Simulation Analysis of the UC-QoS Routing Strategy

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Abstract

Quality of Service routing plays a major role in the deployment of services for traffic with special requirements. We developed a Quality of Service routing strategy - the University of Coimbra-Quality of Service routing strategy (UC-QoSR) - suitable for networks where traffic differentiation is done following the class-based paradigm, as in the Differentiated Services framework. This strategy extends the OSPF routing protocol in order to distribute a Quality of Service metric through the network and to compute paths suitable for all traffic classes. Presently, the traffic model evaluated includes four traffic classes. Each class is characterized upon its degree of sensitivity regarding delay and loss.

In this paper we describe the main aspects of UC-QoSR, namely, the metric used for path selection and the path selection algorithm. The mechanisms conceived to control the communication and processing overhead induced by the dynamic nature of UC-QoSR are also exposed.

The UC-QoSR strategy was evaluated on the Network Simulator (NS). We describe the simulation environment developed, including its core modules and respective interactions. The results concerning UC-QoSR evaluation are presented relatively to communication and processing overhead. We show the efficiency of the mechanisms introduced to reduce communication and processing overhead and evaluate the impact of different network topologies on the results obtained.

Keywords: Quality of Service Routing, Differentiated Services.

1. Introduction

The utilization of the Internet by new types of applications with specific performance requirements such as bandwidth, delay, jitter and loss, and by a growing number of users determines the need for the deployment of Quality of Service (QoS) mechanisms. The Differentiated Services architecture aims at extending the actual best-effort paradigm to provide different levels of QoS to classes of traffic [1].

Major routing protocols currently used on the Internet present several drawbacks when it is necessary to include QoS capabilities in the communication system. Usually, these protocols select the shortest path to a destination, according to a metric such as number of hops or a metric that is defined by configuration. All the traffic for the same destination follows the same path (the shortest path), even when there are better paths according to other dynamic parameters, for instance available bandwidth or loss rate.

In a communication system that aims at providing different levels of quality of service, it is advisable to use routing protocols that make decisions based simultaneously on the needs of traffic and the state of routers in the network, that is, QoS capable routing protocols. In order to achieve this purpose it is necessary to distribute new routing metrics that represent the dynamic state of the network, and to use path selection algorithms to compute paths suitable for the different types of traffic. Particularly, in a service model where traffic is mapped to different classes, there is the need for a routing protocol that selects paths adequate to each class of traffic, based on a metric that represents the state of the network, from the viewpoint of the traffic classes considered.

In this paper we will present some preliminary results of the evaluation of the UC-QoSR routing proposal in a simulation environment, using the Network Simulator[1].

This paper is organized as follows: In Section 2 we present a description of the UC-QoSR strategy; In section 3 it is described the architecture of the simulator modules developed; The experimental framework and results are

[1] <http://www.isi.edu/nsnam/ns/>

presented in Section 4; Conclusions and issues to be analyzed in future work are presented in Section 5.

2. Description of the UC-QoSR Strategy

In this section we describe the service model that motivated the development of UC-QoSR. We then present the main characteristics of UC-QoSR, particularly, those associated with metrics distribution mechanisms.

2.1. Framework

At the Laboratory of Communication and Telematics of the University of Coimbra (LCT-UC) we are developing a new service model for the Internet, where traffic differentiation is done per class, following the approach of the Differentiated Services model. The differentiation of classes is achieved at each router by a scheduler and dropper that implement the Per Hop Behavior Dynamic Degradation Distribution (PHB D3) [2], conceived at LCT. In the service model proposed, we consider four traffic classes. Traffic characterization is based on delay and loss sensitivity of traffic generated by multimedia applications [3]. The characteristics of the traffic classes upon which LCT service model is based are presented in Table 1.

Class	Delay sensitivity	Loss sensitivity	Application
1	Medium	High	Video Training
2	High	Low	Video real-time
3	High	Medium	Internet telephony
4	Low	Low	Best-effort

Table 1- Classes of traffic of the LCT-UC service model.

