Admission Control in IntServ to DiffServ mapping

António Pereira[1, 2], Edmundo Monteiro[2]

[1] Superior School of Technology and Management
Polytechnic Institute of Leiria
Morro do Lena – Alto do Vieiro, 2411-901 Leiria, Portugal
apereira@estg.ipleiria.pt
[2] Laboratory of Communications and Telematics
CISUC / DEI, University of Coimbra
Polo II, Pinhal de Marrocos, 3030-290 Coimbra Portugal
edmundo@dei.uc.pt

Abstract

This work presents an admission control 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 in such a way 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 results obtained by simulation, with TCP and UDP traffic and with two AF classes defined, show that the admission control mechanisms acts based on the bandwidth management mechanisms and improves the use of the available resources for a given AF class. The mapping mechanisms detect Quality of Service (QoS) degradation occurrences and once detected the admission 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]. These two models have been developed by two different IETF work groups [3, 4].

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) [5]. The IntServ model supports two distinct services: Guaranteed Service (GS) [6] for applications with strict needs of throughput, limited delay and null losses; Controlled-Load service (CL) [7] 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 [8]. The packets belonging to specific classes are forwarded according to their Per Hop Behaviour (PHB) associated with the DiffServ Code Point (DSCP) [9], 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 [10]. 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 [11].

In order to combine the superior scalability of the DiffServ model with IntServ superior QoS support capabilities, the ISSLL (Integrated Services over Specific Link Layers) working group of the IETF [12] proposed the interoperation between these two models [13]. 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 [14]. 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]. Other approaches use packet probing [18, 19], aggregation of RSVP messages [20, 21] between an ingress egress routers or Bandwidth Brokers (BBs) [22]. The issue of the choice of the admission control mechanisms was left open by the ISSL IETF group [23].

The DiffServ architecture does not have a specific scheme for accurate admission control, and does not provide end-to-end (e2e) QoS guarantees to Internet traffic [24, 25]. It only specifies the configurations that each domain can receive in order to supply service differentiation to different traffic classes.

One of the solutions to guarantee e2e QoS consists of the interconnection between IntServ and DiffServ models [13]. The resultant architecture is considered in [26] as one of the most promising architectures to deliver QoS guarantees in the next future Internet. In this context there are some important related work referenced in [27], [28], [29], [30] and [31].

In these works, the mapping mechanisms and admission control functions to the flows applications is crucial for the e2e QoS assurance. However, the referenced solutions are characterized by an inaccurate admission control and by an inefficient resource management that does not harness the mapping solutions between IntServ services and DiffServ classes. This situation results from the existing admission control limitations at DiffServ networks that connect the IntServ networks.

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 [32, 33]. The option was due to the less difficulty of the problem when compared with the mapping between GS and PHB EF. The proposed mapping mechanism includes 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 behavior of previous flows to the same IntServ destination network. We call this behavior E2ERB (End to End Region Behavior) and use it to estimate the DiffServ AF classes bandwidth needs. This estimation is made by a bandwidth management mechanism that adjusts continuously the bandwidth used by the DiffServ classes [34, 35].

This paper presents an admission control (AC) mechanism to be used with the bandwidth management and dynamic mapping mechanisms already proposed. The simulation results show that the proposed mechanisms guarantee a good level of bandwidth utilization in the mapping between IntServ CL service and DiffServ AF classes, detect QoS degradation occurrences and once detected the AC mechanism allows the class QoS reestablishment.

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 Admission Control algorithm used 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 [23]. 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 [32, 33, 34, 35], 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 [18] 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. Admission control

The decision of admitting/mapping a flow is made in the mapper mechanism that is constituted by three modules presented in Figure 1: The mapping, the bandwidth management and the admission control modules. The class indicator module indicates the AF class chosen to map the IntServ CL service requested by the flow. The bandwidth management module indicates, for an IntServ network destination, the existing resources to the class chosen. The admission control module, with the bandwidth management module, indicates if admits/maps the flow in the class indicated by the class indicator module.

