

TAMPERE UNIVERSITY OF TECHNOLOGY

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Fuzzy Systems for Adaptive SLA Management in DiffServ Enabled IP Networks

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Some facts

People are different with various data transmission needs. People need different network services.

As users of network services, people are paying customers. They have rights to require valuable services for their money.

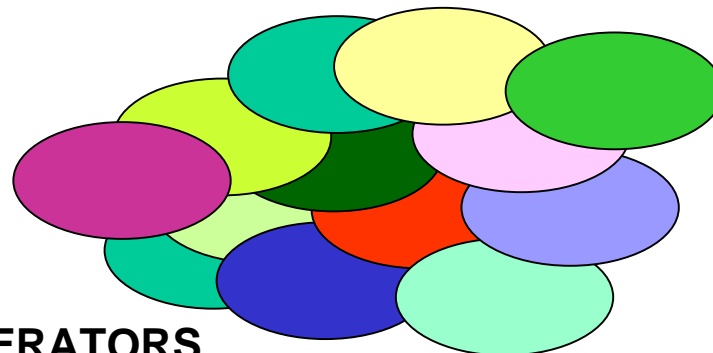
Customers can select operators and network services freely.

Network operators must compete with other operators.

USERS OF NETWORK SERVICES



QoS, prices of services?



OPERATORS
with various network
services



The issues behind the studies

1

The ISPs (Internet Service Providers) are responsible for their customers for ensuring that the **offered end-to-end data transmission services correspond to the quality of service definitions of established SLAs (Service Level Agreements)** at least in some statistical level.

2

Estimation of quality of end-to-end data transmission services is a complex task, if data packets of transferred data flows are routed through IP domains of several network operators. First, the **DS (Differentiated Services) model does not provide any kinds of data flow-based control or resource reservation functions through all networks** used for transferring of data packets. Secondly, **network operators are not willing to share all (if any) information about resources** of their networks between other operators.

3

The ISPs should also consider that their **financial profit aims would fulfill**.

4

For the QoS and pricing decisions, **the ISPs should know opinions of the customers** about the offered data transmission services.



Some words about the studied solutions of other research groups

1

Some research groups have studied **sharing of information** between IP domains of different network operators and **co-operation of bandwidth brokers (BBs)** of different IP domains **for ensuring quality of end-to-end data transmission services.**

→ Inter-domain resource management mechanisms are needed for ensuring the quality of the end-to-end data transmission services.

2

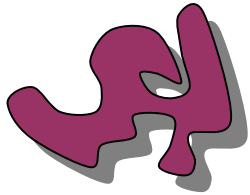
Another way to **be aware of quality of end-to-end data transmission services** is simply **monitor quality** of offered data transmission services.

3

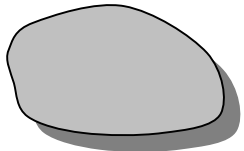
Several research groups have also studied **relations of selling prices and quality of data transmission services.**



Fuzzy Systems for Adaptive SLA Management in DiffServ Enabled IP Networks



Control systems for IP domains of ISPs are developed. The systems set prices and DS services of dynamic SLAs according to operation targets of the ISPs. They are designed for a future network environment, where customers are able to select their ISPs and SLAs dynamically and freely irrespective of their access network operators.



The principal advantage of the systems is that the ISPs are able to consider both the opinions of the customers about offered data transmission services and fruition of their financial profit aims in the SLA management process.



Information flows for the SLA management process

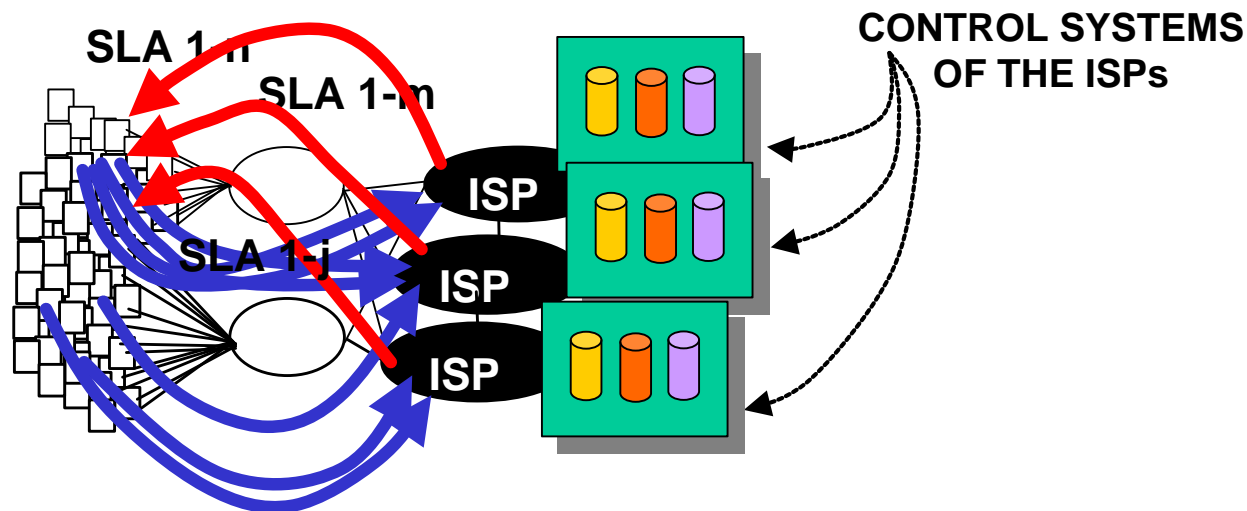
- ➔ **ISPs advertise their various SLAs to potential customers. In this way, the customers have always information about the SLAs of the competing ISPs. They know prices of the SLAs and advertised quality of end-to-end data transmission services, which should be achieved using the SLAs.**