2.2. UC-QoSR

The main issues that must be addressed by a routing strategy are the metrics that represents the resource availability on the network, the requirements of traffic in terms of QoS parameters and the path selection algorithm. This algorithm is responsible for selecting, based on the information about the state of the network, the paths suitable for each type of traffic.

We use the QoS metric developed at LCT-UC [4] to measure the impact of the degradation of QoS characteristics in application performance. This metric is composed of a delay congestion index (*DcI*) and a loss congestion index (*LcI*). These indexes represent the impact that delay and loss at the router will have on application performance degradation. These congestion indexes represent the state of each interface of the routers in the domain.

The objectives of our routing proposal, UC-QoSR, are to distribute the metric of each router to other routers in the network and, based on this information, to select paths adequate to each class of service.

Our routing proposal is based on the QoS routing mechanisms (QoSRM) presented in [5]. We developed our strategy as an extension to the Open Shortest Path First (OSPF) routing protocol [6] and use mechanisms similar to QoSRM to propagate the QoS metric. There are however three main differences that are described in the remaining of this section:

- The metric that represents the state of the network;
- The path selection algorithm;
- The method used for traffic characterization.

In UC-QoSR each link is characterized by a cost that results from the composition of the delay and loss congestion indexes, instead of available bandwidth, the metric used in QoSRM. The cost function used is presented in Equation 1.

$$Cost_i = WL_j * LcI + WD_j * DcI \quad (1)$$

In Equation 1, $Cost_i$ is the cost of link i; WL_j and WD_j are the weights of the loss and delay congestion indexes for class j, respectively.

The combination of the congestion indexes results in a value that represents the congestion state of the interface, as each traffic class perceives it. Since the indexes represent comparable measures, there is no loss of information from aggregation of different kinds of units, as it would be the case if we were combining delay and losses. This fact stems from the nature of the indexes, that measure the impact that delay and losses have on application performance.

Another difference of UC-QoSR relatively to QoSRM pertains to the path computation algorithm used. Since we combine both indexes in a simple cost, there is no need to use path selection algorithms with increased complexity, and thus path selection is done using the Dijkstra algorithm, as in the original version of OSPF.

The last distinction between QoSRM and UC-QoSR pertains to the fact that QoSRM requires the utilization of a signaling protocol, such as RSVP [7] to express traffic characteristics, while UC-QoSR relies on the information associated to the different classes. This information is put in packet headers, in the Differentiated Services Code Point (DSCP) field.

2.3. Mechanisms for Metrics Distribution

In the UC-QoSR routing strategy, the state of the interfaces of each router is represented by the delay and loss congestion indexes that constitute the QoS metric used. These indexes are distributed as an extension to the routing protocol OSPF. We use the fields of OSPF routing messages that were devoted for type-of-service routing. This field is used to express that routing messages carry two additional fields, containing *DcI* and *LcI*, besides the original OSPF metric. With this approach there is not the need for introducing new types of messages, keeping our strategy very similar to OSPF and thus allowing inter-operation among routers running both protocols.

The congestion indexes are monitored in a time scale of ms. In order to avoid routing oscillations, the values advertised are quantified according to the computation of the moving averages of the values registered, with a window average window size (MAW) that is configurable.

In a QoSR approach, the advertisement of link-state messages is more frequent than in traditional protocols. This fact stems from the necessity of all routers maintaining an updated vision of the network. However, the frequent emission of link-state messages can introduce an excessive communication overhead and, consequently, contribute to processing overhead, since paths must be re-computed. In UC-QoSR this problem is minimized by two mechanisms. First, the congestion indexes monitored are subject to the quantification rule described above; second, the emission of link-state messages is subject to the relative criteria presented in the following paragraph.