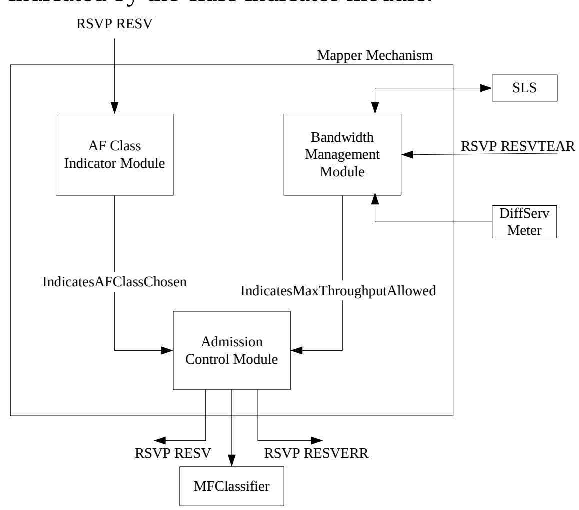

Figure 1 The mapper modules

The information needed by the admission control module is supplied in two important moments: the establishment and the resource release. The resource release determines the E2ERB of the flow in DiffServ region and serves as probing to the new mapped flows into the same AF class destined to the same IntServ network. This E2ERB originates the decrement or the increment of maximum throughput allowed, by the bandwidth management module, for the AF class to the same IntServ destination network, if degradation has occurred or not.

As illustrated in Figure 2, at the reserve establishment the mapper and meter mechanisms are activated by a RSVP_RESV message. The meter mechanism is configured to collect information about the QoS of the admitted flow.

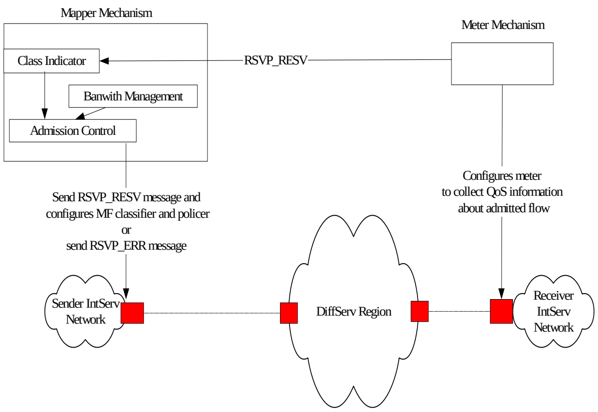

Figure 2. Admission control interactions in resource establishment

When a new CL flow reserve request arrives (RSVP_RESV message) at the edge router Mapper, an admission control process is activated. The class indicator module of 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 admitting/mapping or not, based on the resources allowed for this class to the destined IntServ Network. The CL flow is admitted if the sum of its throughput with that of the active flows does not exceed the maximum throughput determined in the bandwidth management module 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 admission control mechanism previously described with dynamic mapping mechanisms of CL flows into AF classes is evaluated. The implementation of the admission control, bandwidth management and mapping mechanisms was done in the Network Simulator version 2 environment (NS2) [36] integrated with the available NS2 IntServ and DiffServ modules [37, 38].

The aim of this evaluation is to verify the admission control behavior and its interaction with the other defined mechanisms in a congested DiffServ network, with two AF classes defined and with different types of traffic: TCP and UDP. More concretely, is intended to verify if in the mapping, the admission control with the defined algorithm acts based on the E2ERB experimented by a previous flow destined to the same IntServ network. Also, is intended to verify if when a AF class degradation occurs this is detected by the mappers present and, once detected, to verify if the used admission control algorithm allows the AF class QoS reestablishment.

The simulation scenario illustrated in Figure 3 shows four IntServ networks interconnected through a DiffServ network. In this network two AF classes are defined, AF1 and AF2. The AF1 class offers better QoS guarantees. The flows generated in the IntServ A1 network are destined to IntServ B1 network while the flows generated in the IntServ A2 network are destined to IntServ B2 network. At the DiffServ domain entrance the CL flows from IntServ A1, if admitted by the Edge Router Mapper 1 (ERM1), are mapped into the AF2 class. The CL flows from IntServ A2, if admitted by the Edge Router Mapper 2 (ERM2), are mapped into the AF1 class. For the AF1 and AF2 classes, a profile of 1.5 Mbps and 1 Mbps, respectively, was defined at the DiffServ domain entrance.

