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Fuzzy-CAC for LSP Setup in GMPLS Networks

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Introduction

The concept of the NGN (Next Generation Networking) designs the telecommunication networks that are able to use the multiple broadband, QoS (Quality of Service) enabled, transport technologies in which service-related functions are completely independent form the underlying transport-related technological solutions. In order to do Traffic Engineering effectively, the Internet Engineering Task Force (IETF) introduced Multi Protocol Switching (MPLS) and Constraint-based Routing. The current advancements in the technology, such as various QoS mechanisms, e.g. Diff-Serv (Differentiated Services) architecture, MPLS and the underlying physical network components, i.e. optical networking technology are being integrated in the form of the multipurpose control plane paradigm of Generalized MPLS (GMPLS). GMPLS is the proposed control plane solution for the next generation optical networking. It is an extension to current MPLS that enables automatic setup and turn down of the Generalized Label Switched Paths by the means of signalling protocols such as Resource Reservation Protocol - Traffic Engineering extension (RSVP-TE). GMPLS differs form the traditional MPLS with the added switching capabilities for lambdas and fibers, as well for time slots and packets. 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 [1].

While MPLS mainly focuses on the data plane, GMPLS focuses on the control plane. GMPLS extends the concept of Label Switched Path (LSP) setup beyond the Label Switched Routers (LSR) to wavelength and fiber switching capable systems. In such way, GMPLS allows LSP hierarchy, in which one LSP is positioned inside another, at different layers in the network architecture (Fig. 1). In such a hierarchy, the packet switched link is nested inside a lambda switched link, which is located inside a fiber switched link. GMPLS also is capable of performing connection management in optical networks, which provides end-to-end service provisioning for different services belonging to different classes. The management functionalities include connection creation, connection provisioning, connection modification and deletion of connection [2].

The Generalized Label may identify a single fiber in the bundle, a single waveband within fiber, a single wavelength within a waveband, or a set of time-slots within a wavelength (or fiber). It may also be a generic MPLS label, a Frame Relay label or an ATM label (as stated in RFC3471).

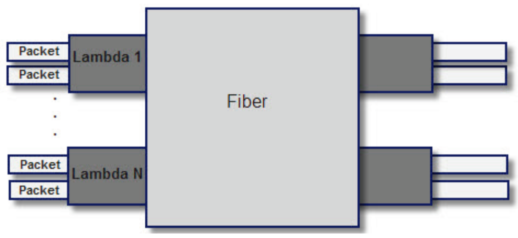

Fig. 1. GMPLS LSP hierarchy

GMPLS allows also establishment of bi-directional symmetric and asymmetric LSPs, (RFC 5467) which have to be setup not only for static use, but also dynamically, using application level information.

As the GMPLS serves as the brilliant solution for NGN development strategy, which is mentioned to be QoS aware and concerning end-to-end provisioning, the effectiveness of signalling protocols for the establishment of traffic-engineered LSPs, such as RSVP - TE, CR – LDP are of great importance. As documented in RFC 3468, the IETF MPLS working group deprecated CR-LDP and decided to focus purely on RSVP-TE. The GMPLS adopts this position and the establishment of traffic-engineered LSPs is mainly based on RSVP-TE.

When concerning dynamic LSP setup process, incoming new LSP requests are accepted or denied to the network by connection admission control scheme (CAC). Decision (accept/deny) has to be based on predefined criterions and on the network loading conditions. This decision has sensible influence on Quality of Service (QoS) parameters, what makes from CAC an essential tool to guarantee required QoS.

In this paper, we introduce a modification to RSVP-TE CAC mechanism, to carry out flexible and robust decision making under uncertain conditions, as well as the selective protection scheme for established LSPs.

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.

Statement of the problem

While not considering signalling capabilities of RSVP-TE, the main problem is about CAC control of dynamically incoming LSP connections. The decision whether to establish the next hop of the LSP or not, is based on primitive threshold CAC algorithm, which uses one argument – *Avail_BW* (available bandwidth). As the result, if the bandwidth required is less than the *Avail_BW*, the LSP is established through the subsequent link segment, and if the required bandwidth is bigger than the *Avail_BW*, the connection is rejected. The answer is received when the CAC table is consulted to check if sufficient resources are available on an interface, after reading the *Avail_BW* value in the CAC table.

The threshold CAC is not capable of making decisions in uncertain conditions, which are to great extent persistent in the modern broadband optical networks [3]. The dynamic traffic demand in the fast changing environment and bursty background traffic practically eliminate the possibility of fast precise online reasoning, which in case of CAC decision making is in second and sub-second time scale [4]. 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 [5].

