Bandwidth management in IntServ to DiffServ mapping

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Abstract. This work presents a bandwidth management mechanism to be used with mapping mechanisms between Integrated Services (IntServ) and Differentiated Services (DiffServ) domains. The mapping mechanisms have a dynamic nature and are associated with the Admission Control functions such that the state of the network is reflected in the admission decisions of new IntServ flows into the DiffServ network. The work is focused in the mapping between the IntServ Controlled-Load (CL) service and the DiffServ Assured Forward (AF) Per-Hop-Behaviour group. The proposed bandwidth management mechanism evaluates the bandwidth needs of the AF classes in the DiffServ domain taking into account the behaviour of the previously mapped CL flows for the same IntServ destination network. The results obtained by simulation show that the mechanism improves the use of the available bandwidth for a given AF class. The mapping mechanisms detects Quality of Service (QoS) degradation occurrences and once detected the control mechanism allows the reestablishment of AF Class QoS.

1 Introduction

The research effort in the area of the Quality of Service (QoS) provisioning in the Internet has been carried out by the IETF (Internet Engineering Task Force) according to two main approaches: the Differentiated Services (DiffServ) model [1] and the Integrated Services (IntServ) model [2, 3]. These two models have been developed by two different IETF work groups [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 a few Classes of Service (CoS) according to their 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 Type of Service (ToS) field of the IP header. Currently the DiffServ model supports Expedited Forwarding (EF) PHB intended to offer a service of type "virtual leased line" with throughput guarantees and limited delay [11]. DiffServ also supports the Assured Forwarding (AF) PHB group that exhibits a similar behaviour to a 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 – the capability to establish and maintain resources reservations through the network – 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 domains 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 on Bandwidth Brokers (BBs) and also on 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 the Laboratory of Communications and Telematics of the University of Coimbra (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 previous work we proposed a mapping mechanism between the Controlled-Load service of the IntServ model and the Assured Forwarding PHB group of the DiffServ model [26, 27]. The option was due to the less difficulty of the problem when compared with the mapping between GS and PHB EF and to the wider acceptance of Int-

Serv CL service among network equipment manufacturers. The proposed mapping mechanism included a dynamic Admission Control module that takes into account the state of the DiffServ network. In our approach, the decision of mapping and admission of a new IntServ flow in the DiffServ region is based on the behaviour of previous flows to the same IntServ destination network. This behaviour is used to estimate the bandwidth needs of the DiffServ AF classes.

To complement the mapping mechanisms previously proposed, this paper presents a bandwidth management mechanism to be used with dynamic mapping mechanisms between the IntServ Controlled-Load service (CL) and the DiffServ Assured Forward (AF) Per-Hop-Behavior group. The proposed mechanism is based in the continuous adjustment of the bandwidth used by the DiffServ classes. The simulation results show that the proposed mechanism guarantees a good level of bandwidth utilization in the mapping between IntServ CL service and DiffServ AF classes.

Besides the present section the paper has the following structure. In Section 2 the principles and the architecture proposed for dynamic mapping mechanisms are presented. The bandwidth management algorithm that supports the Admission Control functions in IntServ flows mapping into AF classes is described in Section 3. In Section 4 the simulation scenario is presented and the proposed mechanisms are evaluated. Finally, in Section 5, some conclusions and directions for future work are presented.

2 Dynamic mapping mechanisms

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 an 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.

In the mapping mechanism proposed in previous work [26, 27], the aim is to complement the traffic control functions of the DiffServ network by using a dynamic Admission Control mechanism that reflect the state of network. 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 which going to the same IntServ network. This behaviour is evaluated by of delay and losses suffered by the flows in the DiffServ region. The underlying idea is inspired in the congestion control mechanism used by TCP, applied to the admission control and mapping of IntServ flows into DiffServ classes.

The strategy adopted is based on the monitoring of flows at both the ingress and the egress of DiffServ domains to evaluate if the QoS of the mapped flows 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.

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 Mapper and the Meter. In the edge router at the ingress of DiffServ domain, the Mapper maps CL flows into the AF class that better supports the IntServ service. 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.

The Meter mechanism 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.