Customers select the SLAs for their transmission needs according to their personal interests and the valid information about the SLAs.



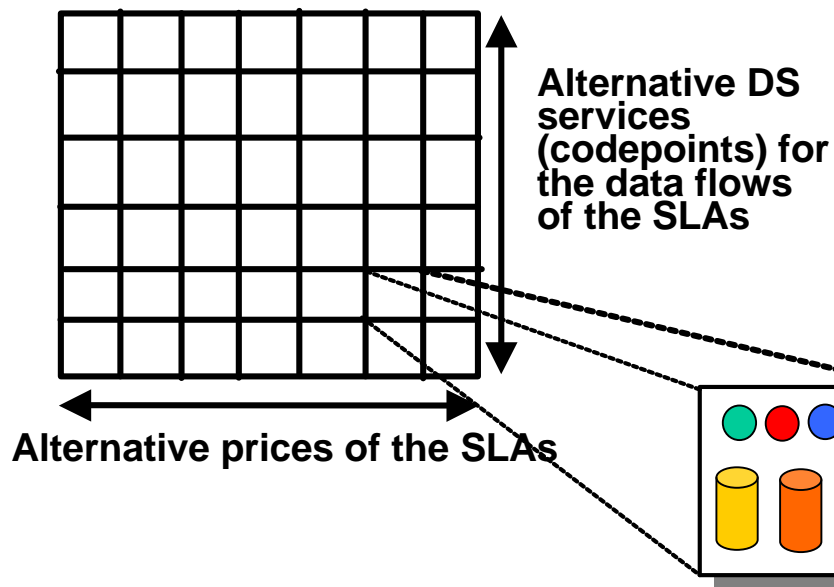
After the data transmissions, customers are allowed to send responses about suitability of the offered data transmission services to the ISPs, whose SLAs were selected for use.



- ➔ **Opinions (or monitored service selection behaviour) of the customers and information about amount of transferred data are stored to the databases of the control system of the ISPs.**



Structure of the developed controllers




➔ **The principal element** of the control system is **a state-chart of the control solutions**. The state-chart describes alternative combinations of prices and DS codepoints, which can be set for the SLAs.

Every state of the chart includes three characteristic factors and three databases. The factors are:

- 1) **codepoint**, 2) **selling price** and 3) **using cost**.

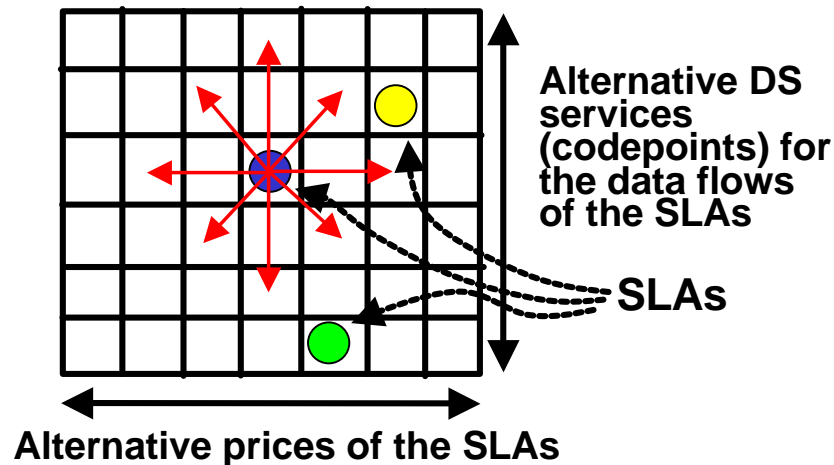
 An **'opinion' database**, which stores opinions (or service selection behaviour) of the customers, if the selling price and the DS service is used for the SLAs.

