A Multi-Granluar Linguistic QoS Model for Networking

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***Abstract*—Recently the increasing use of IP networks, their applications and users requires an increasing amount of networking resources. Therefore, organizations require the guarantee of bandwidth transmission for critical applications for network users, i.e., a guaranteed quality of service. In this contribution we present a decision based model for networking that priors the critical data flow in an organization. This model gathers the preferences of different users with different degree of knowledge about the scenario that might use different scales to express them. Such preferences are based on user's perceptions that imply subjectivity and uncertainty hence, the use of fuzzy linguistic information can improve its treatment and to manage multiple linguistic scales we propose the use of linguistic hierarchies. Eventually a real application of the model in an organization is developed.**

Keywords: QoS, linguistic information, decision analysis, networking, linguistic hierarchies

I. Introduction

Nowadays Internet provides a network service so-called *best effort delivery* that means the network does not provide any guarantee that either data is delivered or that a user is given a guaranteed quality of service level or a certain priority. Therefore, in a best effort network all users obtain best effort service, meaning that they obtain unspecified variable bit rate and delivery time, depending on the current traffic load [1,2]. This type of network service together the commercial use of Internet and its increasing resource demand push the companies to require a higher guarantee of quality of service (QoS). QoS tries to improve the trustworthy of networks facing problems like delivery delays, loss of data packets, low bandwidth and so forth [17,18].

The previous premises help to provide an overall view of the problems that networking QoS are facing up within the companies:

- Network administrators need to design networks able to achieve maximum efficiency for critical applications.
- The routers must be set up such that they would be able to provide different services to different types of network traffic.
- It is very important that network administrators have a clear knowledge about QoS techniques and which scenarios are more suitable for each case.
- The process of traffic priority assignment to the users and/or applications, the planning of network traffic to improve the user's perception are complex and subjective tasks, such that different administrators might have different views of the problem.
- So far, there is no previous researches that joint the abstraction of QoS techniques and Decision Making models in networking.

It is clear the necessity of processes that help to increase the control and use *intelligence* in local area networks by assigning priorities to those network services that users need with higher quality. These processes usually involve uncertainty and subjectivity hence, the use of the Fuzzy Linguistic Approach [11] provides a good toolkit to model preferences about the different network services. Additionally, it is important to take into account that the involvement of several sources of information with different knowledge about the problem consequently, the use of a flexible framework to assess the user's preferences by means of multiple linguistic scales facilitates and improves the results.

Thus in this contribution is proposed a linguistic QoS model based on decision analysis composed by the following phases:

1. *Selection of experts and alternatives.* In this phase are chosen the experts that take part in the problem and the different network services (alternatives) used by the company.
2. *Decision Analysis[5,20,21].* This phase is a multi-step process used to rank the alternatives according to experts' preferences.
3. *Implementation.* It couples the results obtained in the previous phase and the QoS tools.

This contribution is structured as follows: Section 2 reviews concepts, classifications and use of QoS. Section 3 revises the linguistic structure and model that will use the

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proposal. Section 4 introduces a linguistic QoS model for networking. Section 5 shows a real case of the application of the QoS model and eventually Section 6 points out some conclusions and future works.

II. NETWORKING QUALITY OF SERVICE

Networking Quality of Service (QoS) is a set of techniques that try to offer different quality levels to diverse types of network traffic [17,18].

The Internet Engineering Task Force (IETF) has proposed several standards models regarding network services to satisfy the QoS demand. The most spread models are: (i) The model of integrated services/RSVP (Resource Reservation Protocol) [13], the model of differentiated services (DiffServ) [2], the Multiprotocol Label Switching (MPLS) technique [4], the Subnet Bandwidth Manager (SBM) [15], the norms 802.1p and 802.1D [10], the traffic engineering [18,19] and the traffic modeling [16].

The QoS techniques and tools can be applied to local area, wide area and end to end networks [1,17,18] and often they are related to the physical transmission media. In Fig. 1 is showed the application area of the proposed model:

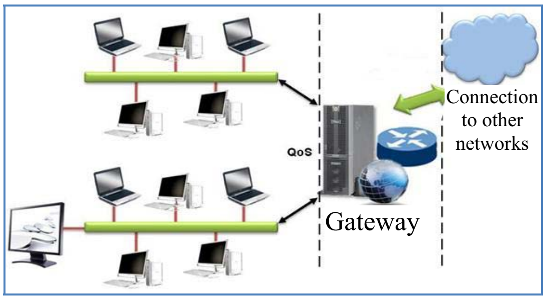

Figure 1. Application Scenario

On the left of the gateway it outlined the local network of the organization that will obtain a differenced service for the different users and/or network traffic. On the right is represented other networks out of the organization such as Internet.

