DECISION ANALYSIS LINGUISTIC MODEL OF NETWORK SERVICES

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Abstract *— The common use of IP networking structures and the increasing demand of resources provoked by users and applications makes that organizations require a guarantee of bandwidth transmission for critical applications and users, i.e., a minimum Quality of Service (QoS). To address this problem different strategies and tools of QoS can be used. It is noteworthy that the user's needs are subjective because they depend on user's perceptions and involve vagueness and uncertainty in the evaluation of the guaranteed quality demanded. In this contribution we propose decision analysis based model of network services by using linguistic information in order to model subjectivity and then prioritize the networking critical traffic of the organization. Moreover the model provides a flexible framework to facilitate experts express their preferences in a multiple linguistic scale domain. Eventually the resulting architecture is applied to a case study in a real organization.*

Index Terms — 2-tuple Linguistic Model, Decision Analysis Model, Fuzzy Linguistic Approach, Linguistic Hierarchy, Quality of Services, Traffic Engineering

1. 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 [2]-[16]-[17]. 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 tries to improve the trustworthy of networks facing problems like delivery delays, loss of data packets, low bandwidth, quality of content and so forth [2]-[3]-[6]-[16]. The process of priority assignment and planning of network traffic are complex and subjective tasks. Different administrators might have different views of the problem.

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Due to these problems then arises the need for processes that increase the control and provide *intelligence* to local networks to prioritize network services. These processes usually involve uncertainty and subjectivity hence, the use of the Fuzzy Linguistic Approach [19] provides a good toolkit to model preferences about the different network services. Furthermore, the involvement of multiple sources of information with different degrees of knowledge and context definition problem requires a more flexible model and different linguistic scales can be used. To address these problems this contribution provides a linguistic QoS model based on a linguistic decision analysis scheme composed of multiple phases detailed later.

This contribution is organized as follows. Section 2 reviews basic concepts, classifications and uses of QoS, Section 3 provides a linguistic background that the model will use to model uncertain information. Section 4 presents the linguistic model of QoS for network services and an application to a real case study. Finally in Section 5, are pointed some conclusions and possible future work.

2. QOS OVER NETWORKING

Quality of Service (QoS) is a generic name for a set of techniques that seeks for providing different quality levels to different types of network traffic [16]-[17].

The Internet Engineering Task Force, IETF, has proposed different models of service standards and mechanisms to meet the demand for QoS. The most well-known are: the integrated services model (RSVP, Resource Reservation Protocol) [1], the differentiated services model (DiffServ) [7], the MPLS technique (Multiprotocol Label Switching) [15], SBM (subnet Bandwidth Manager) [18], 802.1p and 802.1D standards [13], traffic engineering [16] and traffic shaping [6].

Also, in recent years researches have been conducted to describe the strengths and weaknesses relating to each of these mechanisms. They can also be applicable at local or end-to-end transmission [16]-[17].

In Section 4, Figure 3.a shows the application or scope area of the proposed model. On the top 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. At the bottom is represented other networks out of the organization such as Internet.

3. LINGUISTIC BACKGROUND

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 [19] to model and manage the inherent uncertainty in the problem [8].

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.

3.1 The Fuzzy linguistic 2-tuple model

This model was presented in [9], for overcoming the drawback of the loss of information presented by the classical linguistic computational models [8]: (i) The semantic model [4], (ii) and the symbolic one [5]. It 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 $s_i \in S = \{s_0,...,s_g\}$ 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 $S = \{s_0,..,s_g\}$ 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:

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

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

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 [9] 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 numeric value 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 [9].

3.2 Linguistic Hierarchies

The hierarchical linguistic contexts were introduced in [10] to improve the precision of the processes of CW in multi-granular linguistic contexts. 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 LH 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. Thus, it defines a linguistic hierarchy, LH, as:

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

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

A graphical example of a LH can be seen in Figure 1. Generically, we can say that the linguistic term set of level t + 1 is obtained from its predecessor as:

$$l(t,n(t))\rightarrow l(t+1, 2\bullet n(t)-1) \qquad (3)$$

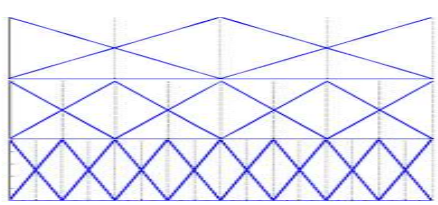

FIGURE 1

LINGUISTIC HIERARCHY OF 3, 5 AND 9 TERMS

In [10] were developed transformation functions which use the 2-tuples model.

