EVALUATING THE RSVP MOBILITY PROXY CONCEPT

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Abstract - Mobility and QoS provision are the two most important burdens to solve, before IP becomes truly ubiquitous. Mobile IP and RSVP are the most visible proposals for those problems. Their interoperability, though, is inefficient. To ameliorate the compatibility problem and performance gap, we have proposed the introduction of the RSVP Mobility Proxy. In this paper, we present the performance evaluation of our scheme versus the plain RSVP operation.

Keywords - RSVP, Mobility Management, QoS, Mobile IP, Proxy

I. Introduction

The Internet Protocol is gradually becoming the unifying infrastructure for any form of communications. IP provides a simple, scalable and robust framework for building data communication applications. However, IP is still not adequate for guaranteed QoS and mobility.

Mobile IP [1] is the mobility management protocol proposed by the IETF [2]. As for QoS provision, there are two main architectures developed by the Internet community: the Integrated Services [3] and the Differentiated Services [4]. RSVP [5] is the signaling protocol for Integrated Services architecture support, and as argued in the literature [6], the Integrated Services architecture is best applied to access networks due to its fine-grained classification. Core networks can support Differentiated Services and interwork with RSVP [7].

Mobile IP and RSVP are mostly incompatible. Several efforts have been underway to cater for this incompatibility (a nice bibliography is included in [8]). However, these schemes exhibit some inefficiencies regarding network resource utilization or heavy modification on the existing RSVP protocol components. We propose the introduction of the RSVP Mobility Proxy [9] [10], so that as few changes as possible be necessary to the network elements in our effort to minimize QoS deterioration for mobile users.

II. RSVP Mobility Proxy

RSVP Mobility Proxy is analytically specified in [9] and [10]. A brief introductory description is presented here.

The motivation behind RSVP-MP stem from the intention of enhancing the efficiency of QoS enabled mobility management, while at the same time, affecting as little as possible the existing infrastructure and protocols. To achieve this, we rely on the deployment of a hierarchical mobility management scheme such as [11] or [12], since it improves the performance of Mobile IP and can help in minimizing any RSVP signaling exchange inside the access network. Thus, our expectations are:

- The significant minimization of the QoS deterioration duration, i.e. the time needed to re-establish a guaranteed QoS session
- The minimization of network resource waste, since any re-configuration actions take place only inside the access network of the mobile user[1].

The main concept in hierarchical mobility management schemes is that a MH may acquire different CoAs (Local Care-of Addresses, LCoAs) while moving inside an access domain, while being always reachable by a “global” CoA (Regional Care-of Address, RCoA) from any “external” network. Hierarchical mobility management schemes are likely to be controlled by a control component such as the Mobility Anchor Point (MAP) [11] or the Gateway Foreign Agent (GFA) [12]. That control component is usually located at the root of the hierarchy and controls local mobility, at least at the top hierarchy level, where multiple levels may exist.

The RSVP Mobility Proxy (RSVP-MP) is actually the router at the edge of the access network, enhanced with combined RSVP and mobility management functionality (Figure 1). It is e.g. an RSVP enhanced MAP, that has intertwined RSVP and hierarchical mobility management functionality.

Resource reservations in the RSVP-MP are based on the (unique for each MH) RCoA. This means that the IP address of the MH is always represented in the RSVP internal State Blocks [13] (Path State Block PSB, Resv State Block RSB, etc.) in its RCoA format. The reservation states outside the access network are configured for the stable RCoA. Only the reservations inside the access network are LCoA dependent. This establishes the necessary infrastructure to accommodate mobility events inside the access network, without the need to propagate the topology modification outside of it

In a handoff case, the mobility control authority of RSVP-MP (MAP/GFA) is either in control or immediately notified about it. An asynchronous notification about the handoff must be delivered to RSVP-MP. When it receives the handoff notification, RSVP-MP examines its internal Binding Cache,

[1] In normal RSVP operation, resources are reserved end-to-end and can be kept reserved for a time period of 60–90 seconds after the mobile user has changed point of attachment.

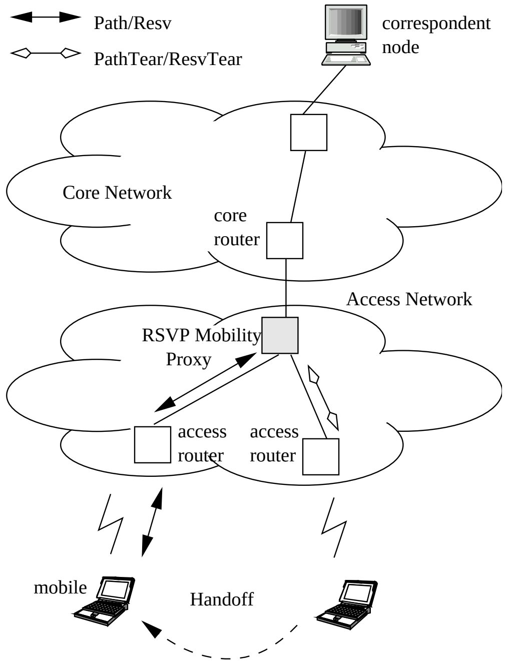

Fig. 1. Network topology with the RSVP-MP

which contains the MHs' <RCoA, LCoA> binding and finds out whether a reservation for the MH that changed its point of attachment was already in place.