The other problem of LSP setup process in modern GMPLS networks is associated with the link protection. The introduced link protection type indicates the protection capabilities that exist for a link. For the dynamic LSP path installation the protection type has to be declared while making the decision of LSP setup.

Six link protection types are currently defined as individual flags by GMPLS signalling functional description, and can be combined: enhanced, dedicated 1+1, dedicated 1:1, shared, unprotected and extra traffic. See RFC3471 section 7.1 for a precise definition of each. The dynamic LSP setup process, which is provoked by the application, has to have the capability of combining CAC and protection policy definition for the established path. The fuzzy interface, which is used in this investigation, uses only 1:1 protection policy for simplifying purposes, but at will any suitable number of protection types can be defined.

Fuzzy-CAC algorithm – implementation and results

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 rules (*if-then* rules) [6]. Fuzzy inference system performs four basic steps: fuzzyfication, inference, composition and defuzzyfication (Fig. 2).

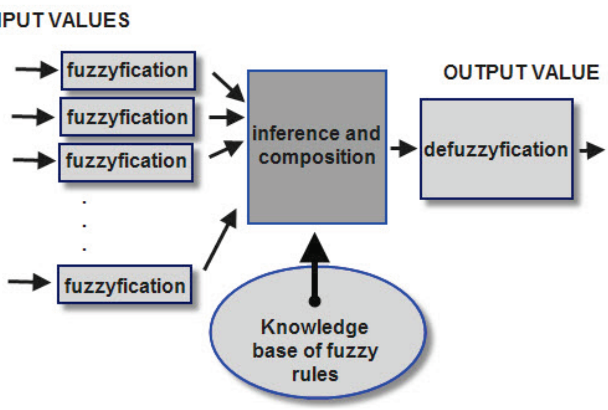

Fig. 2. Fuzzy interface system block scheme

The first step of fuzzy system design is to define fuzzy variables and fuzzy rules. Each fuzzy variable has membership function which transforms, in the fuzzyfication step, crisp value (from the input) into degree of membership (value form 0 to 1).

The proposed algorithm uses 3 inputs: Bandwidths Ratio (*BW_Ratio*), QoS class and Link Delays, which define the momentary system state and the starting point of LSP setup decision.

The input values are then fuzzyfied using upper and lower boundaries of possible variable values. The *BW_Ratio* variable shows the ratio between the available resources and the requested amount of bandwidths (1)

$$BW\_Ratio = Avail\_BW / Request\_BW. \quad (1)$$

The *BW_Ratio* was calculated using real network statistical flow data. The requested QoS classes and link delays 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 [7].

The knowledge base for current implementation of the Fuzzy-CAC algorithm is made as 33 rule database and is based only on the "expert knowledge", where the experts are the authors of the paper, and the rules are assumed as logical assumptions, e.g.:

- If the *BW_Ratio is poor*, and *QoS is Best Effort*, and *Delays are small*, then *Connection is allowed*;
- If the *BW_Ratio is good*, and *QoS is Real-time*, and *Delays are small*, then *Connection is allowed with protection;*
- If the *BW_Ratio is unacceptable*, and *QoS is Real-time*, and *Delays are big*, then *Connection is refused;*

The rules can be freely modified as well as the membership function definitions. The assumed fuzzy-rules and the membership functions of input and output values were used for comparison of Threshold-CAC and Fuzzy-CAC algorithm performance evaluation and the impact of their modification is considered as the field for the future research.

The membership functions were defined as follows:

Bandwidth ratio (triangle function) = {Unacceptable (0-2), Poor (1-3), Medium (2-9), Good (7-100)};

QoS class (triangle function) = {Best Effort (0-4), Medium (2-8), Real-time (6-10)};

Delays (triangle function) = {Small (0-4), Medium (2-8), Big (7-10)};

CAC response (triangle function) = {Connection discarded (0-3.5), Connection allowed (2-8), Connection allowed with protection (6-10)}.

After composition follows the defuzzyfication, which is in principle, reverse fuzzyfication. Input for the defuzzyfication process is a fuzzy set and output is a crisp value. Most popular defuzzyfication method is the centroid calculation, which returns the center of the area under the curve.

