An Active Network Solution to the Problem of RSVP Reservation Gaps

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Abstract : With the increasing diversity in network applications and traffic types in the Internet, providing end-to-end QoS support to user traffic has been identified as one of the prime solution to provide deterministic service levels within the network. Due to the heterogeneity exhibited by the Internet, a route for a flow requiring QoS guarantees may not be available from source to destination comprising exclusively QoS supporting path segments. Hence the flow must traverse one or more non-QoS segments referred to here as "reservation gaps". In this paper we study the problem of reservation gaps and present a solution to address the deficiencies caused by these gaps, using an Active Network approach based on the mobile agent paradigm. The solution we propose is scalable to large networks, like the Internet. We demonstrate the advantages of such a solution using simulations which compares operational characteristics of QoS flows when traversing non-managed and actively managed reservation gaps.

1 Introduction

With the Internet emerging as one of the largest available multi-service networks there is a pressing need for providing deterministic service levels for the user traffic within the network. This has resulted in a need to introduce Quality of Service (QoS) mechanisms [1] in the Internet. QoS refers to the capability of a network to provide priority including dedicated bandwidth, controlled jitter and latency, and improved loss characteristics to selected traffic classes (audio, video, etc.). These enhancements to the Internet are expected to provide an end-to-end QoS supportive network model.

The Internet is a heterogeneous network environment interconnecting different autonomous network system on a global scale. Due to this, the future availability of QoS support features at all nodes in the Internet is highly unlikely. Hence, non-QoS nodes will coexist with QoS supporting nodes in the network. Throughout our discussion we will refer the later as "Q-nodes" and path segments comprising them as Q-segments. We call the flows requiring QoS guarantees as "Q-flows". If a mixture of both Q and non-Q segments is present along a Q-flow's path, no global end-to-end service levels can be guaranteed. We refer to the non-Q segments present along a Q-flow's path as "reservation gaps". It is desirable to provide mechanisms to support Q-flows in internetworks which may contain such "reservation gaps".

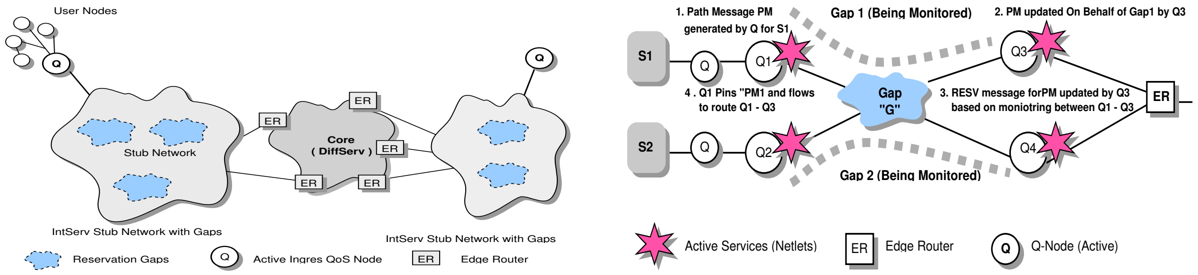
Two distinct approaches to overcome deficiencies caused by reservation gaps are: (1) To restrict Q-flows to path segments comprising exclusively Q-nodes; or (2) Permitting Q-flows to traverse reservation gaps if best-effort service provides adequate QoS. Traffic monitoring will be required to determine whether this is the case. The former approach results in a Q-flow being blocked even though adequate network resources are available to carry the flow.

Comparatively little work [2] has addressed the issue of reservation gaps in the Internet. In recognition of this, in this paper, we present an Active Network [3] approach that autonomously works to rectify such reservation gaps present along a Q-flow's reservation path. Due to unpredictable behaviour of the non Q-segments and the inability to support strict service levels within the segments, we propose to discover and monitor those paths efficiently using nodes running Active Network services. To support accurate end-to-end reservation results we discuss a mechanism that can be used to manage the Q-flows traversing these reservation-gaps. The rest of the paper is organised as follows: In section 2 we discuss about the reservation gap problem. Section 3 describes the reference architecture used. In section 4 and section 5 we describe the proposed solution and present a simulation study of its effectiveness. In section 6, we present a comparison to a related work and conclude the article.

2 Reservation Gaps in the IntServ Network

RSVP [4] is used as the QoS signalling protocol in the IntServ network. When non Q-nodes (non-RSVP) are present along a Q-flow's path, the RSVP signalling messages messages reserve required resources at the RSVP nodes (Q-nodes) and works with best-effort service offered across the non Q-nodes. In this paper, we focus our work on the reservation-gaps present in the IntServ enabled networks, primarily referring to the IntServ based stub network domains (see Fig. 1(a)). We refer to the Q-nodes that encapsulate a reservation-gap as "entry" and "exit" nodes of the gap.