III. LINGUISTIC INFORMATION

The networking QoS will depend highly on subjective, vague and ill-structured information provided by the users. Therefore, we consider the use of the fuzzy linguistic approach [11] to model and manage the inherent uncertainty in the problem.

Additionally due to the need of multiple scales to offer a greater flexibility to the different users involve in the problem, the model proposed is defined in a multi-granular linguistic context. The use of linguistic information implies processes of Computing with Words (CW). This section reviews in short the concepts and methods used in the proposed model such as the fuzzy 2-tuple linguistic model and the linguistic hierarchies.

A. The Fuzzy linguistic 2-tuple model

This model was presented in [6], for overcoming the drawback of the loss of information presented by the classical linguistic computational models [7]: (i) The semantic model, (ii) and the symbolic one.

The 2-tuple fuzzy linguistic representation model is based on the symbolic method and takes as the base of its representation the concept of Symbolic Translation.

Definition 1. *The Symbolic Translation of a linguistic term $s_i \in S = \{s_0,\ldots,s_g\}$ is a numerical value assessed in [-0.5,0.5) that supports the "difference of information" between an amount of information $\beta \in [0, g]$ and the closest value in {0,...,g} that indicates the index of the closest linguistic term in S (s_i), being [0,g] the interval of granularity of S.*

From this concept a new linguistic representation model is developed, which represents the linguistic information by means of 2-tuples $(s_i, \alpha_i), s_i \in S$ and $\alpha_i \in [-0.5, 0.5)$.

This model defines a set of functions between linguistic 2-tuples and numerical values.

Definition 2. *Let $S = \{s_0,\ldots,s_g\}$ be a linguistic term set and $\beta \in [0, g]$ a value supporting the result of a symbolic aggregation operation, then the 2-tuple that expresses the equivalent information to β is obtained with the following function:*

$$\Delta_S : [0, g] \rightarrow S \times (-0.5,.0.5)$$

$$\Delta_S(\beta) = (s_i, \alpha), with \quad \begin{cases} s_i & i = round(\beta) \\ \alpha = \beta - i & \alpha \in [-0.5, 0,5) \end{cases} \quad (1)$$

where round(·) is the usual round operation, s_i has the closest index label to "β" and "α" is the value of the symbolic translation.

It is noteworthy to point out that Δ_S is a one to one mapping [6] and $\Delta_S^{-1} : S \times [-0.5, 0.5) \rightarrow [0, g]$ is defined as $\Delta_S^{-1}(s_i, \alpha) = i + \alpha$. Thus a 2-tuple is identified by means of a Lumber in the interval [0, g].

Remark 1. The transformation of a linguistic term into a linguistic 2-tuples consists of adding value 0 as symbolic translation: $s_i \in S \Rightarrow (s_i, 0)$

This model has a linguistic computational technique associated, for further detailed description see [6].

B. *Linguistic Hierarchies*

The hierarchical linguistic contexts were introduced in [7] to improve the precision of the processes of *CW* in multi-granular linguistic contexts, that it is the aim of this contribution. A Linguistic Hierarchy (LH) is a set of levels, where each level represents a linguistic term set with different granularity to the remaining levels. Each level is denoted as **l(t, n(t))** being,

- *t* a number that indicates the level of the hierarchy
- *n(t)* the granularity of the term set of the level t

The levels belonging to a linguistic hierarchy are ordered according to their granularity, i.e., for two consecutive levels t and t+1, n(t+1) > n(t). Therefore, the level t+1 is a refinement of the previous level t.

