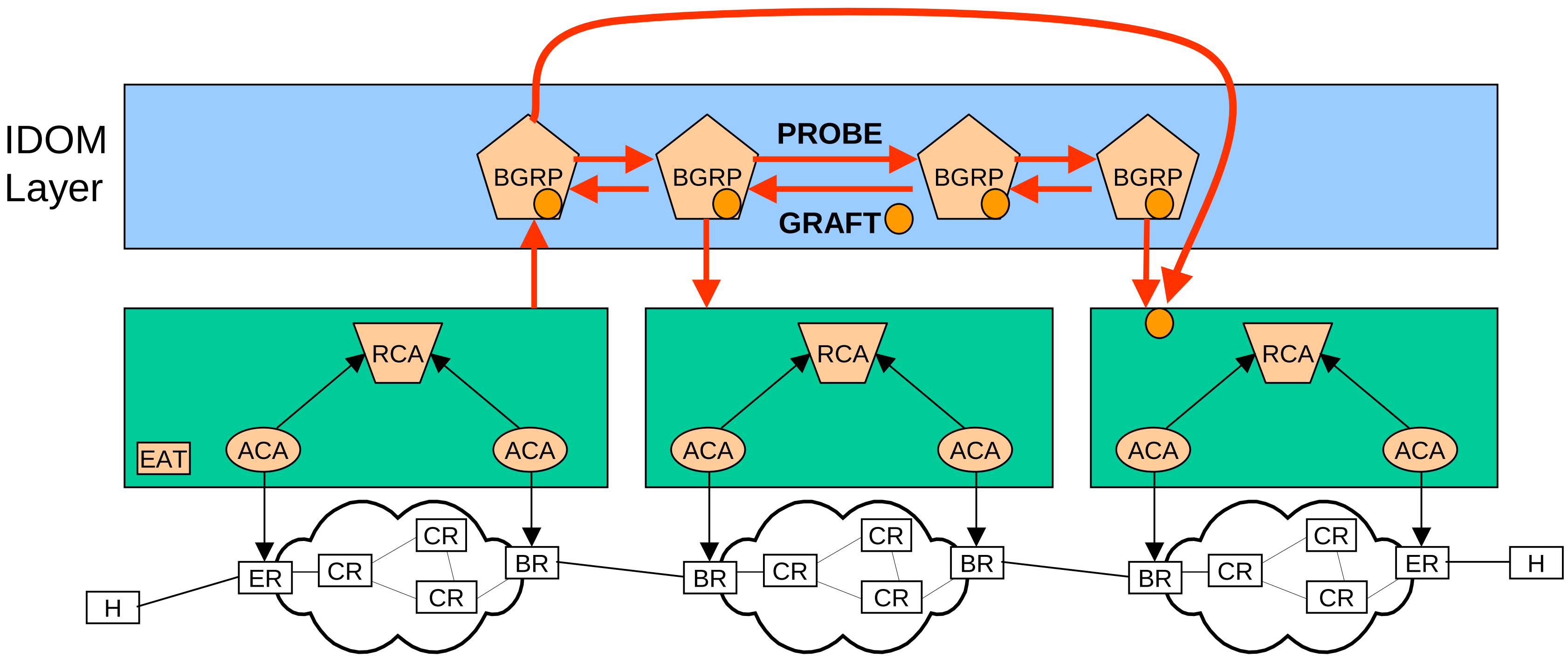
# Problem 3: Reservation in the Last Domain

- **Destination domain is not aware of new reservation**
  - With quiet grafting, there is no signalling message travelling to the destination domain, which indicates the new reservation
  - Resource availability is guaranteed throughout the way to the destination domain, but not within that domain

# Solution 3: Direct Signalling

- **Establish communication**
  - Along with the GRAFT message, return an object reference to the intra-domain resource control
  - Store this object reference along with the sink tree identification and NLRI at each intermediate BGRP agent
- **Direct interaction**
  - Use direct communication between the source domain and the destination domain to establish a reservation in the destination domain
  - No signalling load for intermediate domains