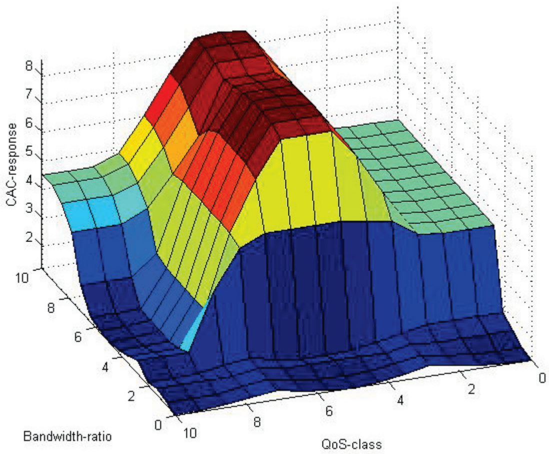

Fig. 3. Fuzzy-CAC decision surface. Inputs: bandwidth ratio and QoS class. Output: CAC response

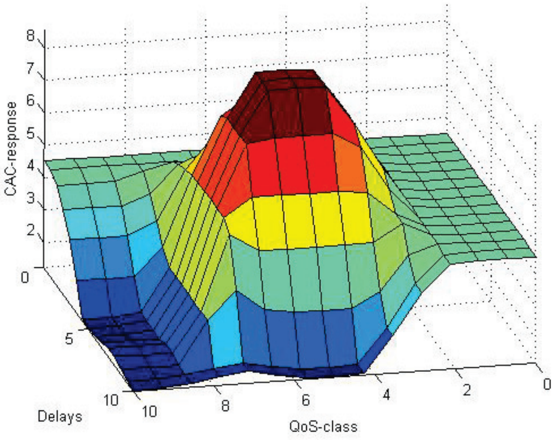

Fig. 4. Fuzzy-CAC decision surface. Inputs: delays and QoS class. Output: CAC response

The COG (center of gravity) defuzzyfication method was used in this investigation and the resulting decision surfaces were obtained (Fig. 3 and 4). Obtained surfaces can be easily implemented in a CAC controller and reduce the computational actions. Although, this will significantly reduce the main advantages of fuzzy-logic: its ability of online optimisation by dynamically changing the rule-base and membership function declarations.

For Fuzzy-CAC algorithm testing we have used more general notion of traffic engineered (TE) link, which is used for LSP setup. A TE link is assumed as a logical link that has TE properties – in out case *BW_Avail* and delays, the QoS class is obtained from the calling party – application.

The proposed algorithm was implemented in the self-made test-bed, which simulated the discrete conditions of the TE link while operating with the fuzzyfied input values. The deffuzified CAC responses were tested for threshold to fire the concrete decision. E.g. the threshold of 1.5 from the central position of positive connection decision resulted either in connection refusal or the connection establishment with protection (Fig. 5).

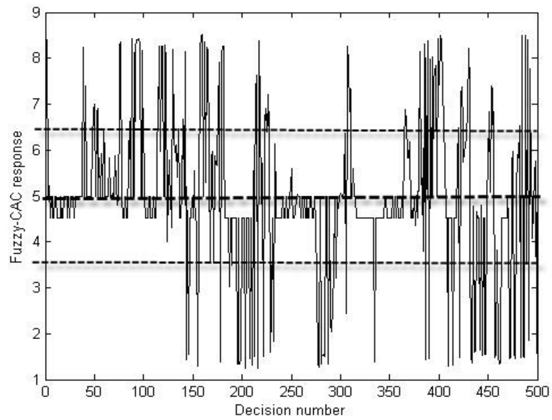

Fig. 5. Fuzzy-CAC response – the thresholds for decision firing are set at 1.5

As a result the fuzzy-CAC scheme allowed achieving selective LSP protection and more flexible and robust decision making even when the input data were out of the specified input range.

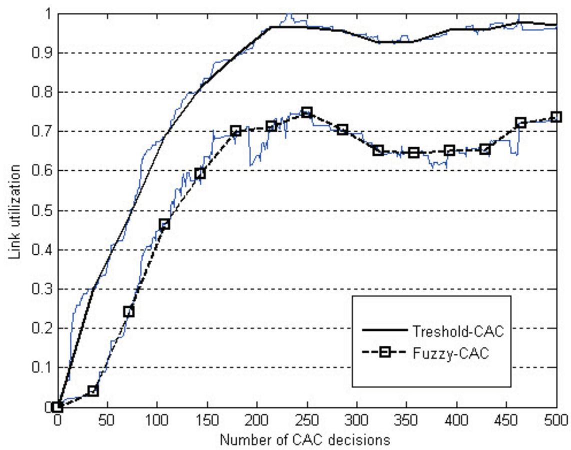

Fig. 6. Fuzzy-CAC and Treshold CAC algorithm operational link state after 500 decisions

The resulted TE link state after 500 LSP setup decisions is depicted on Fig. 6. 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 Treshold CAC refused connections for certain number of decisions

Refused connections		
Decisions	**Threshold CAC**	**Fuzzy CAC**
500	76	46
1000	203	127
2000	432	222
3000	740	474