The emission of advertisements is triggered by a relative criterion consisting of two thresholds (*T1*, *T2*) and a transition point (*TP*). With this kind of trigger, a new advertisement is issued only when the actual value of the congestion index is significantly different from the last value announced. The threshold used determines the level of significance; if the value being evaluated is below the transition point, *T1* is applied, otherwise *T2* is used. We define two thresholds to avoid the loss of sensitivity when the congestion indexes have higher values since, in these situations, the same absolute variation may not trigger an advertisement as would happen with smaller index values.

The excessive number of link-state messages could also be avoided if we used a periodic criterion. However, in this case the triggering of advertisements would be independent of the state of the router, and thus would not allow for the dynamic adjustment of the protocol.

3. Simulator Architecture

We have developed, in NS, a new agent that implements the UC-QoSR strategy and a monitor that computes *DcI* and *LcI*. The architecture of the modules implemented is presented in Figure 1.

The modules that implement UC-QoSR are responsible for the advertisement of the congestion indexes (congestion indexes monitoring, congestion indexes quantification and advertisement criteria), path computation (cost function calculation and routing table management), and packet forwarding according to destination address and class.

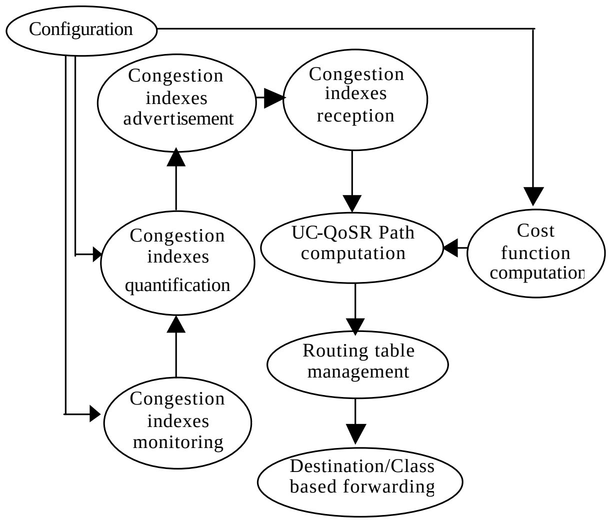

Figure 1- Simulation modules developed for the evaluation of the UC-QoSR strategy.

4. Experimentation

In this section we describe the conditions of the simulation study conducted and present some results concerning the evaluation of UC-QoSR upon the frequency of emission of link-state messages.

4.1. Simulation Design

We have implemented the UC-QoSR strategy as an extension to OSPF, using the GateD[2] platform, running on the FreeBSD operating system. Presently we have a

[2] <http://www.gated.org>

functional prototype and have conducted extensive tests concerning its evaluation [8, 9].

The main objective of this work is to extend the scope of our previous research, testing the strategy in larger and more complex topologies. For this purpose, were evaluated the number of Router Link State Advertisements (R-LSA) issued per minute, in the conditions presented below.

It is well known that the deployment of QoS routing introduces a non-negligible overhead on the network [10]. The major problems that must be addressed are an increased communication cost due to a higher number of routing message updates, and processing cost due to the more frequent application of the path selection algorithm and messages processing. This overhead is even more significant for networks with a large number of nodes that are highly interconnected.

We present the results of the evaluation of UC-QoSR according to communication overhead. This impacts naturally the nature of the processing overhead introduced by a QoS routing approach.

The conditions of the tests are presented in Table 2. In this table it is indicated the types of load used in the tests, the window sizes used for the computation of the moving average for congestion indexes quantification, and the values of the thresholds of the advertisement criteria. The values of the congestion indexes were generated according to a uniform distribution with the parameters shown for each type of load.

Each test had the duration of 5 minutes and was done on the topologies of Figures 2,3, and 4.