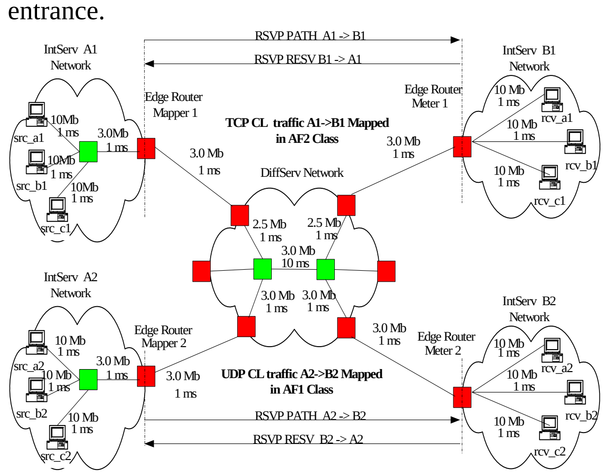

Figure 3 Simulation scenario

In order to separate BE traffic and AF traffic, three queues in the DiffServ domain have been defined. The BE queue is a FIFO, while the AF queues are RIO (Random Early Detection with in and Out) [39] and are configured with the values obtained from [38]. All the queues are served by the WFQ (Weighted Fair Queuing) scheduler [40], which is configured such that the profile defined for the AF classes is assured. The weights attributed to the AF1, AF2 and BE queues are 3, 2 and 1, respectively. The DiffServ backbone has a bandwidth of 3 Mbps to guarantee the resources defined in the profiles and for the best-effort traffic.

Initially, best-effort flows of 100 Kbps are introduced in each IntServ network. Reserve requests of TCP CL flows of 100Kbps are generated every 15 seconds by IntServ A1 network. Reserve requests of UDP CL flows of 100Kbps are generated every 10 seconds by IntServ A2. A CL flow is mapped into the AF class and transmitted if resources are available in the IntServ networks and if the dynamic admission control in the edge router mappers 1 and 2, based on the bandwidth management mechanisms, at the DiffServ domain entrance accepts the request.

After 200 seconds of simulation time, and every 50 seconds thereafter, the existent TCP CL flow reserves of the 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 UDP CL flow reserves of the 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 admission control mechanisms evaluation with the other mapping mechanisms. Also, IntServ A2 network generates more traffic and communicates more frequently its state through the reserve releases and, therefore, it uses a higher slice of DiffServ resources. The probing flow admitted after degradation detection has duration of 100s to verify the effect of the active flows, already removed from the probing list. After this, the CL admitted flows have duration of 100s. This situation permits the CA mechanism evaluation when the number of reserve requests is identical to the reserve releases. The admission of new flows happened until t=710s. In the period of time between t=710s and t=810s, the reserves of the existing flows were released to terminate the simulation.

The results obtained by edge router mapper 1, in the admission and mapping of TCP CL flows into AF2 class, as well as the maximum throughput (MaxThroughput) allowed by the bandwidth management mechanism, are presented in Figure 4. The results obtained in the admission and mapping of UDP CL flows into AF1 class by the edge router mapper 2 are presented in Figure 5.

The figures 5 and 6 show the behavior of admission control mechanisms based on the information supplied by the bandwidth management mechanisms. In the beginning, the flows were admitted until the throughput of the predefined profiles 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 bandwidth management algorithm, in such case the variable MaxThroughput is incremented by 10%.