The actual RSVP signaling is purely restricted inside the access network, whereas any Path or Resv messages transmitted to the core network merely serve as state refresh messages. No actual Path or Resv state modifications are performed in routers outside the area controlled by the RSVP-MP.

A parallel activity, of equal importance, is the release of the downlink and uplink reservations corresponding to the MH's previous LCoA. The release of the downlink Path and Resv state is triggered by the RSVP-MP that sends a PathTear/ResvTear submission toward the old LCoA, i.e. toward the old Access Router. The reservation release from the old Access Router to the RSVP Mobility Proxy and any wireless reservation controlled by that Access Router is trickier. An asynchronous notification to that Access Router is necessary for the immediate release of the resources.

We should note here, that our scheme is applicable also in more complex topologies where a hierarchy of RSVP-MPs can exist in a network. As described in [10], this is achieved without any further modifications or requirements.

The increased complexity of the edge router in the RSVP-MP is the main important drawback for our proposed QoS solution. However, the edge router is the only network component affected. Every other network component, including, most importantly, the mobile terminal devices should only conform to the RSVP standard [5].

The most important benefit from the introduction of the RSVP-MP is the QoS signaling exchange reduction outside the access network. The same session will not have to be re-established in the core network for different IP addresses, avoiding resource waste and leading to QoS degradation (best effort time) minimization. The minimized RSVP signaling in the core network also reduces processing and bandwidth requirements in the core routers. The end-user operating the mobile device, on the other hand, will likely notice a huge improvement in reliable real-time service re-establishment after a handoff.

III. Performance Evaluation

One of the fundamental benefits in RSVP-MP, derived from hierarchical mobility management, is the minimization of the reservation re-establishment delay. The reservation signaling needs to travel twice end-to-end, and since the RSVP-MP scheme limits the signaling endpoints in the access network, it exhibits a much enhanced behavior compared to plain RSVP.

For evaluation purposes, we consider every RSVP request to be a request for a telephone call. Since admission control is also assumed to be in place, circuit switching terminology, such as call blocking probability is used. A call request is blocked when there are no free channels to reserve. An artifact of mobility is that, when a mobile hands off to a new IP address, the reservation to the old IP address becomes stale and wastes network resources. In our evaluation we measure the active and stale reservations in the links between the correspondent nodes and show that RSVP-MP performs much better in mobility-related scenarios. We have developed a simulation model using the Octave tool [14] in a Linux PC to gather the measurements.

We focus our study on the link between the edge router in the access network and the core router in the upstream ISP, since we believe that this link is usually the bottleneck for access networks. This link is also expected to be an expensive resource, and its optimum utilization is economically beneficial.

An access network covering a geographical area by contiguous cells is considered. These cells are organized in clusters served by access routers as depicted in Fig. 2. The edge router directs its input traffic to the core network through a border router. All clusters at the same level are assumed statistically identical and of the same shape, which for analysis reasons is assumed to be circular with radius r_i (the subscript i denotes the level index).

Two hierarchy levels are considered in the hierarchical model of the access network (Fig. 2). The clusters of the second level ($i = 1$) consist of N_0 clusters of the first level ($i = 0$). For simplicity reasons and analytical tractability, the following assumptions are made:

- New traffic is generated at the lowest level according to a Poisson process with parameter λ_0.
- The call durations are modeled as independent random variables, following the exponential distribution with parameter μ.

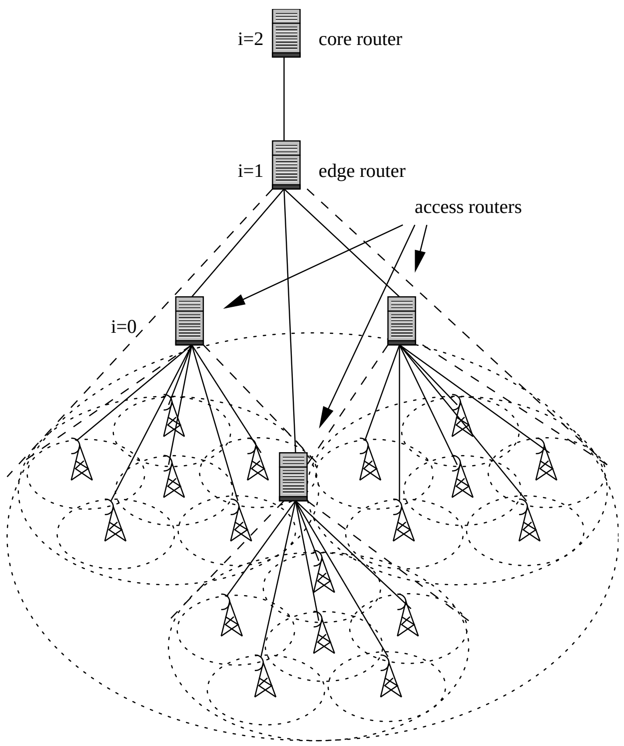

Fig. 2. Access Network Topology

- Mobile stations' cluster dwell times are modeled as exponentially distributed random variables with parameter n_i, depending on the cluster level.
- A fluid flow mobility model is used to describe cluster boundary crossings and thus to find n_i.

