Dynamic mapping between the Controlled-Load IntServ service and the Assured Forward DiffServ PHB

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Abstract. This work addresses the interconnection of the IntServ and DiffServ models. In particular, new mapping mechanisms between the Controlled-Load service (CL) of the IntServ model and the Assured Forward (AF) Per-Hop-Behaviours group of the DiffServ model, are proposed and analysed by simulation. The proposed mechanisms have a dynamic nature and they are associated to an admission control such that the state of the network is reflected in the new admission decisions of the new IntServ flows into the DiffServ network. For the same IntServ destination network, the behaviour of the previous flows is taken into account. The results show that the functionality of IntServ networks can be extended through DiffServ regions without perceptible degradation of QoS. Moreover the dynamic mapping mechanisms take into account the state of the network, improve the use of the available resources for each AF class and guarantee the AF class QoS even when congestion rises.

1 The problem

The research effort in the area of the quality of service (QoS) provision on the Internet has been carried out by the IETF (Internet Engineering Task Force) according to two main models: the Differentiated Services (DiffServ) model [1] and the Integrated Services (IntServ) model [2, 3]. These two models have been developed by two work groups of the IETF [4, 5].

The IntServ model provides individually QoS guarantees to each flow. For such, it needs to make resource reservation in network elements intervening in the communication. For resources reservation the Resource Reservation Protocol is used (RSVP) [6, 7]. The IntServ model supports two distinct services: Guaranteed service (GS) [8] for applications with strict needs of throughput, limited delay and null losses; Controlled-Load service (CL) [9] that emulates the behaviour of the best-effort service in an unloaded network. The need of maintenance of state information on the individual flows is usually pointed as the origin of the scalability problems of the IntServ model.

The DiffServ model embodies the second approach where the flows are aggregated in service classes (CoS) according to specific characteristics. The packets belonging to specific classes are forwarded according to their Per Hop Behaviour (PHB) associated with the DiffServ Code point (DSCP) [10], which is included in the field Type of Service (ToS) of the IP header. Currently the DiffServ model supports Expedited Forwarding (EF) PHB destined to offer a service of type "virtual leased line" with throughput guarantees and limited delays [11]. Also, the Assured Forwarding (AF) PHBs group that exhibits a similar behaviour to the low loaded network for traffic that is in accordance with the service contract [12].

In order to combine the superior scalability of the DiffServ model with IntServ superior QoS support capabilities, the ISSL (Integrated Services to over Specific Link Layers) working group of the IETF [13] proposed the interoperation between these two models [14]. The defined approach combines the IntServ model features – capability to establish and maintain resources reservations trough the network elements – with the scalability provided by the DiffServ model. The IntServ model is applicable at the network edge, where the number of flows is small, while the DiffServ model is applicable in the network core to take advantage of its scalability. The boundary routers between these two networks are responsible for mapping the IntServ flows into the DiffServ classes. These functions include the choice of the most appropriate PHB to support the flow and the use of admission control (AC) and policing functions on the flows at the entrance of the DiffServ region.

In DiffServ networks admission control is based in Bandwidth Brokers (BBs) and in pricing schemes associated with Service Level Agreements (SLAs) at the entrance of the DiffServ Domains. This solution does not intrinsically solve the problem of congestion control. Upon overload in a given service class, all flows in that class suffer a potential QoS degradation. To solve this and to integrate the DiffServ and IntServ models in a end-to-end service delivery model with the associated task of reservation, a new admission control function, which can determine whether to admit a service differentiated flow along the nominated network is needed [15]. There are several proposals of admission control mechanisms that can be used to address this problem. One approach of admission control developed at LCT-UC [16] uses a metric to evaluate a congestion index (CI) at each network element to admit or not a new flow [17, 18]. Other approaches use packet probing [19, 20, 21], aggregation of RSVP messages [22, 23] between an ingress egress routers or Bandwidth Brokers (BBs) [24]. The issue of the choice of the admission control mechanisms was left open by the ISSL IETF group [25].

In this work a mapping mechanism between the Controlled-Load service of the IntServ model and the Assured Forwarding PHB group of the DiffServ model is proposed. This option was due to the less difficulty of the problem when compared with the mapping between service GS and PHB EF and to the wider acceptance of IntServ CL service among network equipment manufacturers. This mapping mechanism includes a dynamic admission control module that takes into account the state of the DiffServ network. In this approach, the decision of mapping and admitting a new

IntServ flow in the DiffServ network is based on the behaviour of previous flows to the same IntServ destination network.

