Measurement-based Admission Control in the AQUILA Network and Improvements by Passive Measurements

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Outline

- Introduction
- MBAC method based on the mean bit rate
- Improving MBAC by measuring the bit rate variance
- A method for measuring the variance of traffic
- Conclusions

Introduction

- **The AQUILA architecture defines a set of Network Services**
  - Each dedicated for carrying different type of traffic
- **Admission Control (AC) is invoked for guaranteeing QoS**
  - DBAC (Declaration-based AC) approach
    - Precise declaration a-priori is difficult
  - MBAC (Measurement-based AC) approach
    - Possible simplification of traffic declarations
    - Possible better network utilisation
    - Capturing stochastic characteristics of user traffic
- **Practical applicability of two MBAC methods was investigated**
  - Based on measured mean rate
  - Based on measured rate variance

MBAC for AQUILA PVBR service

- **Designed for handling streaming VBR traffic**
  - Target QoS objectives: low packet losses and low packet delay
  - Typical application: real-time video
- **REM (Rate Envelope Multiplexing) assumed for the AC**
  - Buffer-less link model
  - Fluid-flow model of the source behaviour
  - Packet loss ratio as the QoS parameter

MBAC with known mean bit rate of traffic

Hoeffding bound algorithm [Floyd96]

- Simple user traffic declaration: only peak bit rate, h_i
- Simple measurements: only aggregate mean rate, M
- Profit over DBAC when users over-declare the submitted traffic

$$h_0 + M + \sqrt{\frac{g}{2}\left(\sum_{i=1}^{N} h_i^2 + h_0^2\right)} \leq C$$

Implementation of MBAC in AQUILA

Mean bit rate measurements performed by ACA

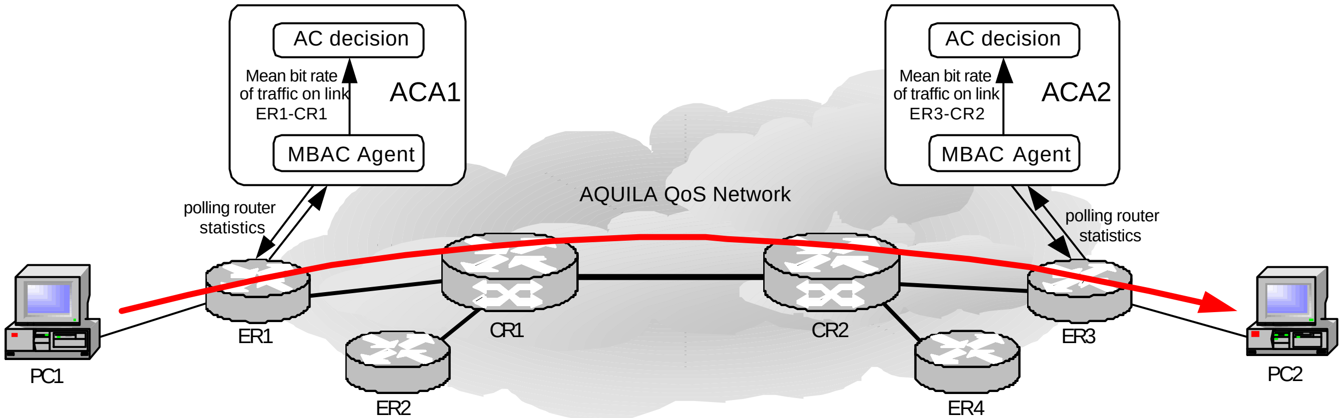
- Polling the router in constant time intervals *L* (in the order of sec.)
  - – Number of transmitted bits, D_j, sent to the ACA
- Mean rate within the polling interval

$$S_j = \frac{D_j}{L}$$

- Stationary mean rate estimated using „moving window" algorithm
  - – Arithmetic mean from *W* latest bit rate samples S_j $(j=1,\ldots,W)$

Verification of MBAC in the trial network (1)