Definition 3. Let $LH=\bigcup_t l(t,n(t))$ be a LH 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 t' is defined as:

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

$$TF_{t'}^{t}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta_{n(t')}\left(\frac{\Delta_{n(t)}^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \bullet (n(t') - 1)}{n(t) - 1}\right) \quad (4)$$

4. QoS LINGUISTIC MODEL FOR NETWORK SERVICES

The most important problems of QoS require a management process to prioritize critical network services within the organization. To achieve this objective, this section presents a QoS Linguistic Analysis Decision Model for Network Services with 3 phases that are further detailed below.

Figure 2 shows graphically the phases of this model.

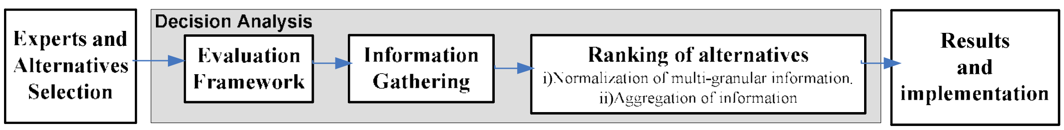

FIGURE 2

MODEL PHASES

To clarify the performance of the model is introduced and explained the results of Real Cased Study (RCS) developed in an organization with approximately 200 network devices connected to Internet and external networks.

1. Experts and Alternatives Selection.

This phase accomplish preliminary studies about relevant network services, important users or group of users. It consists of:

a) Identification and selection of experts and/or users that take part in the problem.
b) Identification of group of users with similar critical tasks.
c) Identification of useful network services and network applications.

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

RSC: We have selected 7 experts and 22 alternatives (useful services for the organization) after a preliminary study. Experts are computer technicians who work in maintenance and they know all needs of the organization.

2. Decision Analysis.

This phase examines alternatives to obtain the results of traffic management and services to be implemented in the system.

It consists of three steps:

a) *Evaluation Framework.*

It defines the structure and representation of the information.

Let $E = \{e_1, \ldots, e_n\}$ be a set of experts expressing their preferences regarding a set of alternatives $X = \{x_1, \ldots, x_m\}$ by using different linguistic scales of information in $LH = \{S_t^{n(t)}, \ldots, S_p^{n(p)}\}$, being $S_j^{n(j)} = \{s_0^{n(j)}, \ldots, s_{n(j)-1}^{n(j)}\}$.

RSC: It was selected a LH with three linguistic term sets of 3, 5 and 9 linguistic terms each one. See Figure 1.

b) *Information Gathering.*

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

Let $U_i = \{u_1^i \ldots u_m^i\}$ be a vector of preferences given by the expert e_i and $u_k^i \in S_r^{n(r)}$ the expert's preference for alternative x_k in $S_r^{n(r)} \in LH$.

RSC: 7 experts provided their linguistic preferences as showed in Table I, column a). For the sake of simplicity and space limitations the results are summarized in the table I.

c) *Ranking of 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:

i) 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 as *t'*. This BLTS might be any of the level of the LH according to (4). Once the information has been unified, is expressed by means of linguistic 2-tuples in $S^{n(t')}$.

ii) Aggregation of information. 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 [9]-[11]-[12] on the unified information.

TABLE I

PHASES APPLIED TO RSC

Alternatives	1) Information gathering.				2) Normalization in BLTS				3) Aggregation
	Experts				Experts				$\overline{x}^e$
	e_1	..	e_6	e_7	e_1	..	e_6	e_7	
x_1	$(s_2^3, 0)$	..	$(s_3^5, 0)$	$(s_8^9, 0)$	$(s_8^9, 0)$	..	$(s_6^9, 0)$	$(s_8^9, 0)$	$(s_8^9, -.29)$
..	..	..	..	..	..	..	..	..	
x_{22}	$(s_1^3, 0)$	..	$(s_4^5, 0)$	$(s_5^9, 0)$	$(s_4^9, 0)$	..	$(s_8^9, 0)$	$(s_5^9, 0)$	$(s_6^9, .14)$