From the above concepts, we define a linguistic hierarchy, LH, as the union of all levels t:

$$LH = \bigcup_t l(t, n(t)) \quad (2)$$

Given a LH, we denote as $S^{n(t)}$ the linguistic term set of LH corresponding to the level t of LH characterized by a granularity of uncertainty n(t):

$$S^{n(t)} = \{s_0^{n(t)}, \ldots, s_{n(t)-1}^{n(t)}\} \quad (3)$$

Generically, we can say that the linguistic term set of level t + 1 is obtained from its predecessor as:

$$l(t, n(t)) \rightarrow l(t+1, 2 \bullet n(t) - 1) \quad (4)$$

A graphical example of a linguistic hierarchy can be seen in Figure 2:

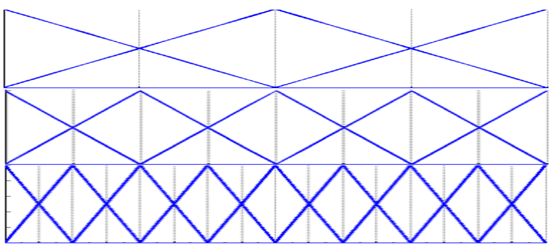

Figure 2. Linguistic Hierarchy. 3,5,9 terms

In [7] were developed different transformation functions between labels of different levels without loss of information. These functions use the computational model for linguistic 2-tuples.

Definition 3. Let $LH = \bigcup_t l(t, n(t))$ be a linguistic hierarchy whose linguistic term sets are denoted as $S^{n(t)} = \{s_0^{n(t)}, \ldots, s_{n(t)-1}^{n(t)}\}$, and let us consider the 2-tuple linguistic representation. The transformation function from a linguistic label in level t to a label in level t' is defined as:

$$TF_{t'}^{t} : l(t, n(t)) \rightarrow l(t', n(t'))$$

$$TF_{t'}^{t}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta_{n(t')}\left(\frac{\Delta_{n(t)}^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \bullet (n(t') - 1)}{n(t) - 1}\right) \quad (5)$$

Proposition 1. The transformation function between linguistic terms in different levels of the linguistic hierarchy is a one to one mapping [7]:

$$TF_{t}^{t'}(TF_{t'}^{t}(s_i^{n(t)}, \alpha^{n(t)})) = (s_i^{n(t)}, \alpha^{n(t)}) \quad (6)$$

IV. A Multi-Scale Linguistic QoS Model For Networking

In this section is presented a proposal for a QoS model in networking that provides a tool to prior critical services in the network of the company, according to the phases enumerated below (see graphically Fig. 3) that are described in detail in the following subsections.

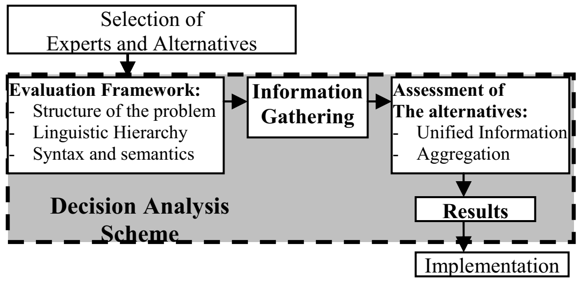

Figure 3. QoS model based on a decision analysis scheme

A. *Selection of Experts and Alternatives*

This phase accomplish preliminary studies about relevant network services, important users or group of users and own features of each organization. It consists of:

1) Identification and selection of experts and/or users that take part in the problem.

2) Identification of group of users with similar critical tasks that should be managed in different way.

3) Identification of network services and network applications used by the organization frequently.

The steps 2) and 3) are the alternatives that the experts of step 1) assess in a multi-granular linguistic domain according to their knowledge, necessity and preference.

B. *Decision Analysis*

This phase accomplishes an analysis of the different alternatives in order to obtain a priority of the services and traffic that will be implemented in the system. This analysis consists of the following processes:

1) Evaluation Framwork

It defines the structure and representation of the information. In this problem is a set of experts,

$E=\{e_1,\ldots,e_n\}$, that express the $S_j^{n(j)}=\{s_0^{n(j)},\ldots,s_{n(j)-1}^{n(j)}\}$ ir preferences about a set of alternatives, $X=\{x_1,\ldots,x_m\}$, by using linguistic labels belonging to the different levels of a linguistic hierarchy, being $LH = \{S_t^{n(t)},\ldots, S_p^{n(p)}\}$