Besides this section the article has the following structure. Section 2 describes the proposed dynamic mapping mechanisms. It includes the architecture, the mapping algorithm and the admission control module developed. In Section 3 the simulation scenario is presented as well as an evaluation of the proposed mechanisms. Finally, in Section 4, some conclusions and directions for future work are presented.

2 Proposed Solution

In the border between the IntServ and DiffServ regions, the network elements must perform the mapping of the requested IntServ service into a DiffServ class of service. The DiffServ class must be selected in a way to support the type of IntServ service requested for the application. Taking into account the already defined IntServ services (CL and GS), the PHBs currently available in DiffServ (AF and EF) and, considering the characteristics of each service and PHB respectively, the choice of mapping between service CL and PHB AF and between service GS and PHB EF is evident.

The mapping of the CL service into the AF PHBs must be based on the burst time of the CL flow [25]. This way, the flows are grouped in the AF class which provides the better guarantee that the packet average queue delay does not exceed the burst time of the flow. The mapping can be static or dynamic: static mapping is defined by the administrator of the network; dynamic mapping is driven according to the characteristics of the existing traffic in the network.

The mapping mechanism proposed in this work, intends to complement the control traffic of the DiffServ network by using a dynamic Admission Control mechanism that reflects the network state. In the adopted strategy, the decision of mapping and admitting a new flow at the ingress of the DiffServ region is based on the behaviour of previous flows with going to the same IntServ network. This behaviour is a consequence of the delays and losses suffered by the flow in the DiffServ region. The underlying idea is inspired in the congestion control mechanism used in TCP/IP, applied to the admission control and mapping of IntServ flows in DiffServ classes.

The strategy adopted is based in the observation of flows at the ingress and the egress of DiffServ domains to evaluate if the QoS of the mapping flow was degraded or not. In the case where no degradation occurs new flows can be admitted and mapped. On the other hand, if the QoS characteristics have been degraded, no more flows can be admitted into the DiffServ network ingress and the number of active flows must be reduced. By monitoring the flows at the egress of the DiffServ domain, the QoS characteristics are evaluated on the basis of the packet loss, since the queuing delay is less representative [19] and more difficult to treat with passive measurements due to its wide variability and to the difficulty of clock synchronization.

2.1 Mapping system architecture

The proposed strategy for mapping IntServ flows into DiffServ classes is based on two mechanisms located in the network elements at the boundary of the DiffServ region: the mapping and the meter. In the edge router at the ingress of DiffServ domain, the mapping mechanism makes the mapping of CL flows into the AF class which better supports the type of service defined by the IntServ message. This mechanism acts on the basis of the information supplied by the meter mechanism located in edge router at the egress of the DiffServ domain.

In Figure 1 the integration of the mapping mechanism with the IntServ and Diff-Serv modules is illustrated. The meter module shown in Figure 2 belongs to the Diff-Serv model and should not be misunderstood with the meter mechanism. Besides doing the necessary measurement to the operation of the DiffServ network, this module also counts, for each flow, the packets marked with determined DSCP. This information together with the one sent by the meter mechanism at the egress edge router allows the evaluation of the behaviour of the flows in the DiffServ region.

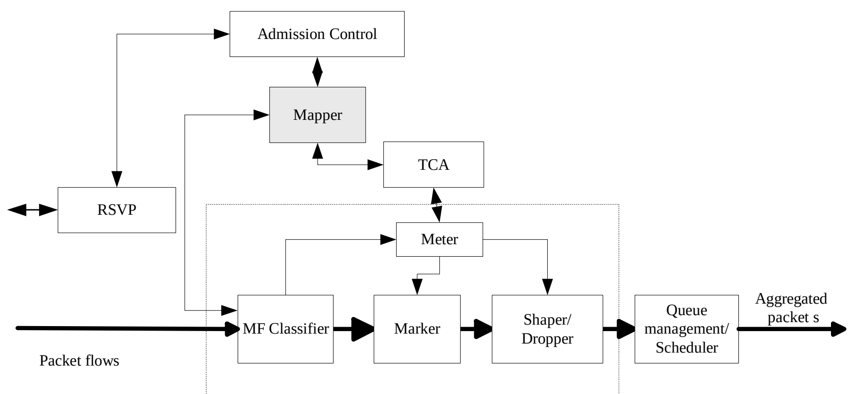

Fig. 1. The mapping mechanism

The meter mechanism, illustrated in Figure 2, interacts with the modules of the IntServ model, and with the meter module of the DiffServ model (which is responsible for accounting, for each flow, the packets in agreement with the attributed DSCP). Whenever a RSVP message of reserve removal occurs, the collected information is inserted in a new object called DIFFSERV_STATUS and is sent to the ingress edge router of the DiffServ domain such that it can be taken into account for the next flow mapping.