3 Bandwidth management mechanism

The Mapper mechanism needs to reflect the state of the network. In order to allow this the edge router Mapper mechanism needs to know the available resources for each DiffServ class. The evaluation of these resources is based on what happened to the previously mapped flows for each particular IntServ network destination. This calculation is made by the resource control mechanism when a *DIFFSERV_STATUS* object arrives at the Mapper. The Meter sends this object in a RSVP message when a reserve removal message is received.

When the Mapper receives the *DIFFSERV_SATUS* object, the bandwidth management mechanism extracts the number of packets received by the meter in the egress edge router, collects on the local Meter the number of packets sent to the DiffServ domain and compares them to evaluate if QoS degradation has occurred or not. If the difference is less than the threshold of allowed losses then it is considered that no QoS degradation has occurred. In this case, the allowed throughput (number of admitted flows) can be increased. Otherwise, it is considered that degradation occurred and the allowed number of flows is reduced. The increasing of the number of flows is additive and the reduction is multiplicative which allows the AF class of DiffServ Network to recover quickly from the degradation. Figure 1 shows the algorithm of the bandwidth management mechanism.

The concrete values used to increase and decrease the number of flows are defined in the TCA (Traffic Control Agreement) specification. When the flow QoS has not been degraded the resources (throughput) allowed by the algorithm for a specified AF class will be increased by a given amount (10% in the current analysis). All the mapped flows present in the DiffServ network are validated, i.e., any one of these flows can serve as probing to the DiffServ AF class (they not suffered degradation). If the QoS has been degraded the resources allowed by the algorithm will be decreased by a multiplicative factor (50% in the current analysis). If the active flows have been degraded, only a new flow admitted later can act as probing to the AF class.

```
inc = 0.1  {Throughput increment}
dec = 0.5  {Throughput decrement}
losses = LOSSES {allowed losses threshold}
throughput {throughput of the active CL mapped flows}
r          {TSpec flow throughput}
degradation {QoS flow degradation}
MaxThroughput {max throughput admitted in DiffServ region}
npkts_sent {number of packets sent to the DiffServ region}
npkts_rcv  {number of packets received at DiffServ region}

begin
  extract_from (DIFFSERV_STATUS object, npkts_rcv);
  collect_from_local meter (npkts_sent);
  if npkts_sent - npkts_rcv <= LOSSES then
    degradation = FALSE;
    MaxThroughput += inc * MaxThroughput;
    Remove_flow_from_probing_list;
  else
    degradation = TRUE;
    MaxThroughput = dec * MaxThroughput;
    Clean_probing_list;
  end if
  Remove_flow_from_mapping_list;
  throughput -= r;
  Update_policer;
  Send_upstream_RSVP_reserve_removal;
end
```

Figure 1. Bandwidth management algorithm

After degradation is verified, the flow is removed from the list of admitted flows and the throughput of the active mapped flows is updated. In this case the total throughput of active flows is reduced by *r* (throughput of removed flow) and the policer is updated. After this, the removal message is sent upstream to complete the flow release process.

When a new CL flow reserve request arrives (*RSVP_RESV* message) at the edge router Mapper, an admission control process is activated. Then the Mapper chooses the AF class that better guarantees that the CL flow QoS is preserved in the DiffServ network. Once the AF class is determined, the AC takes the decision of mapping or not, based on the resources allowed for this class. The algorithm defined above calculates these resources. The CL flow is admitted if the sum of its throughput with that of the active flows does not exceed the maximum throughput determined by the algorithm for the class. If the flow is admitted, the throughput of active flows is updated to take into account this flow, which is then inserted in the mapping and probing lists. The policer is updated and a RSVP_RESV message is sent upstream to the sender. Otherwise, if the flow is not admitted, a *RSVP_RESVERR* message is sent to release the reserve on the downstream network elements.

4 Results and evaluation

In this section, the bandwidth management mechanism for the dynamic mapping of CL flows into AF classes, previously described, is evaluated. The implementation of the mapping and bandwidth management mechanisms was done in the Network Simulator version 2 environment (NS2) [28] integrated with the available NS2 IntServ and DiffServ modules [29].