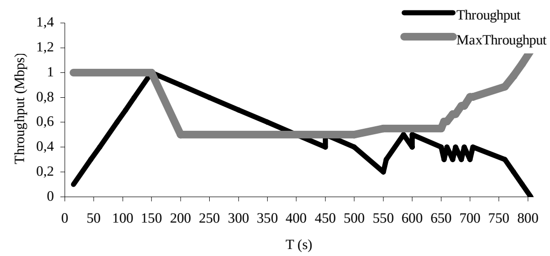

Figure 4 Throughput of IntServA1 TCP CL flows admitted in the DiffServ network

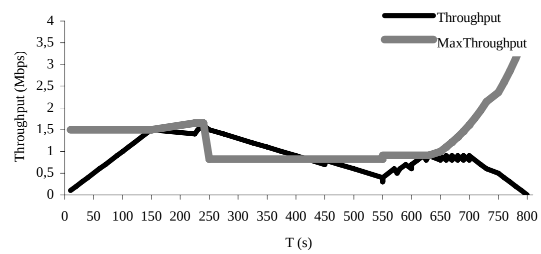

Figure 5 Throughput of IntServA2 UDP CL flows admitted in the DiffServ network

When QoS degradation occurs, the bandwidth management algorithm imposes a period for degradation recover, through the decrement of maximum throughput allowed to the CL flows (50% of the current value). In the scenario presented, degradation has occurred and was detected in different periods by each edge router mapper. This happens because the TCP and UDP CL flows are mapped in different classes. The AF2 degradation occurrence was detected at t=200s by edge router mapper1 whereas AF1 degradation was detected at t=250s by edge router mapper 2. Thus the AF1 class takes advantage of the available DiffServ resources. 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. In this scenario is also verified the functioning of the algorithm of the admission control mechanism in the admission of flows until the maximum throughput allowed.

In these figures also it can be verified that when the number of admitted flows is significantly equal to terminate ones, the considered mechanisms allow an increment of 10% in the allowed maximum throughput. This situation appears between t=650s and t=710s in the two figures. The resources calculated are not used in this scenario but they could be when the IntServ networks request them.

The end-to-end results for throughput, delays and losses obtained by the TCP CL and BE flows generated in IntServ A1 network are presented in figures 7, 8 and 9, respectively. The results obtained by simulation for UDP CL flows generated in the IntServ A2 network are not presented in this paper but they have a behavior similar to our previous work [34, 35].

For better perception of the figures presented in this paper, the most important flows are enhanced, i.e, those that contribute to the functioning of the presented mechanisms and modules. Thus, the flow that provokes the QoS degradation, the flow that communicates this degradation occurrence to the edge router mapper and the probing flow after degradation detection, have bolder lines.

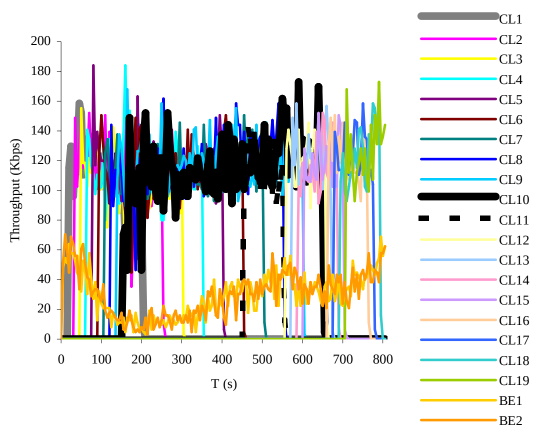

Figure 6 Throughput of IntServA1 TCP CL and two BE flows

The Figure 6 shows that the TCP flows throughput measured in the receiver floats, initially, around reserved values, slightly above 100Kbps. However, in the load situation, it oscillates around 100Kbps, decreasing for some TCP flows and increasing for others. This situation is justified by the typical behavior of TCP flows and by the characteristics of CL flows specified in the reserve. Thus, some flows take advantage of fewer throughputs of other flows to increase their throughput. BE flows absorb the congestion when the number of admitted CL flows increases, and are degraded in terms of delay throughput and losses. After the admission of TCP CL10, at t=150s, QoS degradation occurs. This situation is detected when the TCP CL1 flow is released at t=200s. This release brings information about the state of the corresponding AF2 class and triggers the bandwidth management mechanism at edge router mapper 1 that decrements de MaxThroughput allowed to the class. The admission control mechanism acts allowing the rapid QoS reestablishment of the class since it does not allow the admission of new flows while the new state of the network is not verified.