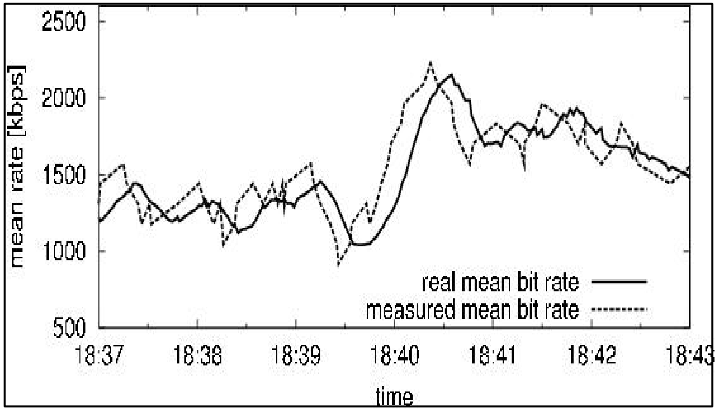
- **Laboratory testbed in Warsaw**



- **Artificial traffic was submitted to the PVBR service**
  - Poisson traffic model at the flow level
  - Trace-driven traffic at the packet level
- **MBAC on the ingress link ER1-CR1**

Verification of MBAC in the trial network (2)

- **Mean bit rate measured in the ACA1 was monitored for the period of the test**



- **The measured value closely follows the real mean bit rate**
  - Hoeffding bound MBAC can be effectively applied in practical implementations of QoS IP networks

Improving MBAC by measuring the variance

- **Hoeffding bound MBAC**
  - Profitable when declared sustained rate is greater than the real mean rate
- **MBAC with known bit rate variance [Brichet&Simonian98]**
  - More complex declarations: peak bit rate, h_i, and sustained bit rate, r_i
  - More complex measurements: variance of the aggregate traffic, V (assuming fluid-flow model)

$$e_0 + \sum_{i=1}^{N} e_i - d_{K'+1}\left(\sum_{i=1}^{K'+1} r_i(h_i - r_i) - V\right) - \sum_{K'+2}^{N} d_i r_i (h_i - r_i) \le C$$

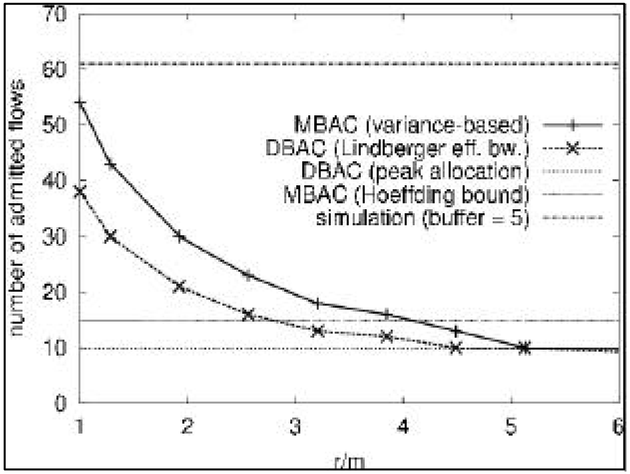
$$d_i = \frac{(h_i - e_i)e_i}{h_i^2 (h_i - r_i)\log\left(\frac{h_i - r_i}{h_i - e_i}\right)}\left[\frac{h_i(e_i - r_i)}{r_i(h_i - e_i)} - \log\left(\frac{e_i(h_i - r_i)}{r_i(h_i - e_i)}\right)\right]$$

$$\sum_{i=1}^{K'} r_i(h_i - r_i) \le V \le \sum_{i=1}^{K'+1} r_i(h_i - r_i) \qquad \frac{1}{h_i}\log\frac{e_i(h_i - r_i)}{r_i(h_i - e_i)} - \frac{1}{e_i}\log\frac{h_i - r_i}{h_i - e_i} = \frac{g}{C}$$