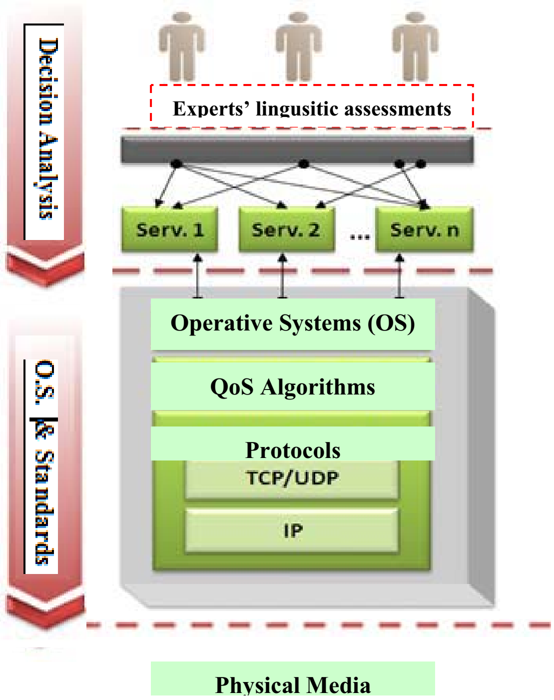

Figure 4. Archichecture of the Model

2) *Information Gathering*

This phase gathers the linguistic assessments in linguistic vectors provided by the experts that indicate the QoS desired for each alternative.

3) *Rating Alternatives*

Here a global assessment is computed for each alternative. Due to the fact, that the gathered information is assessed in multiple linguistic scales, this phase is carried out in two steps:

a) Unification of Multi-granular Linguistic information

All the preferences provided by the experts in different linguistic scales, LH, are transformed to a unique expression domain, so called *Basic Linguistic Term Set* (BLTS) and noted ad *t'*. This BLTS might be any of the level of the LH according to eq. (5).

Once the information has been unified , it is expressed by means of linguistic 2-tuples in $S^{n(t')}$.

b) Aggregation Process

In order to obtain the global assessments for each alternative the information must be aggregated. To do so, the proposal uses aggregation operators for 2-tuples [6,8,9] on the unified information.

4) *Results and implementation*

By using the global assessments obtained in the previous phase a prior order will be establish to planning the network traffic. The ordered alternatives will be implemented in the QoS system of the organization.

The Fig. 4 outlines a general view of the architecture of the proposed model that shows the coupling method, such that, the top layer develops the decision process and the bottom layers implement the QoS mechanism together the operative systems and the network standards.

V. Illustrative Example

Here we provide a real case study with an implemetation based on open source software. This case study applied the model depicted in Fig. 3 and implements the results in a real organization.

A. *Selection of Experts and Alternatives*

In Fig. 5 is showed the network scheme used in the case study. The top area represents a local area network, around 200 computers, that is connected to external networks and Internet through a Gateway that will implement the networking QoS model.

It was chosen 7 computer technicians that usually work in the organization and therefore know its critical necessities and services. However, it does not imply knowledge about network administration either QoS. According to their experience it was assigned different linguistic scales to provide their preferences.

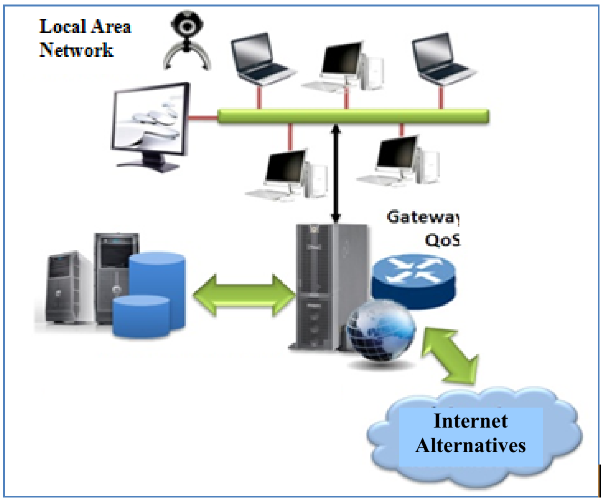

Figure 5. Case study network

Regarding the alternatives, it was identified 3 users' groups and 19 network services that need a differenced treatment. Therefore there were 22 alternatives.