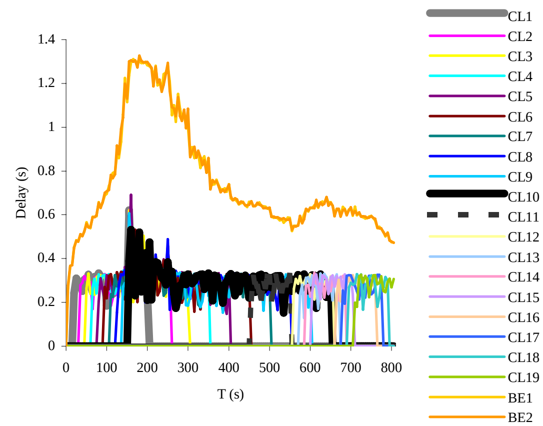

Figure 7 End-to-end delay of IntServA1 TCP CL and two BE flows

The delays presented in Figure 7 oscillate around a constant value. This value increases in the period of losses occurrence in DiffServ network. The delay and the losses of BE flows increase with the admission of new TCP CL flows and decrease with the reserve releases.

The losses of CL flows presented in Figure 8 happen essentially in the sender IntServA1 network since this network is overloaded. In the period between t=150s and t=200s the losses also occurred in the DiffServ network as it can be verified in Figure 9.

The losses obtained in the DiffServ network by the flows proceeding from the IntServA1 network are presented in Figure 9. These losses occur in the period between the admission of the TCP CL10 flow (t=150s) and the reserve release of the TCP CL1 flow (t=200s). At the instant t=250s, when the congestion in AF1 class occurs, the TCP CL8 flow also suffers small losses, due to the congesting of DiffServ network. This congestion is resolved by the AC mechanism in edge router mapper 2, that decrements the maximum throughput allowed to AF1class, at t=250s, when a UDP CL flow communicates the degradation. This mechanism does not permit the admission/mapping of more flows until the sum of the active flows throughput with the throughput of new flow does not exceed the MaxThroughput allowed and until the probing flow does not communicate the end of the congestion in the AF1 Class.

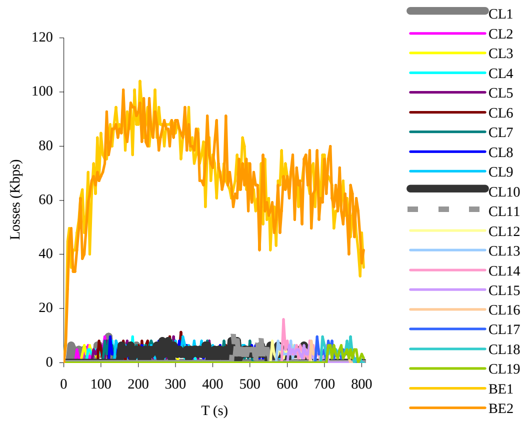

Figure 8 Losses of TCP CL and two BE flows

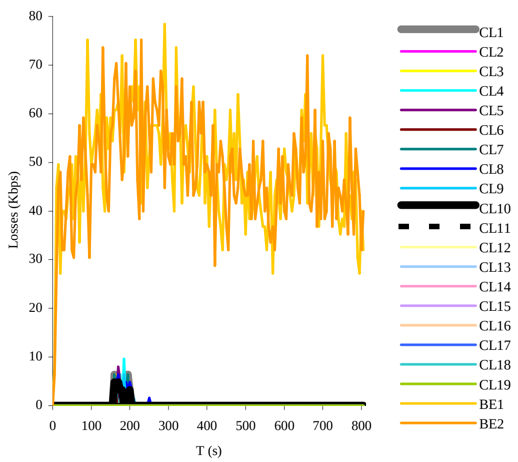

Figure 9 Losses of TCP CL and two BE flows in the DiffServ network

The results obtained in the simulation with the mechanisms and modules presented 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 CA module with the bandwidth management and mapping modules acts in accordance with the E2ERB defined in the architecture, reflects the state of the network, harnessing the improvement of the existing resources in a DiffServ region and allows detecting and eliminating the congestion in a DiffServ network.

