Fuzzy CAC Adaptation for Effective Traffic Control in GMPLS Networks

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Abstract **— Current paper presents the report of some issues on adaptation techniques of the specific implementation of fuzzy-CAC algorithm over an RSVP-TE agent that can be used in GMPLS network domain. The algorithm is used to provide stable link utilization and achieve preferable rate of rejected LSP connections, while maintaining selective reasoning under uncertain conditions. Fuzzy-CAC implementation is applied to a testbed where a client application requests a real-time data transfer through a GMPLS network, which results in dynamic LSP setup and exclusion. Adaptation to the continuously changing environment is achieved by the modifications to the membership function declarations and fuzzy-CAC interface decision firing threshold for deffuzified response values.**

Keywords **— Fuzzy logic, GMPLS networks, LSP setup, traffic management.**

I. Introduction

THE role of the multimedia applications over the Internet have been rapidly growing in the past few years. Especially IPTV and Video on Demand (VoD) applications are gaining an ever increasing popularity [1], favored by the massive deployment of diverse access technologies. An advanced video traffic, including three-dimensional 3D and high-definition TV is projected to increase 13 times between 2009 and 2014 [2], meaning that, for the first time in 10 years, peer-to-peer traffic will not be the largest type of Internet traffic. Herewith, the completely new paradigm of traffic engineering comes into account, which has to be able to dynamically manage large traffic flows with guaranteed QoS demands. Supporting modern multimedia applications requires QoS provisioning and management at all the relevant points in the Internet. In particular, QoS provisioning implies to master the cooperation of several building blocks (e.g., routing algorithms, resource management schemes, admission control algorithms, traffic analysis techniques, signaling protocols) [3].

As it is defined as a cardinal building block of NGN, the application driven traffic control is the basic necessity to achieve fully dynamic resource management manner. The GMPLS control plane is the proposed control solution for the next generation optical networking, which enables automatic setup and turn down of the Generalized Label Switched Paths by the means of signaling protocols such as RSVP-TE. GMPLS makes the first step towards the integration of data and optical network architectures and significantly reduces the operational costs with easier network management and operation [4].

The dynamic LSP setup process is based on the acceptance or denial of the incoming new LSP requests to the network by CAC module of RSVP-TE. The decision, whether to accept or deny, has to be based on predefined criterions as well as on the network loading conditions. As this decision has very sensible influence on the QoS parameters of the established connections, it makes from CAC an essential tool to guarantee the required QoS.

The classical threshold CAC, on which an actual RSVP-TE implementation is based, is not capable of making decisions in uncertain conditions, which are to great extent persistent in the modern broadband optical networks [5]. The dynamic traffic demand in the fast changing environment and bursty background traffic practically eliminates the possibility of fast precise online reasoning, which in case of CAC decision making is in second and sub-second time scale [6]. Fuzzy logic serves as the great tool to cope with uncertain multivariable data and provides flexibility and robustness for decision making in uncertain conditions based on fuzzy rules [7].

In this paper, we introduce several adaptation tended modifications to the fuzzy-CAC mechanism, which was introduces by authors of the current paper in previous publications [8], [9].

The performance of this algorithm is evaluated using simulated per-flow decision analysis based on synthesized input data and expert knowledge database of fuzzy-rules.

In this paper we do not discuss complex neural network or evolutionary algorithm based fuzzy interface optimization techniques, but focus on the overall fuzzy-CAC performance dependence on the major fuzzy reasoning component changes.

II. Fuzzy-CAC algorithm implementation

The main feature of fuzzy logic is the ability to map input space to output space. Fuzzy logic overcomes the mathematical complexity of many problems, it works with fuzzy terms, fuzzy sets, fuzzy operations and it makes decisions based on fuzzy IF-THEN rules [10]. Fuzzy inference system performs four basic steps: fuzzyfication, inference, composition and defuzzyfication (Fig. 1).

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To be able to carry out flexible and robust decision making under uncertain conditions, as well as the selective protection scheme for established LSPs, the proposed algorithm uses 3 input values: Bandwidths Ratio (*BW_Ratio*), *QoS_Class* (or level requested) and *Link_Delays*, which define the momentary system state and the starting point of LSP setup decision.