Conclusions and future research

The proposed fuzzy CAC scheme is the generic connection admission control algorithm which can be used as the potential modification of the RSVP-TE CAC control mechanism to deal with multiple class traffic of next generation fast optical networks which are anticipated to operate under GMPLS control plane. Based on diverse QoS parameters be included in connection request, a multi variable fuzzy CAC algorithm is presented to satisfy the QoS requirement and utilize the system resource efficiently. The simulation results show that the performance of proposed algorithm is preferable to that of existing threshold scheme of RSVP-TE and gives unfailing modification and improvement facilities for possible adjustments. The future research anticipates fuzzy interface membership function and fuzzy rules to be dynamically modified to attain optimal decision making under uncertain network conditions. The curiously interesting appears the possibility of development of multiagent traffic management system based on fuzzy agents, to provide common knowledge base for certain network clusters and provide the interactivity to the knowledge bases to guarantee their online mode adaptation to the changing network environment.

References

1. **Scoglio C., Anjali T.** A novel method for QoS provisioning with protection in GMPLS networks // Computer Communications USA, 2006. – Vol. 29, issue 6. – P.757–764.
2. **Tricha A., Scoglio C., Akyildiz I. F.** LSP and λSP Setup in GMPLS Networks // Proceedings of IEEE Infocom Hong Kong, 2004. – Vol. 4. – P.2318–2328.
3. **Debasis M., Qiong W**. Stochastic traffic engineering for demand uncertainty and risk-aware network revenue management // IEEE/ACM Transactions on Networking, USA, 2005. – Vol. 13, issue 2. – P.221–233.
4. **Asars A., Petersons E.** Determining the Optimal Interval of the Parameter Identification of Self-Similar Traffic // Automatic Control and Computer Sciences, 2009. – Vol. 43, No. 4. – P.211–216.
5. **Kun-Yung L., Chun-Chin S.** A real-time decision-making of maintenance using fuzzy agent // Expert Systems with Applications, Pergamon Press, USA, 2009. – Vol. 36, issue 2. – P. 2691–2698.
6. **Navara M., Petrík M**. Fuzzy Control – Expectations, Current State, and Perspectives // Computational Intelligence, Theory and Applications International Conference 9th Fuzzy Days in Dortmund, Germany, 2006. – P.667–676.
7. **Bardet Lang G., Oppenheim G., Philippe A., Stoev S., Taqqu M.S.** Generators of long-range dependence processes: a survey // Theory and applications of long-range dependence, Birkhäuser, 2003. – P.579–623.

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In this investigation the new Fuzzy-CAC algorithm is proposed for RSVP-TE protocol development for use in GMPLS networks. The Fuzzy-CAC algorithm is based on expert knowledge IF-THEN rule collection. Decision making is flexible, due to the contemporaneous analysis of input variables and lack of crisp valued inputs. Classical threshold CAC algorithm is compared to the Fuzzy algorithm implementation, main characteristics are analyzed. Experimental data are depicted and future research subjects are described. Ill. 6, bibl. 7, tab. 1 (in English; summaries in English, Russian and Lithuanian).

Я. Елинскис, Г. Рутка, Г. Лаукс. Фаззи-CAC для установления LSP в сетях GMPLS // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 31–34.

Представлен новый алгоритм Фаззи-CAC для протокола RSVP-TE, предназначенный для применения в сетях GMPLS. Фаззи-CAC алгоритм основан на экспертных знаниях в виде комплекта правил ЕСЛИ-ТО. Гибкое принятие решений обусловлено одновременным анализом входных переменных и отсутствием четких значений. В данном исследовании Фаззи-CAC алгоритм сравнен с классическим алгоритмом CAC, основанным на граничном значении, и проанализированы основные характеристики действия алгоритма. Указаны экспериментальные результаты и темы последующих исследований. Ил. 6, библ. 7, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

J. Jeļinskis, G. Rutka, G. Lauks. Neraiškiojo CAC algoritmo galimybių GMPLS tinkluose įvertinimas, naudojant LSP // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 31–34.

Aprašomas naujas, originalus neraiškusis protokolo RSVP-TE CAC algoritmas, plačiai taikomas GMPLS tinkluose. Pasiūlytasis algoritmas įvertina sukauptas ekspertines žinias ir pateikia priimamų sprendimų technologiją. Pateikiami neraiškiojo CAC algoritmo pranašumai ir trūkumai, palyginti su klasikiniais CAS algoritmais. Plačiai išnagrinėti eksperimentiniai rezultatai ir galimos tolesnių tyrimų kryptys. Il. 6, bibl. 7, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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