# Signalling to the Last Domain




Domain may use other QoS mechanisms than AQUILA

# Will This Work?

- **Sink tree identification**
  - How early can we identify a sink tree?
- **Resource cushion**
  - How often can we re-use resources from a resource cushion?
- **Answers depend on many parameters**
  - Network topology
  - Traffic pattern
  - Configuration of algorithms

# Outline

- Short Review of BGRP
- BGRP and scalability: problems and solutions
- Simulation results

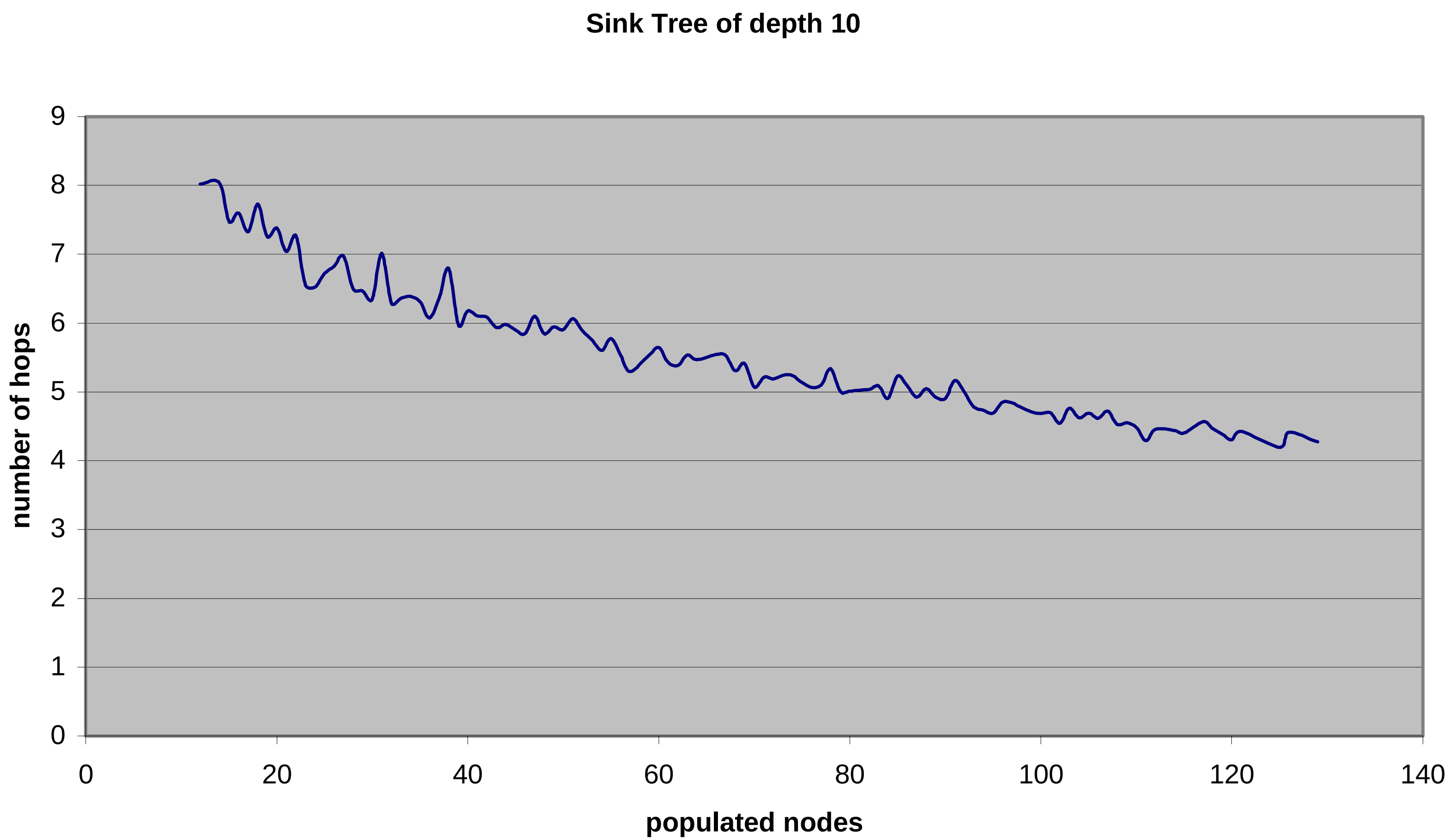
# Proof of Concept by Simulations

- **Earliest point for quiet grafting**
  - How far has a PROBE message to travel, until we can identify the corresponding sink tree?
- **Effectiveness of resource cushions**
  - Are resource cushions available where needed?
  - What is the overhead of unnecessarily reserved resources?