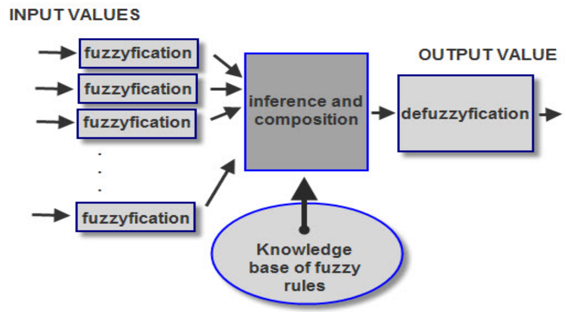

Fig. 1. Fuzzy interface system block scheme

Fuzzy-CAC gives the response, whether to reject, accept or accept the new LSP with reservation, applying appropriate decision firing threshold to the deffuzified crisp response values. Values are defined form 0 to 10, where 0 stands for the "strongest" denial and 10 for the "strongest" acceptance with enforced LSP reservation and the middle point, with the value of 5, stands for the "definite" acceptance of connection

The results show, that contrary to the Threshold CAC, fuzzy algorithm is more selective while allowing new LSPs to be setup. As a result the link is not overutilized, selectively chooses high priority connections to be protected in the appropriate conditions, while Threshold CAC utilizes all the available resources and refuses much more new connections regardless of their nature and state of the link (Table 1.).

TABLE 1: FUZZY-CAC AND THRESHOLD CAC REFUSED CONNECTIONS FOR CERTAIN NUMBER OF DECISIONS.

Decisions	Threshold CAC	Fuzzy CAC
500	76	46
1000	203	127
2000	432	222
3000	740	474
5000	1025	657

More detailed description of the proposed algorithm and its implementation can be found in the previous papers of the authors of this publication [8], [9].

III. FUZZY-CAC ADAPTATION METHODS AND RESULTS

In fact, there are two basic ways to change the fuzzy-CAC reasoning system behavior. First, the knowledge data base, which is expressed with the IF-THEN rules, can be changed. By doing this, not only the required system behavior definition is changed, but also the preciseness of the decision making and overall system performance that also considerably affects the decision making time [8].

The second method involves changing membership function declarations. By performing this step, it is possible to emphasize or to diminish the particular linguistic declaration of value of the input variable. It means, that by leaving the knowledge rule base unchanged, we modify the meaning of specific linguistic variables, and by doing this, it is possible to shift the decision making tendency to the preferable manner.

It is worst also to mention one more technique, which does not promptly affect the fuzzy-CAC mechanism, but can be used for extremely fast and efficient fuzzy-CAC interface performance online modification – the change of decision firing threshold.

While the IF-THEN rule base serves as the overall fuzzy reasoning system behavior descriptor, it is worth to focus purely on the membership function declaration change and decision firing threshold influence on the dynamic link state, as they can guarantee considerable fuzzy-CAC algorithm operational character changes, providing wide shade off possibilities.

Let`s consider the existing fuzzy-CAC algorithm under the worst case scenario: connection rate is several times bigger than the link capacity can accept and the background traffic is bursty, thus considerably affecting momentarily link delays.

The *BW_Ratio*, requested *QoS_Class* and *Link_Delays* in this case were simulated using fractional Brownian motion synthesis, which exhibits long-range dependence for H > 0.5. A complete overview of long-range dependence process generator is available in [11].

Our scope was to redefine the meaning of the linguistic variables of the fuzzy-CAC reasoning system. In this specific experiment, *Link_Delays* variable was changed with an intention to emphasize the overall fuzzy-CAC interface feedback to the fuzzyfied values of the delays in the link under the test.

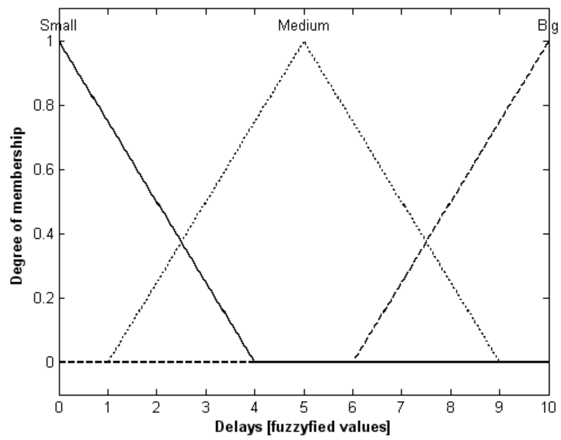

Fig. 2. *Link_Delay* input variable membership function declaration – initial state.

In result, greatest part of the fuzzyfied values are treated as "big delays", which means that entries of the IF-THEN rule knowledge base, which states that some action has to be taken if Link Delay is "big" will have the dominant degree of influence.

In fact, variable *Link_Delays* was chosen because of its strong impact on the overall reasoning system performance, as it is defined in the knowledge base of the IF-THEN rules for this specific fuzzy-CAC implantation, and any other input variable membership function re-declaration can be used for algorithm adaptation.