A solution to overcome deficient reservations was presented in [2] using a receiver initiated agent-based approach. In that approach, individual receiver end applications initiated mobile agents for solving the problem of deficient reservations, when reservation-tunnels [2] were detected across the end-to-end path of a Q-flow. The tunnel detection mechanism used was to back-trace and probe every node on the session's end-to-end path to identify the existence of



(a) IntServ-DiffServ End-to-End QoS Model With Gaps

(b) IntServ Network with a Gap “G”

Figure 1: The Reservation Gap

tunnel segments. On identifying the exact location of the tunnel(s), mobile agents were deployed by the end application to monitor the tunnel(s) characteristics and notify results to it. In comparison to the receiver initiated approach [2], we present an adaptive approach that autonomously works to rectify deficient reservations caused by reservation gaps.

3 The Reference Architecture

IntServ Over DiffServ QoS Model: IntServ over DiffServ framework [1] provides a scalable end-to-end QoS model in the Internet. In this, the stub network domains are based on an IntServ network model while the core network follows a DiffServ based architecture. This approach is currently one of the most valuable solutions for end-to-end QoS provisioning, since it tries to conjugate benefits of both the IntServ [1] and the DiffServ [1] architectures. This model provides QoS signalling capabilities for resource reservation by end applications and also provides higher scalability when working in the core network. The reference architecture (see Fig. 1(a)) which we have used to describe our approach for enabling accurate QoS reservations in the Internet is based on this end-to-end QoS model. For the sake of generality, we make our approach independent of the end application’s in-built QoS features. We assume QoS support to non-QoS aware applications are provided by an active gateway node connecting the user to the Internet [5], such as node Q in Fig. 1(a) & 1(b). Thus a general assumption we make is that ingress nodes connecting the users to the stub network are QoS provisioned.

Active Enabled QoS Nodes: Our solution to the problem of reservation gaps requires additional features (management and monitoring of gaps) to be present at the Q-nodes in the network. We advocate the Active Network approach for this purpose. The reasons for using an Active Network approach are: (1) Since the network’s topology changes dynamically in the Internet, Q-nodes can become entry and/or exit points for dynamically formed reservation gaps in the network during their service lifetime; and (2) Statically incrementing required feature support at the network nodes will lead to a case of unwanted software accumulation in the network. Overall, the reservation gap problem demands a network architecture that autonomously decides to extend features dynamically.

We follow the autonomous Active Network service architecture, the Netlets [6,7], that lends itself to dynamically load network services in the network as and when required. Introducing new services in the Netlets network is performed dynamically. The service code in the Netlets architecture is mobile and autonomous which avoids manual intervention for service deployment. The benefits such an Active Network architecture is not confined to the problem of reservation gaps. A large scale of such problems demanding an Active Network solution is discussed in [3]. In our discussion below, we assume Q-nodes (RSVP) in the Internet are also able to support autonomous Active Network services [6,7]. To support monitoring of non Q-segments, we assume all nodes in the network support SNMP [8].

4 An Enhanced Reservation Scheme

The purpose behind working to solve the problem caused by reservation gaps is to ensure an accurate reservation model in the Internet. Our approach to support such an “accurate end-to-end QoS reservation” is based on the following three mechanisms: (a) Discovering reservation gaps; (b) Monitoring each gap; (c) Managing the Q-flows traversing the gap.

Reservation Gap Structure

Fig. 1(b) depicts a reservation-gap caused by a non-Qos region, G, in an IntServ network. For example in Fig.1(b), Q1 - Q3 are the entry and exit nodes of the reservation gap (Gap1) caused by the non-QoS region, G. In the case of a completely non-QoS provisioned stub network, the maximum path length of a reservation-gap will span from the Ingress/Gateway QoS Node (node Q) to Edge Node (ER) of the DiffServ domain, which is always both RSVP and DiffServ enabled.

Dynamic Discovery of Gaps

We use the PATH messages of the RSVP protocol to discover the reservation-gaps present along a Q-flow's path. Each PATH message in the RSVP protocol includes the address of the last known RSVP-capable node in the Phop (previous hop) field. When a downstream Q-node such as Q3 (see Fig 1(b)) receives a PATH message from an upstream sender node, such as S1, node Q1 is identified as the Phop node. Since node Q3 does not have direct connectivity to Q1 (based on the information available in the neighbourhood table), it recognises the existence of a "reservation-gap" between itself and Q1.