2.2 Mapping Algorithm

The algorithm used for the mapping mechanism is activated in the ingress edge router by the RSVP_RESV messages. These messages include a *filterspec* and a *flowspec* fields. The filterspec field specifies the flow used in the configuration of the Multi-

Field classifier. The flowspec field specifies the intended QoS characteristics for the flow and is used for updating the available resources. In the case of dynamic mapping, the flowspec is also used to determine the flow burst time.

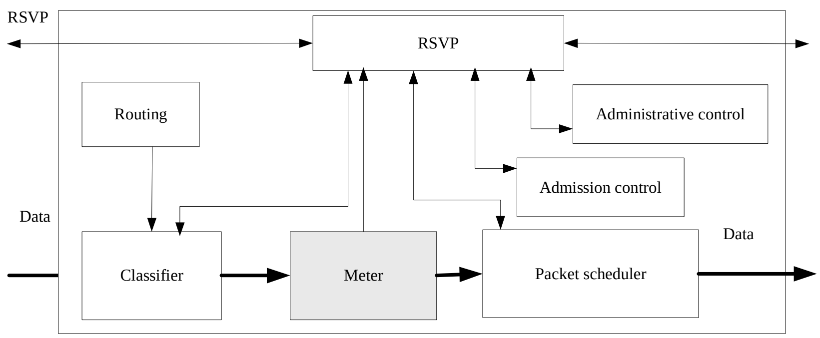

Fig. 2. The meter mechanism

After the identification of the flow and the intended QoS characteristics, the mapping mechanism of edge router verifies the existence of a static mapping table entry defined for that flow. If this entry exists, the available resources in the TCA are updated, the packet classifier is configured and a RSVP_RESV message is sent upstream to the router in IntServ network. When the entry corresponding to the TCA does not exist, or the resources in this TCA are not available, a RSVP_ERR message is sent downstream to the IntServ routers in order to remove the reservation.

In the case where a static mapping is not defined, the edge router uses the dynamic mapping. The mapping module evaluates the burst time of the flow and identifies, if any, the AF class that better guarantees that this burst time is not exceeded. Then, it verifies if the flow can be mapped based on the previous behaviour of the flows mapped for the same destination network identified by the NHOP field of the message. If the mapping is made, the available resources are refreshed, the packet classifier is configured and a RSVP_RESV message is sent to the upstream router. If either the AF class is not defined or the network is congested, then a RSVP_ERR message will be sent.

In the meter mechanism at the egress edge router, the information about the flow (number of packets received for each DSCP) is generated after receiving a reserve removal message (RSVP_ResvTear, for example). This information is inserted in a new RSVP object – DIFFSERV_STATUS – and added to the RSVP message, which will be sent later to the mapping mechanism of the ingress edge router. This router is identified by the field PHOP, when the RSVP_PATH message is received.

3 Evaluation of the proposed mechanisms

In this section the evaluation of the proposed mechanism for dynamic mapping of CL flows into AF classes is made. The evaluation was supported by the implementation of the mapping mechanisms in the Network Simulator v.2 environment (NS2) [26] integrated with the available NS2 IntServ and DiffServ modules [27].

The evaluation has two distinct objectives. Firstly, to verify if the proposed mechanisms are able to extend the functionality of the IntServ network through the DiffServ network. That is, to verify if, in the presence of several flows of best-effort traffic, the QoS characteristics of CL flows are not degraded. Secondly, to evaluate the dynamic Admission Control mechanism concerning the admission of new CL flows and its adaptation to the congestion state of the network, and to verify if there is an improvement in the use of the resources available in the AF classes.

The simulation scenario is illustrated in Figure 3. The scenario has a bandwidth bottleneck in the backbone DiffServ to evaluate if the excess of best-effort traffic affects the mapping of the flows. For the AF class a profile of 1 Mbps was defined. In order to separate BE traffic of AF traffic, two queues in the DiffServ domain have been defined. The BE queue is a FIFO, while the AF queue is a RIO (Random Early Detection with in and Out) [28]. The latter queue is configured with the values obtained from [27]. Both queues are served by the WFQ (Weighted Fair Queuing) scheduler [29], which is configured such that the profile defined for the AF class is assured.