Type of load	Low	*IcL* = 0 *IcD* = U(0,25)
	Medium	*IcL* = U(0,50) *IcD* = U(25,75)
	High	*IcL* = U(50,100) *IcD* = U(75,100)
Quantification	Moving average window size	1, 10, 20, 30, 40, 50
Criteria	Threshold 1	5, 10, 15, …, 100%
	Threshold 2	Half of threshold 1

Table 2- Conditions of experimentation.

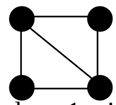

Figure 2- Topology 1: simple network.

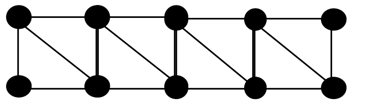

Figure 3- Topology 2: network with several alternative paths.

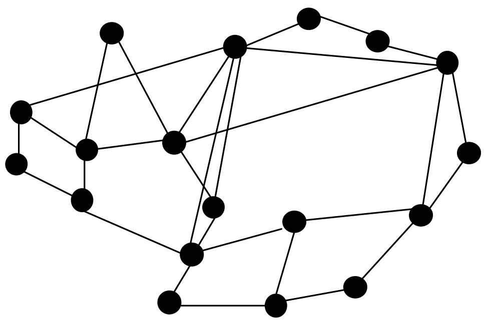

Figure 4- Topology 3: typical ISP USA backbone.

4.2. Simulation Results

The simulation results were evaluated in terms of the number of R-LSA issued in each of the networks considered.

The results obtained for topology 1, in the test conditions described, are presented in Figures 5 and 6. We only show the graphs concerning low and high loads, because it is sufficient to express the obtained behavior.

Figures 5 and 6 show clearly the ability of the quantification mechanisms and of the relative criteria to reduce the amount of routing traffic in the network. For high loads, the number of R-LSAs is smaller than with low loads. This situation stems from the fact that with higher loads, the criteria, even with the use of two thresholds, still looses some sensitivity, ant thus fewer actualizations are issued.

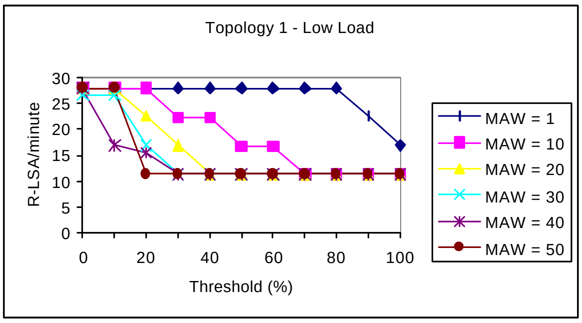

Figure 5- Link-state updates issued in topology 1 with low load.

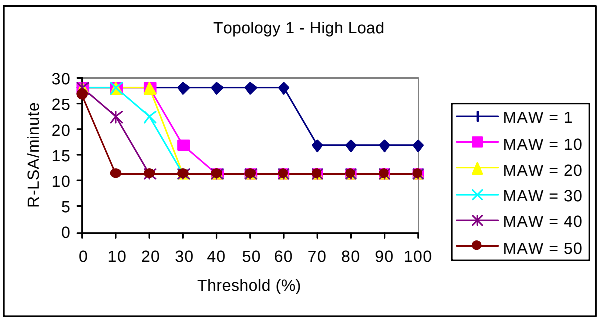

Figure 6- Link-state updates issued in topology 1 with high load.

In Figures 7 and 8 are presented the results obtained for topology 2. It can be seen that, as was the case with topology 1, the use of the moving average for congestion indexes quantification in association with the relative criteria can reduce the communication overhead, and consequently the processing overhead of routers that receive new updates. However, as the network size increases, there is also a significant grow in the number of R-LSAs.

