# Differentiated Quality of Service Scheme Based on the Use of Multi-classes of Ant-like Mobile Agents

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## ABSTRACT

We present AntNet-QoS, a novel approach that taking inspiration from the Ant Colony Optimization (ACO) framework, and in particular from the AntNet routing algorithm, allows dynamic scheduling, forwarding and link sharing among multiple packet classes in a differentiated service (DiffServ) network.

## Categories and Subject Descriptors

C.2 [**Computer-Communication Networks**]: C.2.2 Network Protocols: - *Routing Protocols*. C.2.1 Network Architecture and Design: - *Distributed Networks*

## General Terms

Algorithms, Management, Measurement, Performance, Design.

## Keywords

Quality of Service (QoS), DiffServ, QoS Routing (QoSR), Ant-based Algorithms, Ant Colony Optimization (ACO).

## 1. INTRODUCTION

In a DiffServ network [1], ingress nodes have the aim of classifying those arriving flows into Classes of Services (CoS) that can be provided in the network.

Once the classification is made, core nodes could differentiate the traffic (aggregates of flows) in terms of forwarding (QoSR), scheduling (queuing priority, discarding), and fragmentation (if it is permitted). Most of the QoS schemes for DiffServ networks do the differentiation (known as Per-Hop Behavior – PHB) only in terms of scheduling but not on forwarding.

Schemes that take into account the forwarding differentiation generally propose QoSR algorithms where the focus is on improving the performance of individual CoS. But, since in a multi-class network, as DiffServ is, services with high priority coexist with services with lower priority, the decision in routing and scheduling for the high priority services has to be made carefully to not affect the performance of the lower priority services. Then, a scheme that allows dynamic scheduling, forwarding and link sharing among multiple CoS is needed.

In this paper we present AntNet-QoS, a DiffServ scheme that takes into account all these needs by extending the ideas of AntNet [2], an ACO algorithm [3] designed for best-effort routing in IP networks.

## 2. AntNet-QoS – GENERAL DESCRIPTION

AntNet-QoS [4] is a differentiated QoS scheme where *n* CoS are considered to be provided. Core nodes do the PHB in terms of scheduling and forwarding for the *n* CoS.

In terms of scheduling, we consider *n* queues, serviced proportionally to their priority according to a min-max class-based queuing policy. We allocate resources to each CoS in accordance with its relative weight. In the case of an empty queue, excess capacity is dynamically allocated to the remaining classes based on the relative weights.

Data forwarding decisions are based on stochastic routing tables obtained according to the AntNet model (fig. 1). AntNet-QoS uses *n* different and independent Classes of Ant-like mobile agents (CoA) to deal with the *n* different CoS. The task of each ant belonging to a specific CoA consists in sampling/discovering a path that can provide the QoS required by the CoS managed by the ant's CoA.

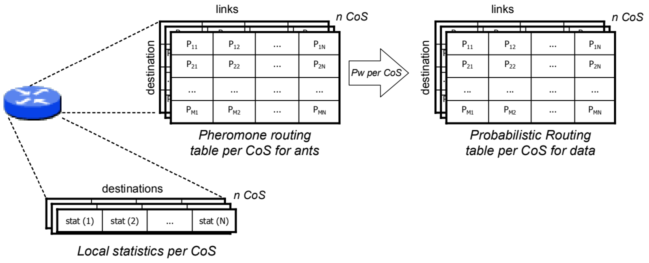

**Figure 1. Forwarding: data structures in every node**

Per each CoS, every node holds an ant routing table (called *pheromone table*), a data routing table, and a vector of statistics. In the $k_{th}$ pheromone table, each value $P_{ij}$ indicates for the $k_{th}$ CoS, the real-valued goodness of going over neighbor $i$ to destination $j$. Values in the $k_{th}$ pheromone table are updated using the end-to-end delay estimates reported by the $k_{th}$ CoA. The vector of statistics (average path delay, best path delay, variation delay) is needed to evaluate the delays reported by the ants.

Data routing tables are derived from the pheromone tables by applying a power function (so data avoid low probability paths).

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## 3. EVALUATION OF THE SCHEME

Using the OMNeT++ simulator [5], we have implemented our AntNet-QoS scheme. We report preliminary results concerning the ability of the algorithm to distribute the different traffic flows across different paths and its overall performance.

### 3.1 Traffic Distribution over Multiple Paths

In a simple network (fig. 2), where all links have the same capacity, two CoS are sent from node 1 to node 5. Three are the possible paths connecting these two end nodes. The priority preference of $CoS_0$ is 70%, and the one of $CoS_1$ is 30%.

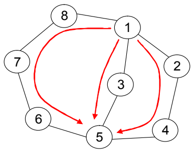


**Figure 2. Simple network formed by 8 nodes and 9 links**

AntNet-QoS shows a quick adaptive response, as it is typical of ant-based algorithms. It rapidly learns about the three possible paths and distributes the traffic in accordance with their respective capacity. After 35 seconds, 83% of the $CoS_0$ traffic follows the best path 1-3-5. The rest of the $CoS_0$ traffic follows the path 1-2-4-5. 59% of $CoS_1$ traffic follows the path 1-2-4-5, 35% follows the path 1-8-7-6-5, and the remaining 6% follows the path 1-3-5 (mainly used for $CoS_0$ traffic).