The aim of this evaluation was, firstly, to verify if there is an improvement in the use of the available bandwidth in the AF classes, that is, if the bandwidth resources are redistributed in accordance with the state of the network by the algorithm. Secondly, to verify if in the occurrence of QoS degradation, this is detected by the Mapper at the DiffServ network entrance and, once detected, to evaluate if the used algorithm allows the reestablishment of the AF Class QoS.

The simulation scenario illustrated in Figure 2 shows four IntServ networks interconnected through a DiffServ network. At the DiffServ domain entrance the CL flows from IntServ A1 are mapped/admitted by the Edge Router Mapper 1 (ERM1) and the CL flows from IntServ A2 are mapped/admitted by the Edge Router Mapper 2 (ERM2). The DiffServ backbone has a bandwidth of 4 Mbps for the resources defined in the profiles for each IntServ network, for the best-effort (BE) traffic and in order to have a bandwidth remainder to test the bandwidth management mechanism on the resources redistribution by the Mapper.

For the AF classes, a profile of 1 Mbps was defined at the DiffServ domain entrance. 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) [30]. The latter queue is configured with the values obtained from [29]. Both queues are served by the WFQ (Weighted Fair Queuing) scheduler [31], which is configured such that the profile defined for the AF class is assured.

In the simulation tests, the bandwidth management mechanism for dynamic mapping of CL flows into the AF PHB that takes into account the state of the DiffServ network was evaluated in the presence best-effort flows of 100 Kbps. The delay, the losses and throughput of CL flows were measured. The throughput of existent mapped flows (*Throughput*) in the class AF as well as the maximum throughput allowed (*MaxThroughput*) in the DiffServ network was recorded. These values were obtained from the dynamic Admission Control mechanism using the bandwidth management mechanism whenever a reserve removal of a CL flow previously mapped had occurred.

In the above scenario, each IntServ network, A1 and A2, generates 15 best-effort flows of 100 Kbps. Reserve requests of CL flows of 100Kbps are generated every 15 seconds by IntServ A1 network and are generated every 10 seconds by IntServ A2. A CL flow is mapped and transmitted if resources are available in the IntServ networks and if the dynamic admission control at the DiffServ domain entrance accepts the request.

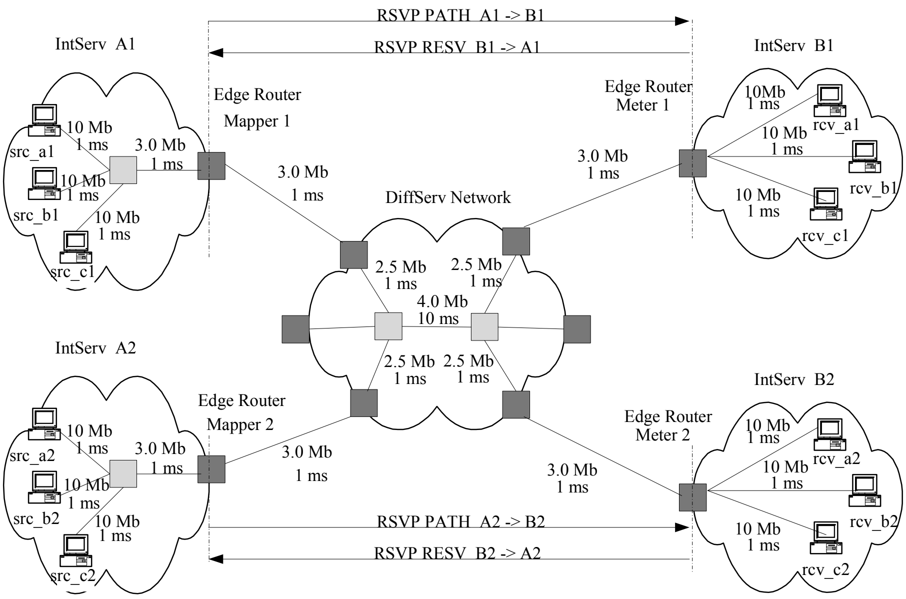

Figure 2. Simulation scenario

After 250 seconds of simulation time, and every 50 seconds thereafter, the existent flow reserves into IntServ A1 and B1 networks are removed in the same order they were created. Also, after 225 seconds of simulation time, and every 25 seconds thereafter, the existent flow reserves into IntServ A2 and B2 networks are removed in the same order they were created. The tests allowed more reserve requests and mappings than reserve releases allowing the evaluation of bandwidth management and dynamic mapping mechanisms. Also, IntServ networks in the scenario generate more traffic and communicate more frequently its state trough the reserve releases and therefore they use a higher slice of AF class throughput in the DiffServ region.