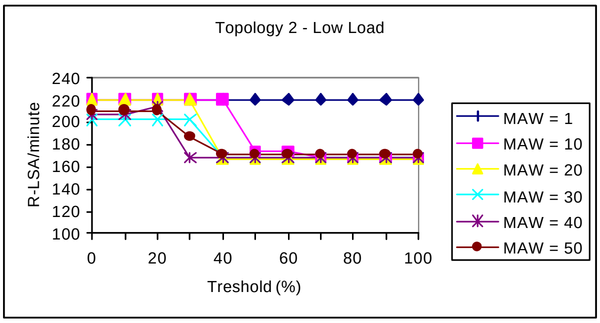

Figure 7- Link-state updates issued in topology 2 with low load.

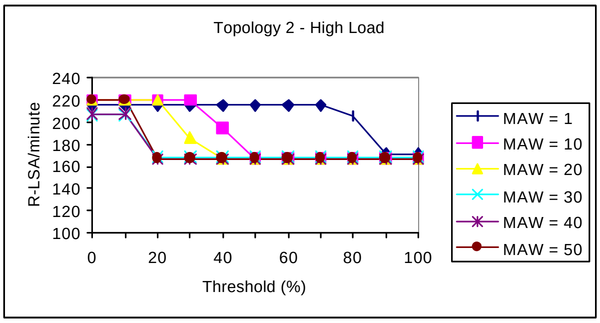

Figure 8- Link-state updates issued in topology 2 with high load.

The results for communication overhead evaluation in topology 3, a typical ISP topology, are presented in Figures 9 and 10. These results show also that the UC-QoSR routing mechanisms used for reducing communication overhead are effective.

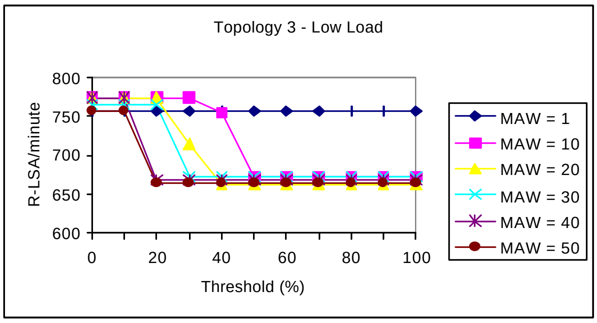

Figure 9- Link-state updates issued in topology 3 with low load.

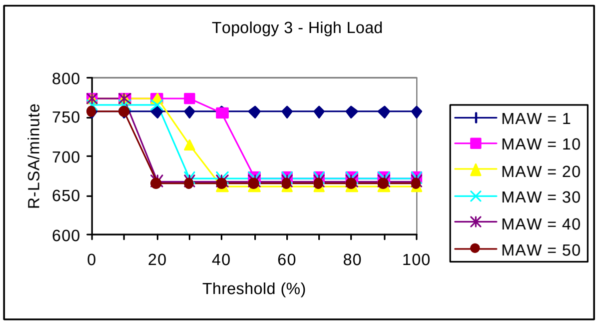

Figure 10- Link-state updates issued in topology 3 with high load.

The results presented above show that using adequate moving average window size and threshold it is possible to reduce communication overhead. This will naturally reduce processing overhead, because the number of messages to process is smaller and the path computation algorithm is applied fewer times. The evaluation of UC-

QoSR in larger topologies shows that the control of overhead is constrained by the size of the network.

5. Conclusions and Future Work

In this paper we presented and evaluated a QoS routing strategy for the Differentiated Services framework. This proposal was conceived as an extension of the OSPF routing protocol. It bases its routing decision on a QoS metric that represents the impact that loss and delay have in application performance. Based on this metric, the Dijkstra algorithm is used to compute a shortest path tree for each traffic class.

We described the main modules of UC-QoSR developed on the Network Simulator and presented some preliminary evaluation results concerning the overhead introduced by QoS routing mechanisms. Simulation results showed that using adequate moving average window size and threshold values, it is possible to reduce the overhead, and thus showing UC-QoSR scalability feature.

In future work we will evaluate the performance of traffic of all classes of service of the LCT service model. The stability analysis of UC-QoSR will also be subject of study.

Acknowledgments

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