### 3.2 Performance Analysis

In a second series of experiments we considered a more complex and realistic network, NSFNET-T1 (fig. 3). In this case, traffic of three CoS is sent from node 1 to node 4. We analyze throughput, end-to-end delay, variation delay, and overhead, when network load increases from 10 to 100% (fig. 4) following the same type of experiments described in [6].

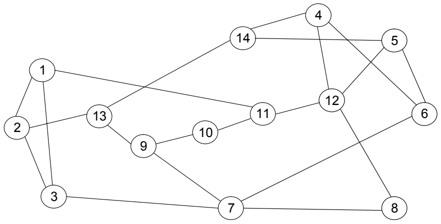
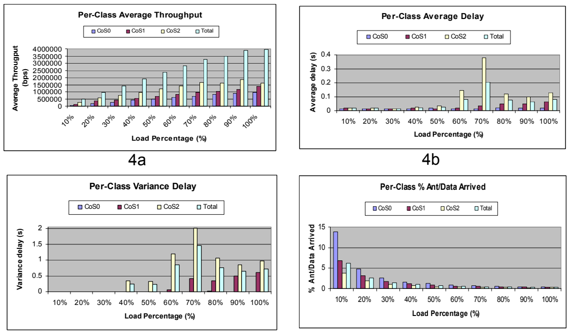


**Figure 3. NSFNET-T1 network: 14 nodes and 21 links**

Traffic marked as $CoS_0$, $CoS_1$ and $CoS_2$ has priority preference of 70%, 20% and 10% respectively. The capacity of each link along path 1-11-12-4 (the shortest path) is 3 Mps, and the capacity of the other links is 2 Mps. 20% of the generated traffic belongs to $CoS_0$, 30% to $CoS_1$, and 50% to $CoS_2$. Forward ants are proactively generated every 0.2 sec.

Figure 4a shows the total average throughput, and the individual class ones. In [6], it is said that the widest bandwidth (WB) algorithm shows a network efficiency (ratio between the average total throughput and the total capacity of the paths connecting node 1 and node 4) of 88.1%, while that of a per-class approach, called PERD, shows a 97.1%. On the other hand, the network efficiency of AntNet-QoS is 93.2%.

In terms of delay, when the traffic load is relatively low, there is no obvious difference between AntNet-QoS and its opponents, but when traffic load increases, it performs much better than its opponents. For instance, in the extreme case of 100% traffic load, the WB algorithm provides an average delay of 512 ms for the $CoS_2$ traffic, while AntNet-QoS provides an average delay of only 129 ms.



4a 4b

4c 4d

**Figure 4. Per-class performance of AntNet-QoS**

In more general terms, the experimental results seem to show that AntNet-QoS can provide a significant advantage over its competitors especially concerning measures of end-to-end delay and jitter (fig. 4b and 4c). Moreover, the low overhead (fig. 4d) of AntNet-QoS shows its efficiency in terms of an effective use of network resources to deliver good performance.

## 4. Conclusions and Future Work

We have proposed a scheme that allows dynamic scheduling, forwarding and sharing link among multiple CoS. In spite of the fact that this work is still in progress, preliminary results show that the proposed scheme can make full utilization of network resources providing good performance in terms of end-to-end delay, throughput, and jitter.

Future work includes the implementation of an admission control scheme, the cooperation among the different CoAs to improve the process of path evaluation and pheromone updating using both positive and negative reinforcements; use of both proactive and reactive ant generation to better support high priority CoS; identification of mechanisms for self-tuning of the internal parameters in order to build a fully autonomic routing system.

## 5. References

[1] S. Blake, D. Black, M. Carlson, E. Davies, W. Weiss, and Z. Wang. An architecture for Differentiated Services. *RFC 2475*, 1998.

[2] G. Di Caro, and M. Dorigo. AntNet: Distributed Stigmergetic Control for Communications Networks. *Journal of Artificial Intelligence Research 9*, pp. 317-365, 1998.

[3] M. Dorigo, G. Di Caro, L.M. Gambardella. Ant Algorithms for Discrete Optimization. *Artificial Life Vol. 5, N. 2*, 1999.

[4] L. Carrillo, J.L. Marzo, P. Vilà, Ll. Fàbrega, and C. Guadall. A Quality of Service Routing Scheme for Packet Switched Networks based on Ant Colony Behavior. In *Proceedings of the SPECTS 2004.*

[5] The OMNET++ Network Simulator, http://www.omnetpp.org/

[6] W. Zhou. Provision and QoS Route Optimization in Differentiated Service Networks. *Master's thesis. Helsinki University of Technology.* Networking Laboratory. 2002.