Figures 3 and 4 show the results obtained using the dynamic Admission Control mechanism with the bandwidth management mechanism to map CL flows into the AF classes. The analysis of the figures 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 was released and if these flows did not suffer any QoS degradation. According to the algorithm, in such case the variable MaxThroughput is incremented by 10%. The figures also show that the resources available for the IntServ A2 network are more frequently updated than the ones for the

IntServ A1 network. This happens because there are more reserve releases on the IntServ A2 and B2 networks.

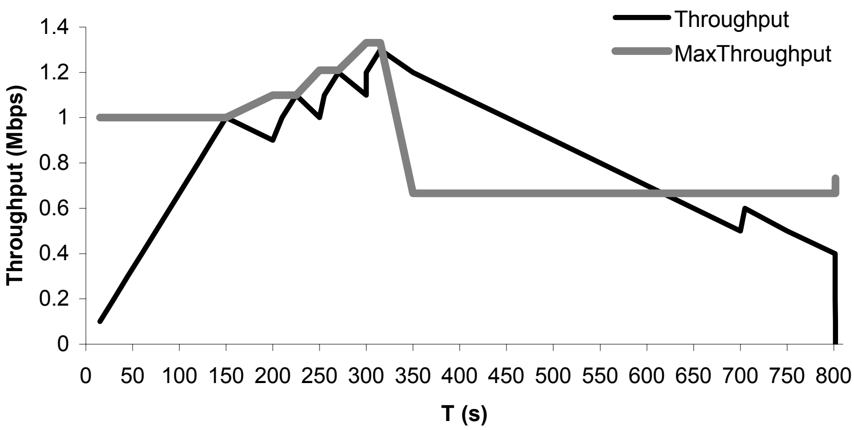

Figure 3. Throughput of IntServ A1 CL flows admitted in the DiffServ network

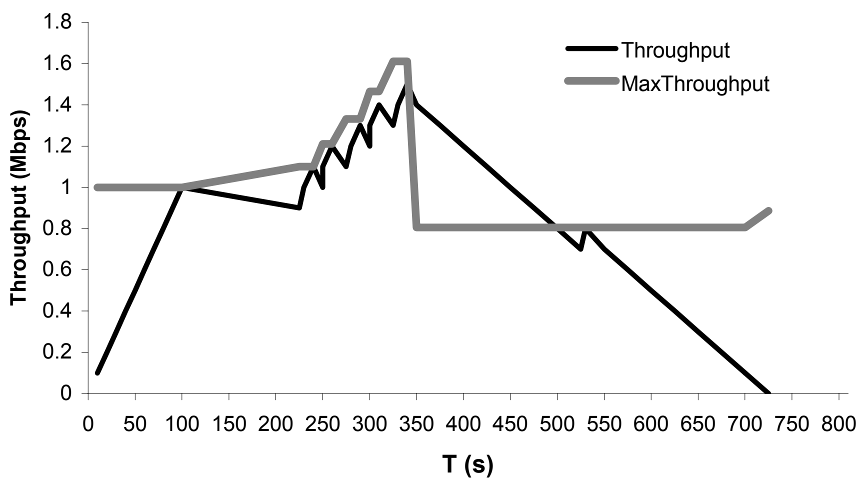

Figure 4. Throughput of IntServ A2 CL flows admitted in the DiffServ network

When QoS degradation occurs, the maximum throughput allowed to the CL flows drops by 50% of the current value. This way, the AF class can recover from the degradation. The variable *MaxThroughput* is updated in the edge router Mappers 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, the *MaxThroughput* value is incremented 10% and the process of mapping new flows is repeated. Otherwise the *MaxThroughput* value is decremented 50% and will be updated only when a new mapped flow probes the network.

The simulation results regarding throughput of the flows generated in the IntServ A1 network, are presented in Figure 5. The delay results are presented in Figure 6 and the loss results are presented in Figure 7. Simulation results for the IntServ A2 flows were also obtained and have a similar behaviour.