Monitoring the Gap

On discovering the existence of a reservation-gap, the relevant exit node (Q3 in Fig. 1(b)), takes on the role of managing the "reservation-gap" and installs autonomous active service code [6,7] at both entry and exit Q-nodes as required. The autonomous mobile service code are referred to as $\text{Entry}_{active-service}$ and $\text{Exit}_{active-service}$. These services, $\text{Entry}_{active-service}$ & $\text{Exit}_{active-service}$ present at the ends of the reservation gap co-ordinate to perform monitoring of the reservation gap (for example, services installed at Q1 & Q3 coordinate to monitor the gap, Gap1, as in Fig. 1(b)). SNMP [8] is used to study the path characteristics of the gap.

The $\text{Entry}_{active-service}$, generates SNMP agents with destination $\text{Exit}_{active-service}$. The SNMP agents traverse the reservation gap collecting relevant metrics (for example, the available bandwidth, queue length etc.) by probing the relevant MIB entries of the non Q-nodes. The delay in traversing the gap is measured by sending time stamped packets from the $\text{Entry}_{active-service}$ to the $\text{Exit}_{active-service}$. The direction of travel of SNMP messages and delay measurement packets conforms with the travel direction of the PATH message along the reservation-gap (for example from Q1 to Q3 for a PATH message from S1 in Fig.1(b)). Continuous packet processing will be necessary, if there is non-Q-flows present in the reservation-gap.

Managing Q-Flows Traversing the Gap

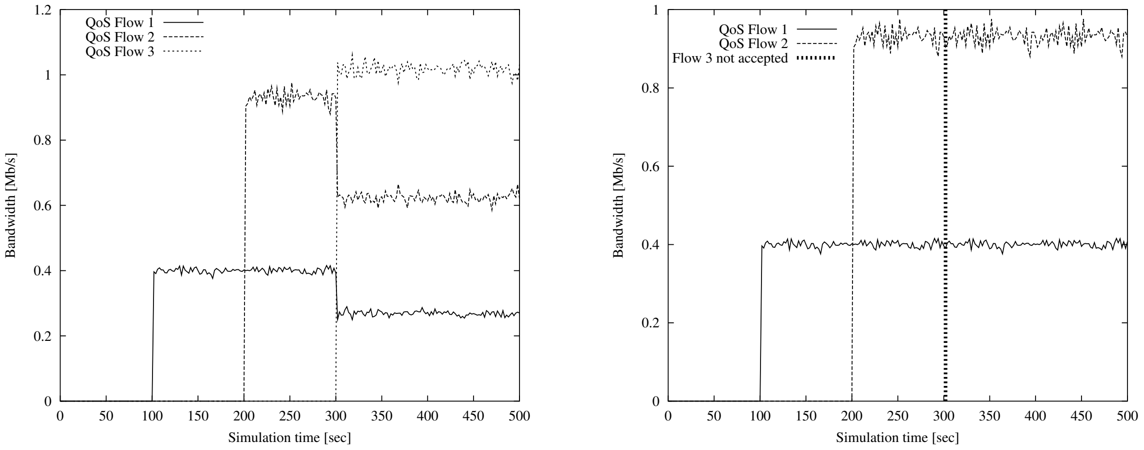
Managing the Q-flows involves interacting with the RSVP signalling messages (PATH and RESV message) corresponding to each Q-flow. The PATH message primarily functions to install reverse routing state in each router along the path, and secondly to provide receivers with information about the characteristics of the sender traffic and end-to-end path so as that they can make appropriate reservations. The RESV messages in turn carries reservation requests to reserve resources based on PATH message content. In the conventional reservation scheme, the PATH and RESV message are ignored along the uncontrolled reservation-gaps. In contrast, by monitoring the "gap" we provide the receiver and sender nodes with accurate information of the path characteristics and reservation availability.