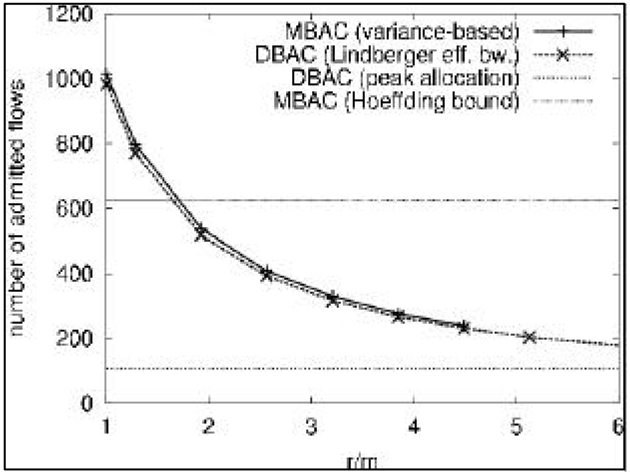
Effectiveness of variance-based MBAC

- **A homogenous set of Star Wars IV movie sources**
  - h = 0.94Mbps, m = 0.15Mbps
  - fluid-flow var = **0.008**Mbps^2 << worst-case var = **0.067**Mbps^2
  - r/m represents the difference between user's declaration and submitted traffic

10Mbps



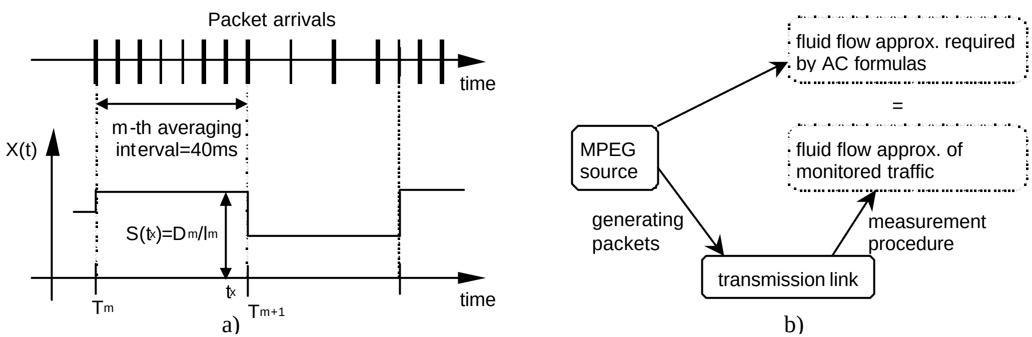
100Mbps



- **Var-based MBAC admits more flows than the DBAC**
- **Hoeffding bound MBAC is more efficient when r/m is high**

Measuring the variance of traffic

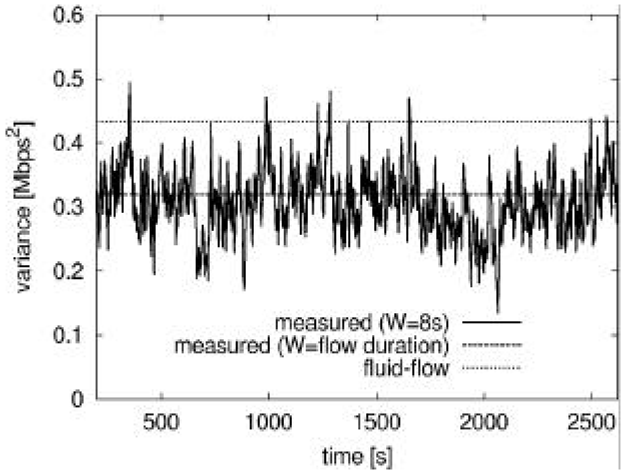
- **Step 1: Monitoring the packet arrival process**
  - Monitoring the number of transmitted bits
- **Step 2: Conversion into the approximation of fluid-flow model**
  - Averaging traffic rate within constant 40ms intervals
  - 40ms intervals: duration of frame period of MPEG video source (natural time-scale for variability of MPEG-source traffic)

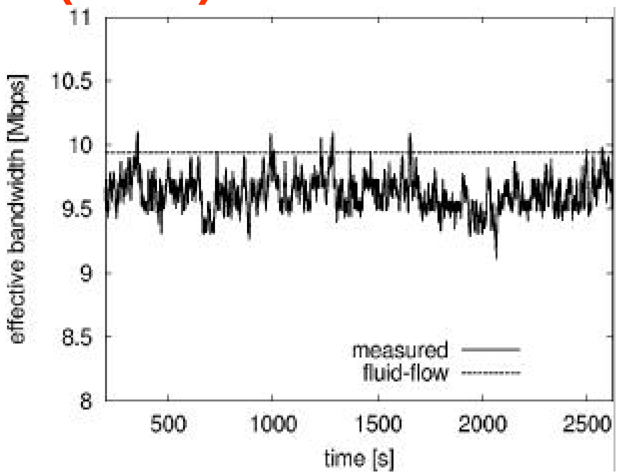


- **Step 3: Estimation of stationary variance**
  - Moving window mechanism

Verification of the measurement procedure by simulations

- 54 flows, generated according to Star Wars IV trace
- Measurement window set to W=200 (8 sec.)