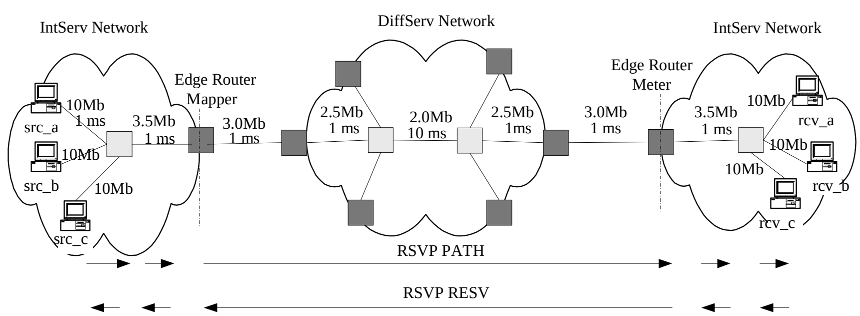

Fig. 3. Simulation scenario

In the tests made, the dynamic mapping of CL flows into the AF PHB with a dynamic admission control mechanism that takes into account the state of the DiffServ network was evaluated, in the presence best-effort flows of 100 Kbps. The delays, the losses and the throughput of CL flows have been measured as for different network loads. The number of existent mapped flows (N_Flows) in the class AF as well as the maximum number allowed (N_MaxFlows) in the DiffServ network was recorded. These values are obtained from the dynamic admission control mechanism whenever a reserve removal of a CL flow previously mapped occurs.

In the scenario presented, 15 best-effort flows of 100 Kbps each were generated to the network to congest the bandwidth bottleneck. Reserve requests of CL flows of 100Kbps are generated every 15 seconds. The flow is mapped and transmitted if resources are available in the IntServ network and if the dynamic admission control at the DiffServ domain entrance accepts the request.

After 250 seconds of simulation time, and every 50 seconds thereafter, the existent flow reserves are removed in the same order they were created. In this way more reserve requests and mappings are allowed than reserve releases. This allows the evaluation de dynamic Admission Control mechanism.

Figure 4 shows the results obtained by using the dynamic Admission Control mechanism in the mapping of the CL flows into an AF class. The analysis of the figure shows that the flows were admitted until the number of flows of the predefined profile is attained. Afterwards, new flows were admitted only if the reserve of a previous mapped flow is released and if these flows did not suffer any QoS degradation. In such case one flow is added to N_MaxFlows.

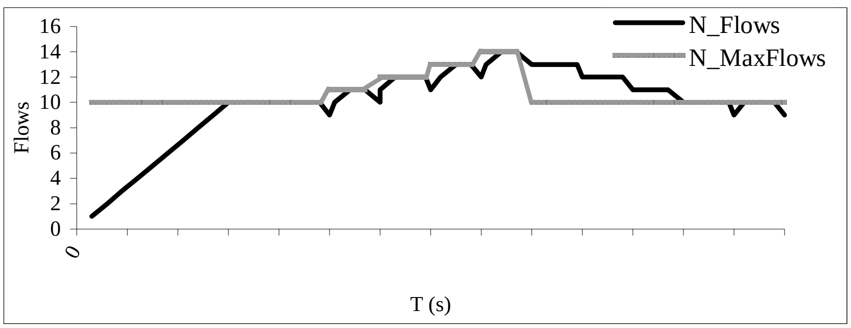

Fig. 4. CL Flows CL admitted in DiffServ Network by Dynamic Admission Control

When QoS degradation occurs, the maximum number of flows allowed drops to the value supported by the profile defined initially. In this way, the AF class can recover from the degradation. The variable N_MaxFlows is updated only when the state of the network is verified after the degradation. The state of the network is known when a new mapped flow probes the network. If this new flow does not suffer QoS degradation, one flow is added to N_MaxFlows and the process of mapping new flows repeats. Otherwise one flow is subtracted to N_MaxFlows and will be updated only when a new mapped flow probes the network.

The simulation results regarding throughput are presented in Figure 5. The results regarding delays are presented in Figure 6.

Both figures show that when the CL flows are mapped/admitted all the BE flows suffer the same throughput and delay degradation whereas the CL flows maintain a reserved throughput which increases slightly the delay when the mapped flows increase. It can also be seen from the figures that the dynamic Admission Control takes advantage of the available resources and that whenever a mapped flow causes degradation, the throughput and delay of all the other mapped flows is affected. Furthermore, once degradation is detected, the dynamic Admission Control mechanism allows the reestablishment of the AF class QoS.

