Warsaw University of Technology

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Ph.D. Thesis

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Ant Algorithms for Adaptive Routing in Telecommunication Networks

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Abstract

This thesis addresses the application of ant algorithms to solve the routing problem in fixed telecommunication networks. With the continuing growth of the Internet and other communication networks, there is a strong need for routing algorithms that can distribute data traffic across multiple paths and quickly adapt to changing conditions. Algorithms based on swarm intelligence, such as the ant algorithms, are well applicable in this field, as they do not need any supervision and are naturally distributed.

In this dissertation we have proposed and developed of a number of significant improvements of the ant routing algorithms based on extending the accessible information about the network's state. We introduce the use of statistical models of the end-to-end packet delay to accurately describe the network's traffic conditions. Based on these models we proposed the following algorithms.

The first improvement addresses the performance of ant routing algorithms together with the TCP protocol. We showed that it is still possible to extend the load range of the network when using TCP. However, in some cases the profit of using ant routing algorithms may decrease, as the TCP sets higher demands on the learning process than UDP. Therefore, we introduced and developed the DelModAnt TCP protocol, which is a modified version of the TCP protocol that improves its robustness to packet reordering in networks controlled by ant routing algorithms. The modification applies to the TCP sender and it utilizes models of the data packets' delay distributions in order to decide whether a packet has been lost and must be retransmitted or the DUPACK is a result of packet reordering. We show that using the DelModAnt TCP significantly reduces the number of retransmissions in the network. Moreover, as a result of the proposed modification, the TCP congestion window is less times decreased, so the transmission is faster.

The next issue concerns the adaptation abilities of the ant routing algorithms. The experiments showed that the ant routing algorithms have high adaptation abilities to load level changes, but the adaptation time to some patterns of the load level change is rather long. Thus, we proposed the Reactive ASR-FA algorithm that utilizes the delay models to quickly detect changes in the network conditions. According to a statistic test a decision is made whether the currently maintained delay model is still adequate. If not, a change in the network conditions is assumed and the learning parameters of the Reactive ASR-FA algorithm are temporary modified in order to speed up the adaptation process. As an effect, the Reactive ASR-FA algorithm can react faster on various load level changes, including DoS and DDoS network attacks. We show in a set of simulations that

using the modified algorithm not only speeds up the adaptation process but also achieves lower values of the mean data packet delay.

The final improvement is based on the analysis of the packet delay cumulative distribution function. The experiments showed that some packets experience very low delays but a relatively big part of the delay distribution focuses near higher values, which are not as competitive. In order to address this issue, we introduced the MB-ASR-FA algorithm that takes advantage of the cross-entropy method in order to optimize a given percentile of the data packet delay distribution. As a result we have obtained a well founded theoretically algorithm that assures a significantly better characteristics of the empirical cumulative distribution function by increasing the probability of lower delay values. Moreover, the experiments show that using the MB-ASR-FA algorithm enables to significantly decrease the mean packet delay value, although it is not directly optimized by this algorithm.

Keywords: swarm intelligence, ant algorithms, adaptive routing, telecommunication networks, ant routing, adaptive control.

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