# Earliest Point for Quiet Grafting

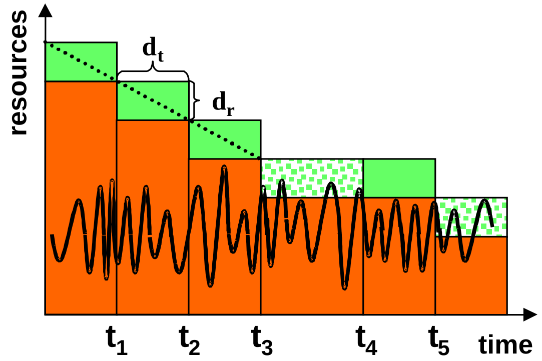
- **Some definitions**
  - Sink tree: exists independently of actual reservations
  - Populated node: node with an actual resource reservation for that sink tree
- **Basic considerations**
  - In a sparsely populated sink tree, the average distance from a node to the first populated node is rather high
  - In a densely populated sink tree, the average distance from a node to the first populated node is rather low
  - As the population of the tree increases, the average distance to the first possible point for quiet grafting decreases

# First Results



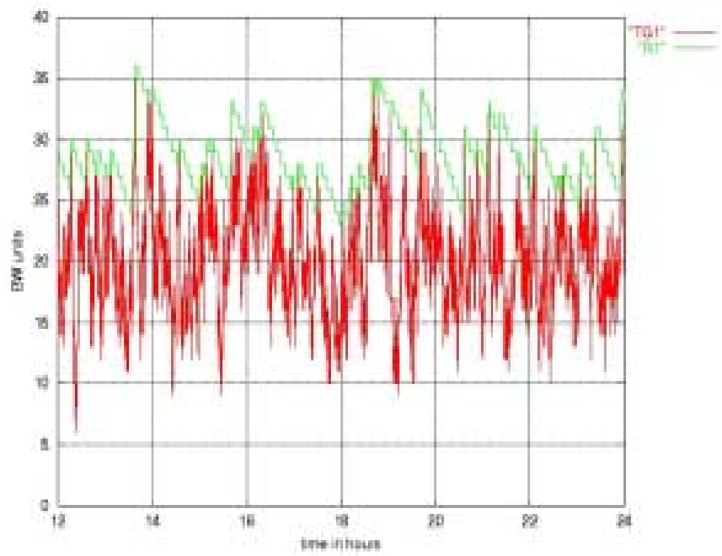
# Effectiveness of Resource Cushions

- **Build resource cushions through delayed resource release**
  - Released resources are not immediately forwarded towards the sink tree root, but used to build a resource cushion
- **Release unused resources**
  - Resource cushions are released step-wise (Retain Period) and block-wise (Return Block Size)
  - When more than RBS resources are unused during a RP, then this block is released