5. Conclusions and future work

In this work we presented an admission control 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 admission control proposed acts in accordance with the E2ERB experimented by a previous flow to the same IntServ destination network. This behavior determines the resources for an AF class. The admission control algorithm is based on these resources to admit/map a flow proceeding for an IntServ network.

The results obtained by simulation show that the admission control module acts based on the bandwidth management module, allowing the use of the available resources by an AF class when does not exist degradation. When the degradation is detected, the admission control mechanism allows the reestablishment of the QoS characteristics of the AF Class affected. Also, it was verified that the action of these two modules allows the use of the available resources for an AF class not affected. This situation shows that these modules, besides detecting and correcting the degradation, also allow, at each time instant, an improvement of the use of the available resources for the AF classes in the DiffServ network.

As future work (already ongoing) we will address the validation of the architecture that integrates the mechanisms and modules presented in this paper in a scenario where the traffic generated in one IntServ network is destined to other networks.

Acknowledgment

This work was partially supported by the Portuguese Foundation for Science and Technology (FCT), by European Union FEDER under program POSI (Project QoSMAP) and by PRODEPIII, Measure 5, Action 5.3.

References

[1] D. Black et al., An Architecture for Differentiated Services, RFC 2475, IETF, Dec. 1998.
[2] R. Braden et al., Integrated Services in the Internet Architecture: an Overview, RFC 1633, June, 1994.
[3] IntServ workgroup charters, http://www.ietf.org/html.charters/IntServ-charter.html.
[4] DiffServ workgroup charters, http://www.ietf.org/html.charters/DiffServ-charter.html.

[5] R. Braden et al, Resource Reservation Protocol (RSVP) – Version 1 Functional Specification, RFC 2205, September 1997.

[6] S. Shenker et al, Specification of Guaranteed Quality of Service, RFC 2212, September 1997.

[7] J. Wroclawski, Specification of the Controlled-load Network Element Service, RFC 2211, September 1997.

[8] Brian E. Carpenter and Kathleen Nichols, "Differentiated Services in the Internet", Proceedings of the IEEE, Vol. 90, No. 9, September 2002, pp. 1479-1494.

[9] K. Nichols et al., Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers, RFC 2474, December 1998.

[10] B. Davie et al, An Expedited Forwarding PHB, RFC 3246, March 2002.

[11] J. Heinanen et al, Assured Forwarding PHB Group, RFC 2597, June 1999.

[12] ISSLL workgroup charters, http://www.ietf.org/html.charters/issll-charter.html.

[13] Y. Bernet et al, A Framework for Integrated Services Operation over DiffServ Networks, RFC 2998, November 2000.

[14] Mohamed A. El-Gendy, Abhijit Bose, and Kang G. Shin, "Evolution of the Internet QoS Support for Soft Real-Time Applications", Proceeding of the IEEE, Vol. 91, No. 7, July 2003, pp. 1086-1104.

[15] G. Houston, Next Steps for the IP QoS Architecture, RFC 2990, November 2000.

[16] D. Lourenço et al, "Definição do Mecanismo de Controlo de Admissão para o Modelo de serviços de LCT-UC", in Proceedings of CRC2000, FCCN, Viseu, Portugal, November 2000.

[17] E. Monteiro, et al, "A Scheme for Quantification of Congestion in Communication Services and Systems", in Proceedings of SDNE'96, IEEE Computer Society, Macau, June 1996.

[18] L. Breslau et al, "Endpoint Admission Control: Architectural Issues and Performance", in Proceedings of ACM SIGCOM 2000, Stockolm, Sweden, August 2000.

[19] V. Eleck et al, "Admission Control Based on End-to-End Measurements", in Proceedings of IEEE Infocom 2000, Tel Aviv, Israel March 2000.

[20] F. Baker et al, Aggregation of RSVP for IPv4 and IPv6 Reservations, RFC3175, September 2001.

[21] Y. Bernet, Format of the RSVP DCLASS Object, RFC2996, November 2000.