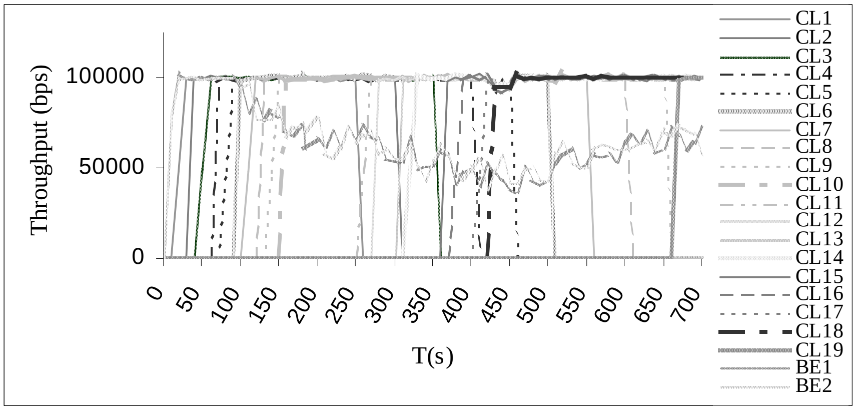

Fig. 5. Throughput of CL and BE flows

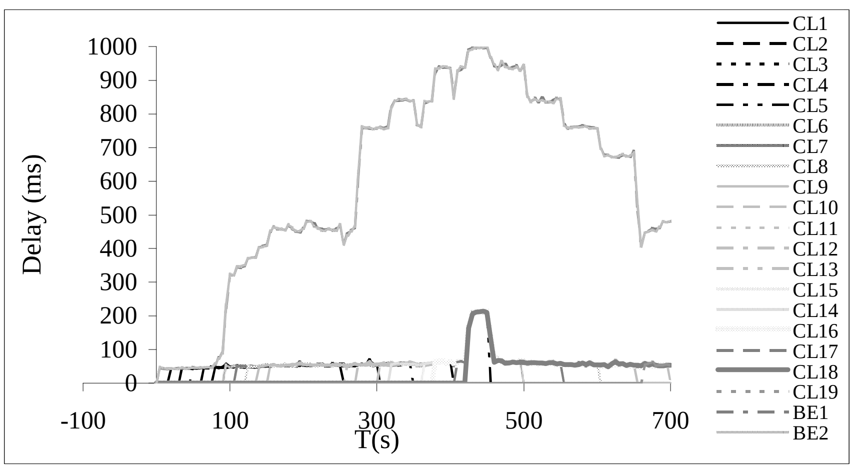

Fig. 6. Delays of CL and BE flows

The results obtained in the simulation with a dynamic mapping mechanism show that the functionality of the IntServ networks can be extended through the DiffServ networks without perceptible QoS degradation. It was also verified the effect of the resource reservation and the protection of the QoS characteristics of CL flows in the presence of best-effort flows.

Furthermore, the results obtained show that the dynamic Admission Control reflects the state of the network and provides an improvement of the available resources of a certain AF class.

4 Conclusions and future work

In this work the interconnection between IntServ and DiffServ models was studied, with emphasis on the interconnection of CL flows through the traffic classes of the AF PHBs group.

A mapping mechanism is proposed to act between the two models. The mechanism is based on dynamic Admission Control in which the active flows serves as probing to the following ones, reflecting the state of congestion of the DiffServ network in the admission decision and mapping of new IntServ flows.

The evaluation results of the proposed dynamic mapping mechanism show that the functionality of the IntServ networks can be extended through the DiffServ networks.

The positive effect of the resources reservation in the IntServ model and the protection of the QoS characteristics of CL flows in the presence of best-effort flows were also verified. Furthermore the results shown that the dynamic mapping takes into account the state of the network to map new CL flows into AF classes and to re-establish AF class QoS once degradation is detected.

The future work (already in course) will address the validation of a dynamic mapping mechanism in more demanding scenarios with more AF classes and with different types of traffic to be generated in the IntServ network. Also other scenarios will be studied including more IntServ networks in the boundary and more DiffServ networks in the core.

In a second phase, the behaviour of the dynamic mapping mechanisms will be evaluated in DiffServ networks badly dimensioned, in the presence of non conformant traffic in situations of forced congestion.

Acknowledgments

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