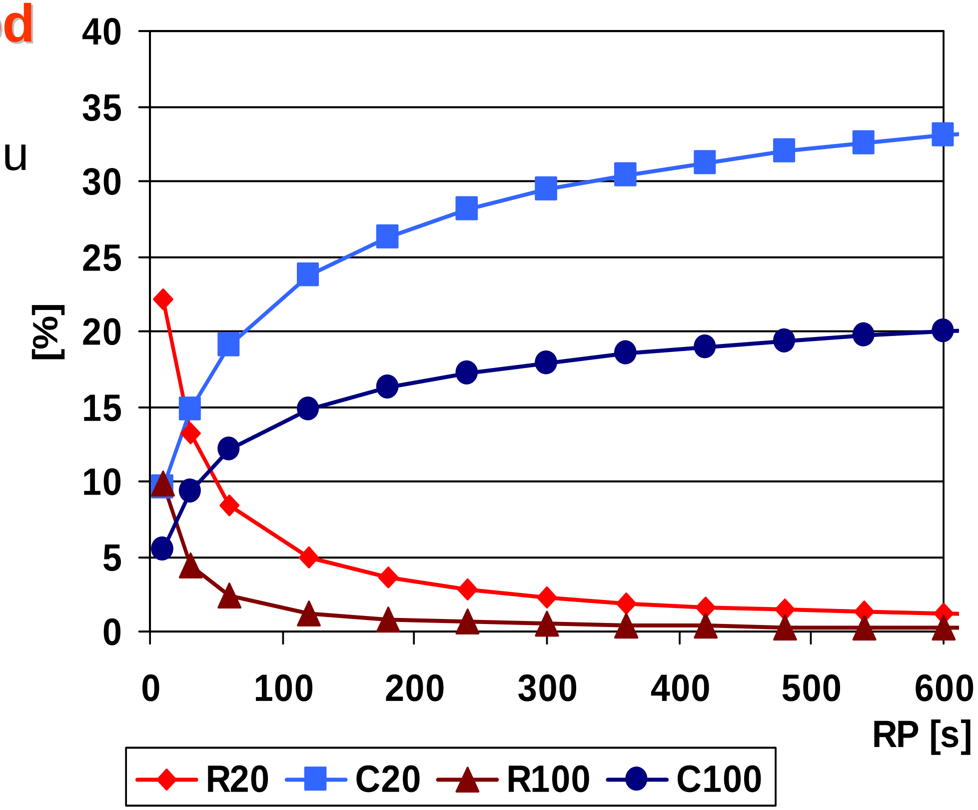
# First Simulation Results (1)

- **Parameters**
  - Traffic generator with exponential distributed inter-arrival time and holding time
  - Request size = 1 u
  - Mean offered load = 20 u
  - Mean holding time = 3 min
  - RP = 5 min
  - RBS = 1 u
- **Results**
  - 30% average resource cushion
  - 97% of requests served by cushion



# First Simulation Results (2)

- **Variation of Retain Period**
  - Mean offered load = 20 u
  - Mean offered load = 100 u
- **Results**
  - R = requests forwarded
  - C = mean cushion size
- **Trade-off**
  - Higher RP yields lower R but higher C
- **Load dependent**
  - Higher load gives better results

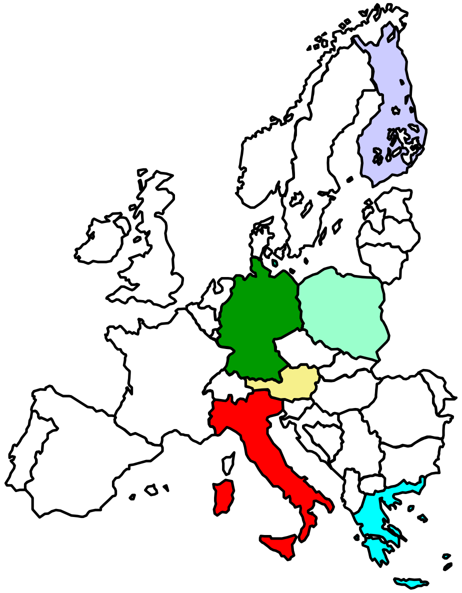


# Conclusions on First Results

- **Proof of concept**
  - Delayed resource release can dramatically reduce the signalling load
  - Reasonable mean size of resource cushions (10% - 30%)
- **Especially effective in lively branches of the sink tree**
  - Best results when number of incoming requests is high
- **Optimal parameter sets will vary at different places in the sink tree**
  - Short RP and small RBS near the leafs
  - Longer RP and larger RBS near the sink

AQUILA (IST-1999-10077)

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



**Project Review No. 3**

*Dresden, Germany*

*November 21 - 23, 2001*

# Thank you for your attention !

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