[22] Z. Zhang et al. "Decoupling QoS Control from Core Routers: A Novel Bandwidth Broker Architecture for Scalable Support of Guaranteed Services", in Proceedings of ACM SIGCOM 2000, Stockolm, Sweden, Agosto 2000.

[23] J. Wroclawski et al, Integrated Services Mappings for Differentiated Services Networks, Internet Draft, draft-ietf-issll-ds-map-01.txt, February 2001.

[24] M. Eder, H. Chaskar, and S. Nag, "Considerations from the Service Management Research Group (SMRG) on Quality of Service (QoS) in the IP Network", RFC 3387, IETF, September 2002.

[25] Shengming Jiang, "Granular differentiated queueing services for QoS: structure and cost model", Computer Communication Review (ACM SIGCOMM), Volume 35, Number 2, April 2005, pp. 13-22.

[26] Zoubir Mammeri, "Framework for parameter mapping to provide end-to-end QoS guarantees in IntServ/DiffServ architectures", Computer Communications, Vol 28, nº 9, June 2005, pp. 1074-1092.

[27] Roberto Mameli, Stefano Salsano, "Use of COPS for Intserv operations over Diffserv: Architectural issues, protocol design and test-bed implementation", in Proc. IEEE ICC 2001 no. 1, June 2001, pp. 3265-3270.

[28] H. Bai, M. Atiquzzaman, W. A. Ivancic, "Running integrated services over differentiated service networks: quantitative performance measurements", Proceedings of SPIE ,Vol. 4866, August 2002, p. 11-22.

[29] E. Lee, S. I. Buyn, M. Kim, "A translator between integrated service/RSVP and differentiated service for ent-to-end QoS", In Proceedings of IEEE, ICT'2003, Vol. 2, Tahiti, Papeete, French Polynesia, February 2003, pp. 1394–1401.

[30] Zoubir Mammeri, "End-to-End QoS Mapping in IntServ-over-DiffServ Architectures", in Proc. of the HSNMC2003, pp. 31-40, Portugal, July-2003

[31] Y.-C. Chang, R.-C. Wang, J.-L. Chen, and C.-H. Kuo, "QoS Scheduling Mechanism for IntServ/DiffServ Network Services" In Proc. of WOC 2004, Banff, Canada. July 2004.

[32] A. Pereira, E. Monteiro, "Interligação IntServ DiffServ: Mapeamento do Serviço CL no PHB AF", in Proc. of CRC2002, FCCN, Faro, Portugal, September 2002

[33] A. Pereira, E. Monteiro, "Dynamic mapping between the Controlled-Load IntServ service and the Assured Forward DiffServ PHB", in Proc. of the HSNMC2003, Portugal, July-2003, pp. 1-10

[34] A. Pereira, E. Monteiro, "Avaliação de mecanismos de gestão de recursos no mapeamento entre os modelos IntServ e DiffServ", in Proc. of CRC2004, Leiria, October-2004, pp. 179-191.

[35] A. Pereira, E. Monteiro, "Bandwidth management in IntServ to DiffServ mapping", in Proc. of the QoSIP-2005, Vol. 3375, Lecture Notes in Computer Science (LNCS) Catania, Italy, February-2005

[36] Network Simulator – NS (version 2), http://www.isi.edu/nsnam/ns/

[37] M. Greis, "RSVP/ns: An Implementation of RSVP for the Network Simulator ns-2", http://titan.cs.uni-bonn.de/~greis/rsvpns/index.html.

[38] J. F. Rezende, "Assured Service Evaluation", IEEE Global Telecommunications Conference, Globecom'99, Rio de Janeiro, Brasil, Dezembro 1999, pp. 100-104.

[39] D. Clark et al, "Explicit Allocation of Best Effort Packet Delivery Service", IEEE/ACM Transactions on Networking, vol. 6, no 4, August 1998.

[40] H. Zhang, "Service Disciplines for Guaranteed Performance Service in Packet-Switching Networks," Proc. IEEE, vol. 83, no 10, October 1995.