 A **'data' database**, which stores amount of transferred data using the SLAs, if the selling price and the DS service is used for the SLAs.

 A **'moving' database**. It stores changes of the opinions (or service selection behaviour) of the customers and amount of transferred data of the SLAs, if combination of prices and DS services of the SLAs are changed to classified directions.



The principal operation of the controller



→ The controller changes periodically the states of the controlled SLAs on the state-chart so that the control aims of a ISP would fulfill optimally.

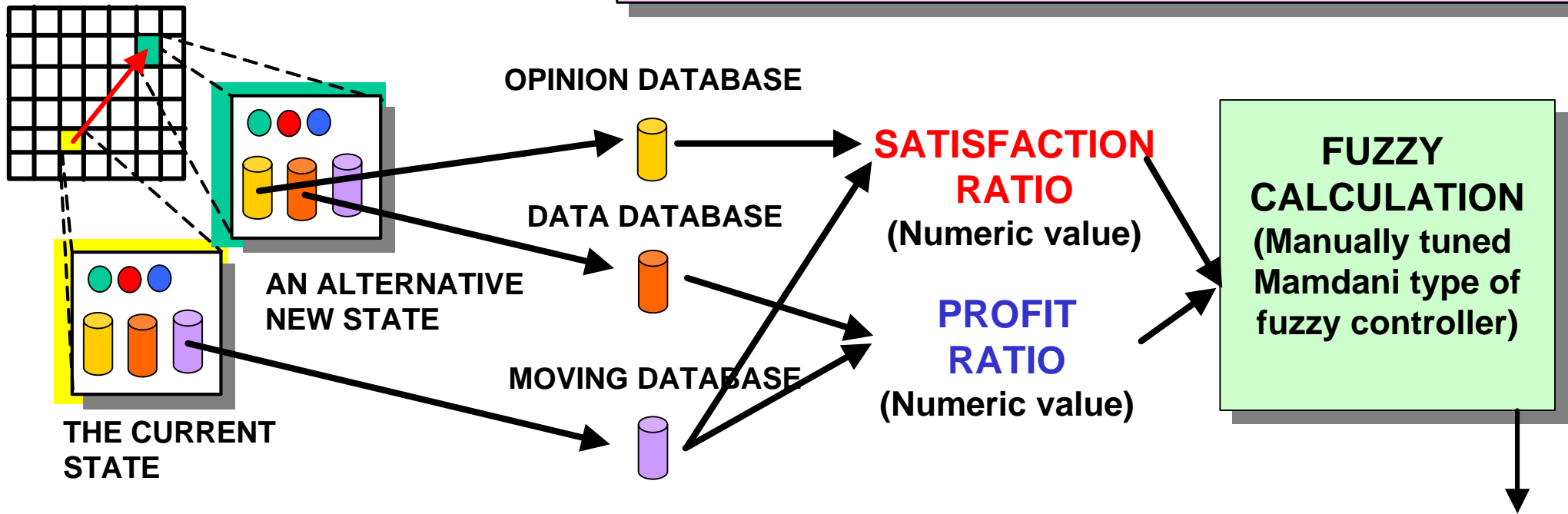
→ Prices of the SLAs and DS services used for data flows of the SLAs vary periodically according to the movements of the SLAs on the chart.



The controlled SLAs



The fuzzy controller for suitability calculation



➔ The **'satisfaction ratio'** –input variable compares the expected and the estimated average satisfaction level of customers using the controlled SLA, if the state of the state-chart would be selected for the controlled SLA.

➔ The **'profit ratio'** input variable compares the expected and the estimated economical profit of the ISP (\$/s) by selling the controlled SLA, if the state of the state-chart would be selected for the controlled SLA.

Output: suitability of the observed state for the controlled SLA



Two examples of different price-setting and service selection strategies

The fuzzy controller represented in Fig. 1 calculated the highest suitability values for the states which produced maximum profits for the ISPs and good service for the customers.

The fuzzy controller presented in Fig. 2 calculated high suitability values for the states which should ensure good service for the customers with just the expected financial profit of the ISPs.