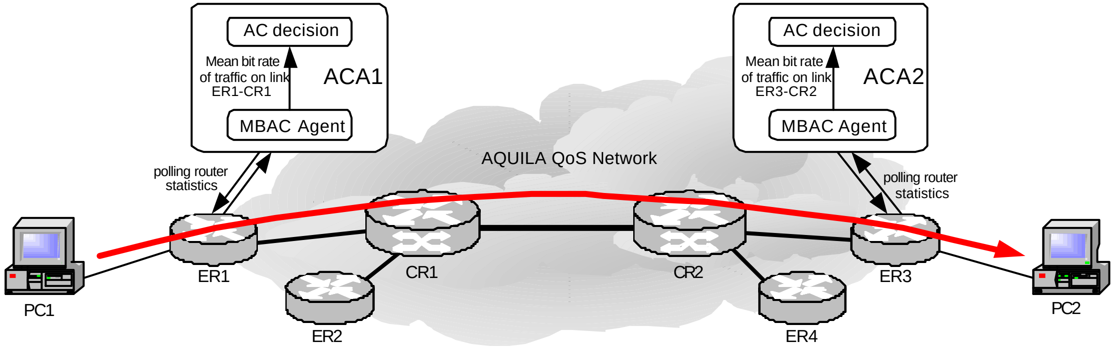


- The estimate fluctuates around the stationary variance
  - Slightly underestimates the real value of fluid-flow variance
- „Estimated" effective bandwidth is close to the theoretical value

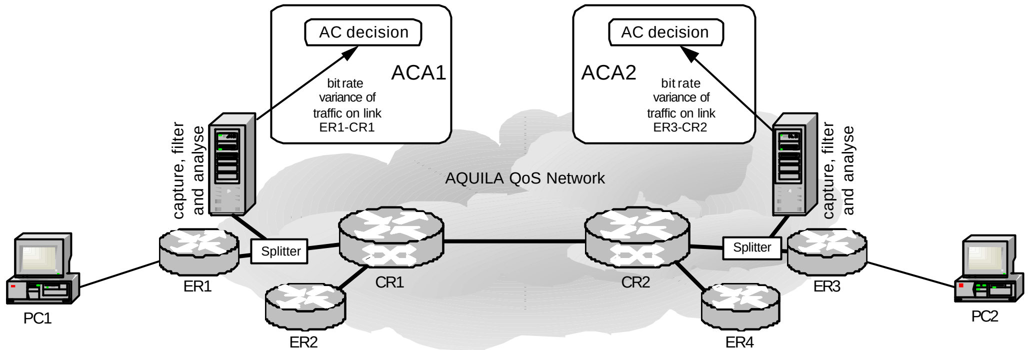
Implementation Issues and Feasibility Study (1)

Current AQUILA MBAC approach (router polling)

- Router performance limits the min. length of measurement interval
- For mean rate measurements, polling intervals in the order of seconds are satisfactory
- Not feasible for variance measurements, where polling intervals in the order of milliseconds are required



Implementation Issues and Feasibility Study (2)



- **Adding capture devices on ingress/egress links**
  - Disburdens router
  - Integration with ACA possible
  - Allows for arbitrarily small measurement intervals
- **Testbed experiments were performed with DAG card and PC computer as a capturing device**

Conclusion

- **MBAC based on mean rate measurements**
  - Implemented in AQUILA
  - Simple measurements, no additional hardware required
  - Profit only when users significantly over-declare the traffic
- **MBAC based on variance measurements**
  - Gain in network utilisation
  - More complex traffic declaration
  - More complex measurements
- **Proposed measurement method**
  - Makes application of var-based MBAC possible
  - Possible enhancement of AQUILA architecture