Here we explain the process involved in managing the Q-flows traversing a reservation-gap. The end host operating over the end-to-end QoS model (node S1 or Q in Fig. 1(a)) sends PATH messages destined to the receiver node with a request for reservation (Step 1 in Fig. 1(b)). The Q-nodes (RSVP) along the path create path-state information at the local node for each PATH message and update the ADSpec object (this advertises the path characteristics to the receiver). When a PATH message is received at an exit Q-node of a reservation-gap (Q3), this node updates the PATH message with information gathered using the monitoring scheme (Step 2 in Fig. 1(b)). By this, the receiver node receives accurate state information regrading the end-to-end path. When the exit Q-node receives the request for resource reservation (RESV message) it checks for the availability of resources (bandwidth) and conformance to the delay constraints specified. The exit Q-node based on the above procedure either confirms and forwards RSVP messages or sends an error message to the reservation requesting node (Step 3). On acceptance of reservation by the exit node of the gap, this node informs the entry Q-node to pin the data-flows (only) belonging to the request between the entry and exit nodes (Q1 & Q3) for the lifetime of the connection (Step 4). This is done to mimic the RSVP behaviour followed in maintaining soft-state routes along the end-to-end path. This will allow the data packets to follow the same path as the corresponding RSVP signalling messages. Pinning of data flows is performed by turning on the source-routing option present in the IP layer at the entry node (source route set to Q3). When the data packets reach the exit node, the source routing option is cleared and the packets are forwarded.

5 Simulations: Non-Managed Vs Actively Managed Gap

For the example, we considered three UDP based Q-flows traversing a non-QoS link, L, of capacity 1Mb/sec. The UDP traffic generator is constant bit rate (CBR) source with exponentially distributed on and off periods. We define Q-Flow 1, and Q-Flow 2 with bandwidth requirement ≈0.4Kb/sec and 0.9Kb/sec respectively. When a new Q-flow, Q-Flow 3, with bandwidth requirement ≈1.5Mb/sec, greater than the available resources, enters the reservation gap, a very high percentage of link's capacity is absorbed by this flow (Q-Flow 3). This causes degradation to the existing Q-flows. This is shown in Fig. 2(a). Overall, all the flows suffer heavy packet losses and the network resources is inefficiently utilised.

With an accurate QoS reservation support the third flow, Q-Flow 3, is informed about the non-availability of resources across the non-QoS link, L (in Fig. 2(b), at $t \approx 300$, the third flow requests for QoS and disappears). By this, the existing



(a) Non-Managed Gap

(b) Managed Gap

Figure 2: Non-Managed Gap Vs The Active Managed Reservation Gap

Q-flows (Q-Flow 1, Q-Flow 2) encounter the offered QoS (see Fig. 2(b)) and the network resources are efficiently utilised.

6 Conclusions and Future Work

The unpredictable behaviour of traffic within the non-QoS path segments present along a Q-flow's path and the inability to support reservations across them can cause problems in providing end-to-end service guarantees in the Internet. A receiver initiated agent-based approach (described in section 2) was presented in [2] to overcome such deficient reservations. We presented another solution to this problem. We have described an Active Network solution using the mobile agent paradigm to build an accurate end-to-end QoS support model and have validated its advantages using simulation. Our technique features, improved dynamics and scalability in comparison to the receiver initiated approach [2]. Our approach is initiated by the network rather than the receiver node [2] and thus scales for larger networks and user population. The dynamics of our approach are superior to [2], making support of short lived Q-flows feasible. The control traffic generated in our approach (to monitor and mange the non-QoS path segments) is confined to the corresponding reservation gap, where in [2], the control traffic traverses between the tunnel and the receiver node.

Techniques such as those described here and in [2] will allow an expedited migration towards an end-to-end QoS supportive Internet. Future work will explore methods to find routing approaches that will select paths with minimal reservation gaps. This will decrease the number of active management points required and will thus increase the reservation reliability.

References

[1] X. Xiao and L. M. Ni. Internet QoS: A Big Picture. *IEEE Network*, Vol.13, Mar 1999.

[2] Hermann de Meer, Jan-Peter Richter, Antonio Puliafito, and Orazio Tomarchio. Tunnel agents for enhanced Internet QoS. *IEEE Concurrency*, 6(2):30–39, 1998.

[3] K. Psounis. Active Networks: Applications, Security, Safety, and Architectures. *IEEE Communications Surveys*, First Quarter 1999.

[4] Lixia Zhang, Stephen Deering, and Deborah Estrin. RSVP: A New Resource ReSerVation Protocol. *IEEE network*, 7, September 1993.

[5] Kalaiarul Dharmalingam and Martin Collier. Transparent QoS Support For Network Applications using Netlets. *Proceedings of Mobile Agent Applications for Telecommunication Applications (MATA)*, 2002.

[6] Martin Collier. Netlets: The Future of Networking? *IEEE OpenArch*, April 1998.

[7] Kalaiarul Dharmalingam and Martin Collier. Netlets: A New Active Network Architecture. *First IEI/IEE Symposium, Dublin, Ireland*, Nov 2001.

[8] W Stallings. SNMP, SNMPv2 and CMIP. The Practical Guide to Network Management Standards. *Addison Wesley*, 1993.