Initial membership function declaration and initiated changes are depicted on Fig. 2 and Fig. 3 respectively.

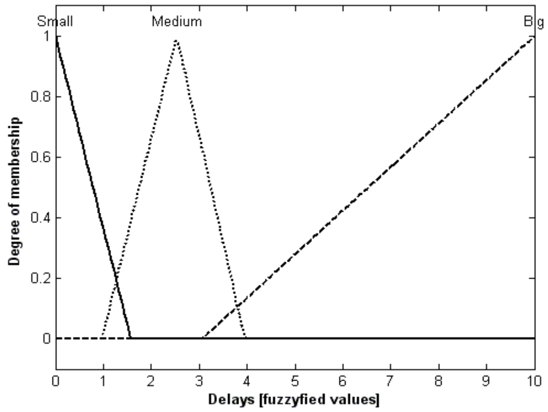

Fig. 3. *Link_Delays* input variable membership function declaration –state after re-declaration.

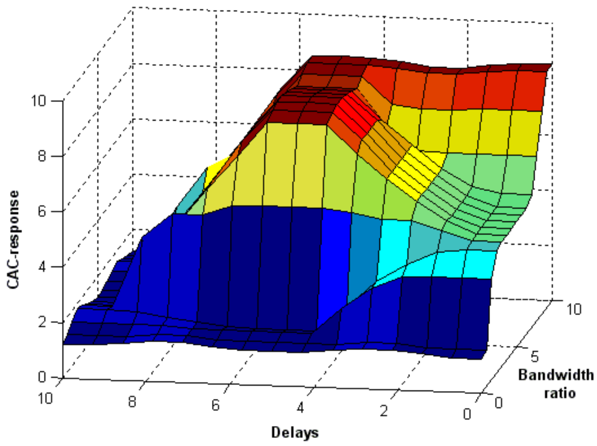

Fig. 4. Fuzzy-CAC decision surface. Inputs: *Link_Delays* and *QoS_Class*. Output: CAC response.

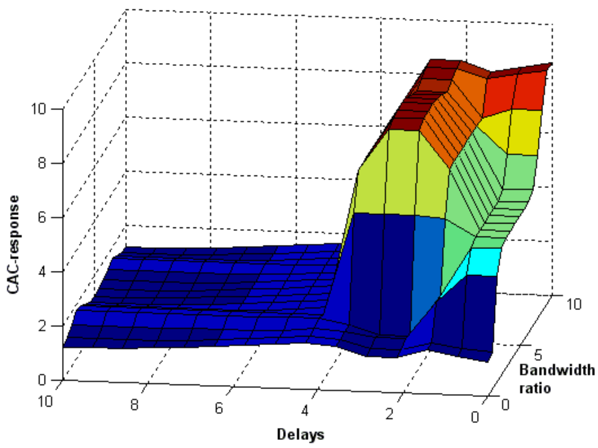

Fig. 5. Fuzzy-CAC decision surface. Inputs: *Link_Delays* and *QoS_Class*. Output: CAC response.

Fig. 4 depicts fuzzy-CAC decision surface for *Bw-Ratio* and *Link_Delays* variables. As one can see, after membership function re-declaration, on Fig. 5, the selectiveness of fuzzy reasoning system increased, and resulted in bigger rate of potentially rejected LSPs.

Fig. 6 and Fig. 7 shows fuzzy-CAC interface response for two previously mentioned membership function declarations with the decision firing threshold set to 1.

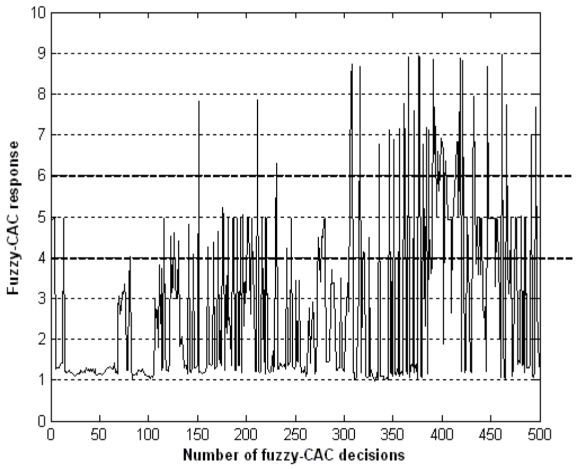

Fig. 6. Fuzzy-CAC response for first 500 decisions – initial state. Decision firing threshold set to “1”.

