The Linguistic Modeling of Fuzzy System as Multicriteria Evaluator for the Multicast Routing Algorithms

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Abstract. The paper presents the use of fuzzy system in multicriteria evaluation of algorithms that generate multicast trees and optimize realtime data transmission in computer networks. These algorithms take into account a number of factors such as: cost, bandwidth or delay, and their efficiency can be represented by total cost of multicast tree or average path's cost in multicast tree [18]. However, there is a lack of accurate methods for comparing and evaluating these algorithms. In addition, it is difficult to identify with precision the weight of the criteria. The paper describes various proposals models underlying linguistic system that performs two-criteria assessment. These proposals show how to implement linguistic changes and their impact on the results of the fuzzy system.

Keywords: multicriteria fuzzy evaluation, fuzzy system, multicast routing algorithms.

1 Introduction

In many areas of science that are experiencing rapid development there is the problem of mathematical modeling, especially in the evaluation of new technologies. The precise science often does not keep pace with the changes, what is understandable, because the creation of accurate models requires a structured access to multiple data of the same nature. In such situations, the fuzzy set theory seems to be a reasonable choice [25,26]. It allows to create a mathematical model based on linguistic description. The resulting theory using this model may not be optimal, but realizes the basic assumptions and, what is important, is highly intuitive. The knowledge that is the basis of the system, can be obtain from people who understand the matter in the practical literate but not well enough to use the mathematical apparatus to create an accurate model representing their skills. Such an area rapidly developing today is telecommunications. One of the subjects intensively evolving is effective transmission of data in computer networks.

Multicasting is a transmission method used in packet-switched networks for delivering mainly voice and multimedia data at the same time from one to many

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receivers. This technique requires efficient routing algorithms defining a tree with a minimum cost between the source node and the particular nodes representing the users. Such a solution prevents from duplication of the same packets in the links of the network. Routing of the sent data occurs only in those nodes of the network that lead directly to destination nodes [16].

The main objective of the publication is to assess the quality of the algorithms that generate multicast tree using fuzzy sets theory. Since there is no specific precise assessment model, it can always be expressed by a linguistic model and on its basis to build a fuzzy system.

The use of fuzzy systems for multi-criteria problems is quite common [6,2]. The same problem is presented in the literature and is called *fuzzy multicriteria analysis*. The paper [5] presents an overview of the developments in this area.

The paper is divided into six sections. Section 2 describes the implemented network model. Section 3 presents the overview of multicast routing algorithms. Section 4 focuses on multicriteria fuzzy evaluators for multicast routing algorithms while Section 5 presents the results of evaluations. Section 6 sums up the paper.

2 Network Model

The network is represented by an undirected, connected graph $G = (V, E)$, where V is a set of nodes, and E is a set of links. With each link $e_{ij} \in E$ between nodes i and j two parameters are coupled: cost c_{ij} and delay d_{ij}. The cost of a connection represents the usage of the link resources; c_{ij} is then a function of the traffic volume in a given link and the capacity of the buffer needed for the traffic. A delay in the link is in turn the sum of the delays introduced by the propagation in a link, queuing and switching in the nodes of the network. The multicast group is a set of nodes that are receivers of the group traffic (identification is carried out according to a unique i address), $M = \{m_1, ..., m_m\} \subseteq V$. The node $s \in V$ is the source for the multicast group M. Multicast tree $T(s, M) \subseteq E$ is a tree rooted in the source node s that includes all members of the group M and is called *Steiner tree*.

The total cost of the Steiner tree $T(s, M)$ can be defined as $\sum_{t \in T(s,M)} c(t)$. The path $p(s, m_i) \subseteq T(s, M)$ is a set of links between s and $m_i \in M$. The cost of path $p(s, m_i)$ can be expressed as: $\sum_{p \in P(s,m_i)} c(p)$, where $P(s, m_i)$ is a set of possible paths between s and $m_i \in M$. The delay is measured between the beginning and the end of the path as: $\sum_{p \in P(s,m_i)} d(p)$. Thus, the maximum delay in the tree can be determined as: $\max_{m \in M}[\sum_{p \in P(s,M)} d(p)]$.

Because of time complexity (the problem is proven to be $\mathcal{NP}$-hard) heuristic algorithms are most preferable for solving this problem.

3 Multicast Routing Algorithms

The implementation of multicasting requires solutions of many combinatorial problems accompanying the building of optimal transmission trees. In the optimization process it can be distinguished: MST – *Minimum Steiner Tree*, and the