RSC: It was selected the BLTS in $S^{n(t')} = S^9$ (see Table I, column 2)). Then, the unified information is aggregated by using the arithmetic mean operator [11] showed in (5) and results are summarized in Table I, column 3).

$$\overline{x^e}[(r_i, \alpha_i) = \Delta(\sum_{i=1}^{n} \frac{1}{n} \Delta^{-1}(r_i, \alpha_i)) = \Delta(\frac{1}{n} \sum_{i=1}^{n} \beta_i) \tag{5}$$

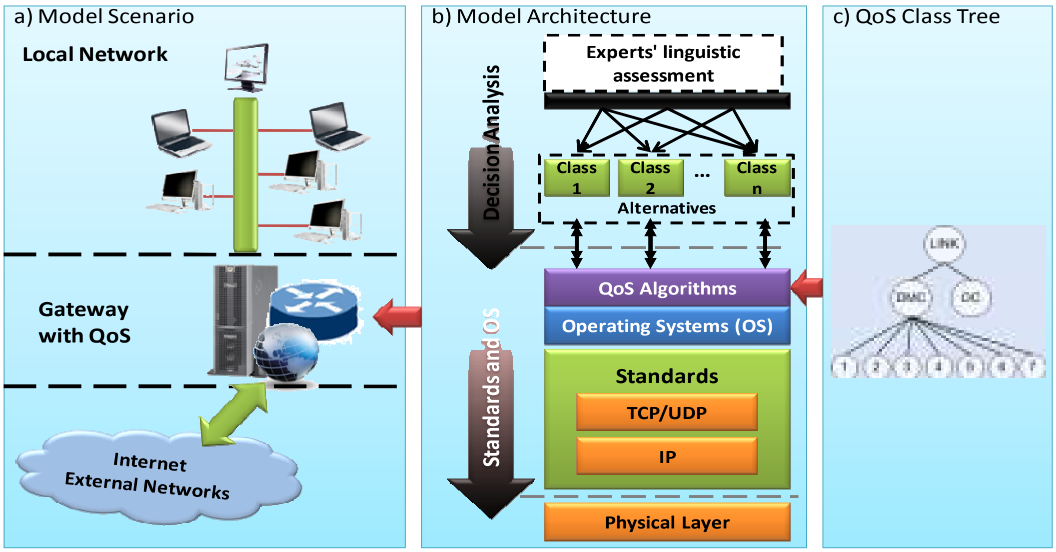

FIGURE. 3

MODEL SCENARIO AND MODEL ARCHITECTURE

3. 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.

TABLE II

MODEL SCENARIO AND MODEL ARCHITECTURE

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

RSC: The alternatives are ranked based on collective preference obtained from previous phase. Table II shows these results for each alternative.

Prioritization process function for alternatives, PRIO(.), follows the basic rule:

$$PRIO(k) := \bigcup_{i=1}^{n} (\overline{x}_i) \begin{cases} \text{PRIO}(1) \Rightarrow \text{n alternatives with the biggest w in } \overline{x}_i = (s_w^{t'}, \alpha) \textit{ and w is the same } \forall i \\ \text{PRIO}(2) = \overline{x}_i / \overline{x}_i (s_{w-1}^{t'}, \alpha), .., \\ \text{PRIO}(z) = \overline{x}_i / \overline{x}_i (s_{w-z}^{t'}, \alpha) \end{cases}$$

where $z \leq t'-1$ and $0 \leq w \leq (t'-1)$. So, this process brings alternatives with closest linguistic values.

Figure 3.b outlines a general view of the proposed model architecture that shows the coupling method, such that, the top layer develops the decision process and the bottom layers implement the QoS mechanism together the O.S. and the network standards.

Figure 3.c shows traffic class prioritization process as a tree, where the root node indicates total bandwidth of the link. Second level nodes are the root classes, DMC (decision making class) has seven type of traffic prioritized by the results of previous phases and OC (others class) is the unclassified traffic class and its priority is the smallest because this traffic is not necessary in the organization.

5. 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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