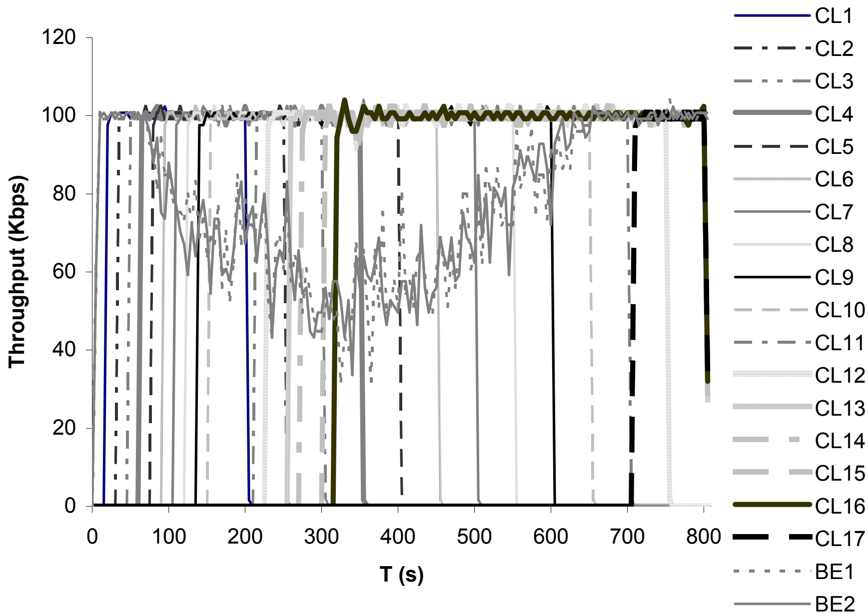

Figure 5. Throughput of Controlled-Load and Best Effort flows

From these figures it can be verified that until t = 315s, the algorithm allows an improvement in the use of the available bandwidth by the AF mapped class. In this situation losses do not occur, the throughput of CL flows is the reserved one and the delay only slightly increases with the admission of new flows. BE flows absorb the congestion when the number of admitted CL flows increase, and are degraded in terms of delay throughput and losses. After the admission of an new flow, at t=315s, QoS degradation occurs. This situation is detected when the next flow is released at t=350s. This release brings information about the state of the corresponding AF class and triggers the *degradation* flag of the bandwidth management mechanism.