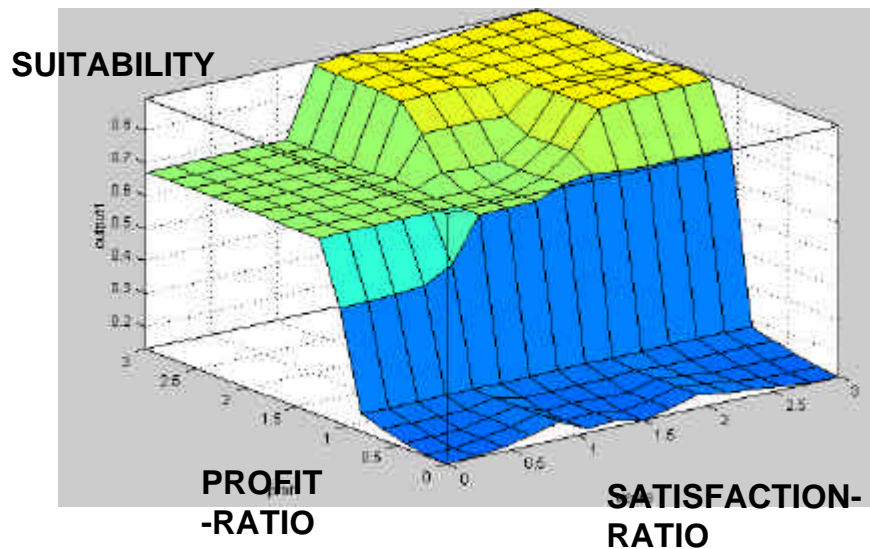


FIGURE 1

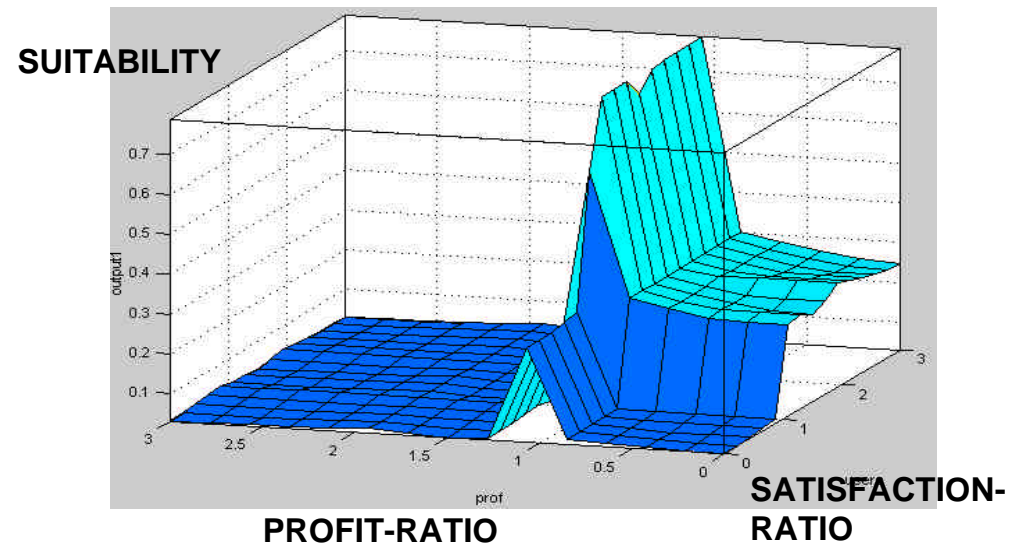
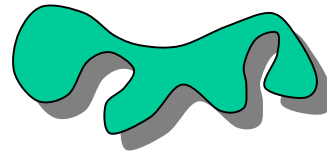


FIGURE 2



Conclusions

The management systems are capable of controlling both the financial profit of the ISPs and satisfaction of the customers, although the operation aims of the ISPs would vary heavily.



Controlling of quality of service of the data transmission services is based on the control of the satisfaction levels (or a measured behaviour) of the customers. The system tries to keep the average satisfaction of the customers in the specified level. From this perspective, the system does not even try to guarantee exact quality of services to specified destinations.

Behaviour of the customers gives the needed information for the control actions. From this point of view, the control system cannot operate faster than the customers establish SLAs.



Publications related to the studies

- 1. Compound doctoral thesis of Kimmo Pulakka (“Soft-Computing Based Control Schemes for QoS in Communication Networks”), which will be published in the Publications series of Tampere University of Technology, Finland. May 7, 2004.**
- 2. Pulakka, K. “A Dynamic Control System for Adjusting Prices and Quality of Service in DS Enabled Networks”. Proceedings of Conference on Network Control and Engineering for QoS, Security and Mobility (Net-Con 2002), October 23-25, 2002, Paris, France, pp. 241-252**
- 3. Pulakka, K. “Controlling of satisfaction of the end-users and profits of the ISPS in the DS enabled Internet”. Proceedings of the 8th International Conference on Communication Systems, ICCS 2002, November 25-28, 2002, Singapore. 7 p.**