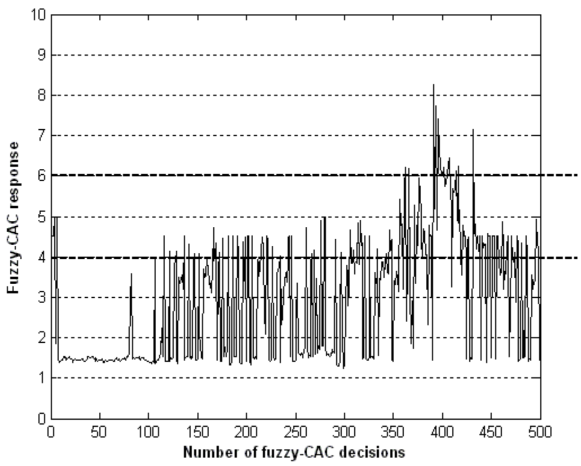

Fig. 7. Fuzzy-CAC response for first 500 decisions – state after *Link_Delays* re-declaration. Decision firing threshold set to “1”.

By changing decision firing threshold, it is possible to achieve an extremely fast and effective fuzzy-CAC interface behavior change. Fig. 8 and Fig. 9 show the graphic representation of fuzzy-CAC performance, indicating fuzzy-CAC decision firing threshold influence on mean link utilization and number of refused connections after 3000 decisions. Fig. 8 represents the initial state fuzzy-CAC interface behavior, and Fig. 9 depicts fuzzy-CAC reaction with the re-defined membership function declaration.

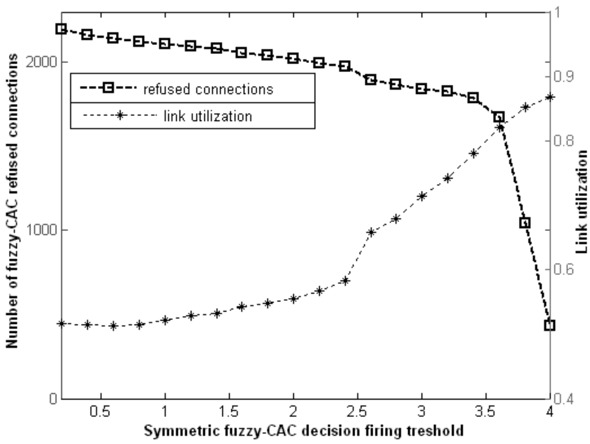

Fig. 8. Fuzzy-CAC decision firing threshold influence on link utilization and number of refused connections.

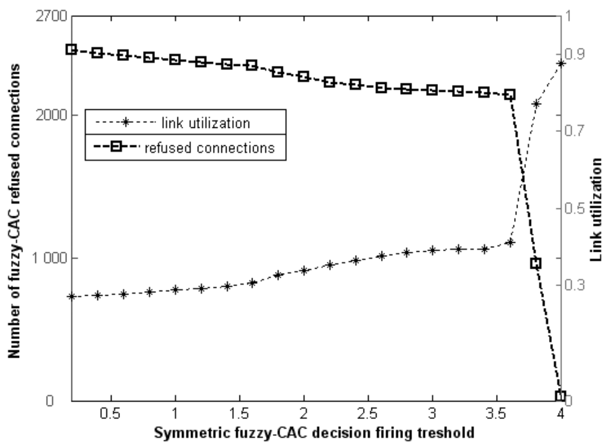

Fig. 9. Fuzzy-CAC decision firing threshold influence on link utilization and number of refused connections.

IV. Conclusion

Whilst sliding the decision firing threshold of the fuzzy-CAC interface, the resultant behavior will differ for every specific knowledge IF-THEN rule base, as well as for every input variable membership function declaration. It means that for effective fuzzy-CAC adaptation, with an intention of providing stable link utilization and achieving preferable rate of rejected LSP connections, "reaction maps", such as depicted on Fig. 8 and Fig. 9, have to be set-up in advance and implemented into an appropriate software solution of CAC algorithm.

Nevertheless, the proposed fuzzy-CAC algorithm is capable of robust and selective decision making and can serve as a potential modification of the RSVP-TE Connection Admission Control mechanism to deal with multiple class traffic of next generation fast optical networks, which are anticipated to operate under GMPLS control plane.

In this investigation the symmetric decision firing threshold change was applied, but asymmetric modification is also possible and can give additional control potentialities. Such an option can be used for more selective QoS control over the network while setting-up dynamic LSPs in GMPLS control plane, which is assumed as a topic for the future research.

Acknowledgment

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