B. Decision Analysis

1) Evaluation framework: it was selected a LH with 3,5 and 9 term sets (See Fig. 2)

2) Information Gathering: The experts provide linguistic vectors in different term sets. In this case 2 experts in the term set with 3 terms, 4 experts with 5 terms and 1 expert with 9 terms. In Table I can be seen a summary of the information provided by experts unified in the term set with 9 terms:

TABLE I. INFORMATION UNIFIED IN S^9

x_i	Experts			
	e_1	..	e_6	e_7
x_1	$(s_8^9,0)$	..	$(s_6^9,0)$	$(s_8^9,0)$
..	..	..	..	..
x_{22}	$(s_4^9,0)$	..	$(s_8^9,0)$	$(s_5^9,0)$

3) Rating the alternatives: Once the information has been unified it is aggregated. In this case study was used the mean operator for 2-tuples [7] obtaining a overall value for each alternative that will be implemented in the next step (see Table II).

C. Results and Implementation

The alternatives are ordered according to the overall values obtained previously in order to assign their priorities of QoS (see Table II)

TABLE II. PRIORITIES FOR THE ALTERNATIVES

PRIO	x_i → Overall values
1	$x_7 \to (s_8^9,-.29)$ $x_1 \to (s_8^9,-.29)$
2	$x_8 \to (s_7^9,.14)$
3	$x_4 \to (s_6^9,.42)$, $x_{22} \to (s_6^9,.14)$, $x_{21} \to (s_6^9,0)$, $x_{19} \to (s_6^9,-.29)$, $x_5 \to (s_6^9,-.29)$
4	$x_{20} \to (s_5^9,.14)$, $x_{11} \to (s_5^9,0)$, $x_3 \to (s_5^9,0)$, $x_{15} \to (s_5^9,-.15)$, $x_{14} \to (s_5^9,-.15)$
5	$x_9 \to (s_4^9,.14)$, $x_{16} \to (s_4^9,-.15)$ $x_{10} \to (s_4^9,-.43)$
6	$x_{18} \to (s_3^9,.14)$, $x_{17} \to (s_3^9,.14)$, $x_2 \to (s_3^9,-.29)$, $x_{13} \to (s_3^9,0)$, $x_{12} \to (s_3^9,-.43)$
7	$x_6 \to (s_2^9,-.14)$

The priority systems for QoS [16,19] assign priority values, PRIO (·), the small values are assigned for higher priority and high values for lower priority. The priority assignment for the alternatives acts according to the following rule $PRIO(k) := \bigcup_{i=1}^{n} (\overline{x_i})$. Such that if *k=1* (maximum priority) it is then assigned to all the alternatives with higher *overall value* grouping by linguistic term.

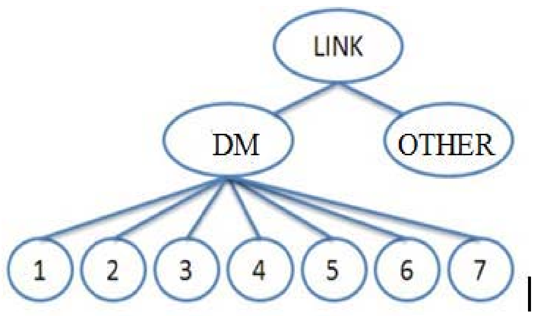

Figure 6. Case study network

In Fig. 6 is outlined the priority of the different types of network traffic by a tree structure, being the root the total bandwidth of link. The second level nodes *DM* and *OTHER* mean the main classes, being the class DM the class that classifies the network traffic and OTHER the class that corresponds to the non-classified traffic, i.e., those services that are not crucial for the organization hence, its bandwidth is very low. Each node of the third level corresponds to a sub-class obtained in the decision analysis phase that means the priority of each alternative. The higher priority alternatives would be classified in the sub-classes with lower values and lower priority alternatives in the sub-classes with greater values in order to avoid the system destabilization.

VI. CONCLUSIONS

The QoS for networking is key problem in organizations due to the imbalance demand of resources of the different network services. In this paper it has presented a flexible model based on the fuzzy linguistic approach for QoS in networking that facilitates the network administrators to give priority to the different network traffic in the network.

A very important feature of this model is the offering of multiple linguistic scales to the experts that make easier the adjustment of the knowledge to the scale used to express their preferences.

Finally just to remark that the QoS mechanisms implemented in this paper allow the development of distributed architectures based on Decision Making for QoS that stabilizes the system very quick and in an interactive way.

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