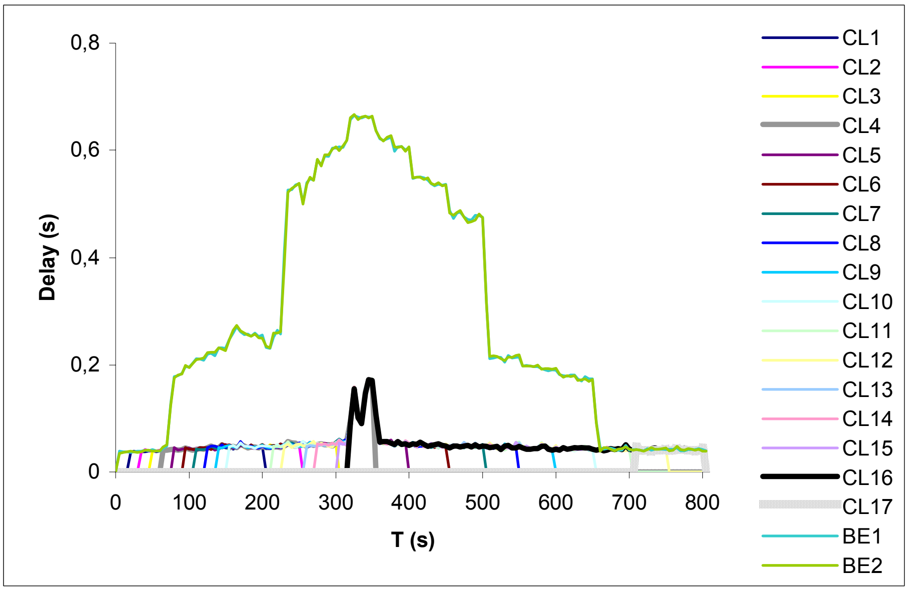

Figure 6. Delay of Controlled-Load and Best Effort flows

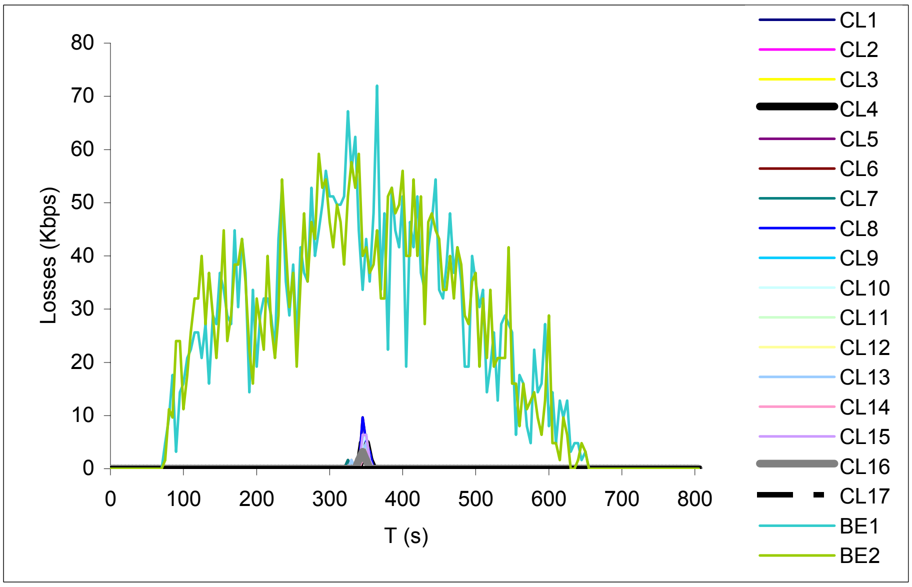

Figure 7. Losses of Controlled-Load and Best Effort flows

From the analysis of Figure 6 it can be noticed that losses only occur in a small period of time, between t=315 and t=350 seconds. When losses take place the proposed bandwidth control mechanism reacts allowing the rapid QoS reestablishment. From Figure 6 it can also be verified that the delay increases with QoS degradation and returns to previous values when degradation is detected. The breaking in terms of losses and delays at t=325s, is a consequence of a CL flow reserve release by In-ServA2 region.

Once degradation is detected, no more CL flows were admitted until t=705s. At this time a new flow was admitted because the sum of its throughput (*r*) with the throughput of the active flows does not exceed *MaxThroughput* value of the bandwidth management algorithm at ERM1. When this flow end it brings back the DiffServ network state and the variable *MaxThroughput* will be incremented allowing the admission of new flows.

It can also be seen from the figures that the use of the bandwidth management mechanics by 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 QoS of the AF classes.

The results obtained in the simulation with the bandwidth management mechanism show that the functionality of the IntServ networks can be extended through the DiffServ networks without significant QoS degradation. It was also verified the effect of the resource reservation and the protection of the QoS characteristics of Controlled-Load flows in the presence of Best-Effort flows.

Furthermore, the results show that the use of the proposed bandwidth management mechanism for Admission Control reflects the state of the network and provides an improvement of the available resources of certain AF classes.

4 Conclusions and future work

In this work we presented a bandwidth management mechanism to be used in dynamic mapping between the Controlled-Load service (CL) of the IntServ model and the Assured Forward (AF) Per-Hop-Behaviour group of the DiffServ model.

The proposed algorithm takes into account the behaviour of the previous CL flows for the same IntServ destination network. Based on this behaviour, the algorithm calculates the resources to the DiffServ AF classes. If no degradation occurred, the resources (throughput) suffer an additive increment. Otherwise, the resources suffer a multiplicative decrement.

The results obtained by simulation shown that the algorithm improves the use of the available resources for the AF classes. Moreover, the results shown that the mapping mechanisms detect QoS degradation occurrences and once detected the algorithm allows the reestablishment of the QoS characteristics of the AF Classes.

Future work (already ongoing) will address the validation of a dynamic mapping mechanism with this bandwidth management mechanism in more demanding scenarios, with more AF classes and with different types of traffic to be generated in the IntServ network.

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