Using the last assumption, the parameters n_i for the cluster dwell time are given by [15]

$$n_i = \frac{2v}{\pi r_i} \quad (1)$$

where v denotes the mobile stations' velocity. The handoff probability $P_{h,i}$ is given by

$$P_{h,i} = \frac{n_i}{\mu + n_i} \quad (2)$$

The session duration (minimum time of cluster dwell time and call duration) follows exponential distribution with parameter $\mu_i = \mu + n_i$.

We focus on the blocking probability at the link between the access and the core router, both for the RSVP and RSVP-MP method, given the rate of new arrivals, the mobility of the users and the number of shared channels (c_i) at each intermediate router of level i. We denote by $P_{b,i}$ the blocking probability at the routers of level i.

The cluster of level $i = 1$ consists of $N_0 = 10$ identical circular clusters of level $i = 0$ with radius $r_0 = 200$ m. We assume that the access routers are able to support $c_0 = 512$ and $c_1 = 1024$ channels respectively, whereas the capacity

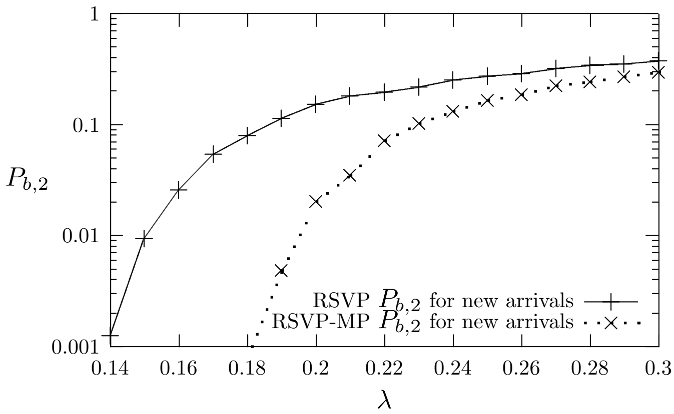

Fig. 3. Blocking Probability vs new arrival rate λ ($v = 1m/sec$)

of the core router is $c_2 = 256$ channels. These values have been chosen with the assumption that the bottleneck will be the link to the upstream ISP, whereas the fixed internal access network can support broadband communications at a fraction of the cost. The bandwidth is chosen so that no congestion occurs in the access network, but only in the edge-core router link.

The simulation used 1-second time intervals as its time step-function. After the expiration of a reservation in a given gluster, a decision for a possible handoff is taken. Each mobile switches to another access router with probability $P_{h,0}$ or terminates its call with probability $1 - P_{h,0}$. If the call terminates, the necessary RSVP signaling is taking place (PathTear, ResvTear), so that the resources are freed.

The call holding time has mean value equal to $1/\mu = 120$ sec and we assume the value of $d = 90$ seconds for the RSVP soft state expiration time as specified in [5]. The rate of new arrivals, λ_0, and the mobile stations' velocity, v, were left as parameters. We should note that we did not use the asynchronous notification for stale resource releases for any of the simulations.

Figure 3 depicts the blocking probability at the link between the edge and the core router with variable arrival rates at the lowest level. The MHs' velocity is considered to be 1m/sec, which is a typical value for indoor environments. It can be observed that the blocking probability increases as expected for both RSVP and RSVP-MP as the arrival rate of new QoS sessions increases. The RSVP-MP case, however, exhibits much lower blocking probability for small values of λ, which is several orders of magnitude smaller compared to plain RSVP.

Similar results are also illustrated in Fig. 4, where the blocking probability for both schemes is plotted against the MHs' velocity. Note that for still users, the two schemes exhibit the same blocking probability. When mobility increases, RSVP shows a remarkable increase in $P_{b,2}$, whereas RSVP-MP retains the same blocking probability it had for no mo-

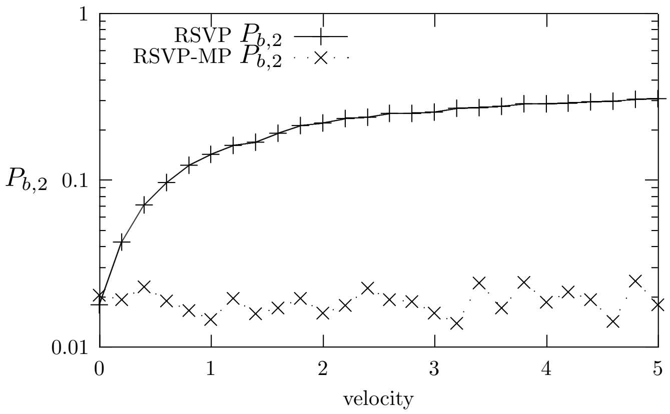

Fig. 4. Blocking Probability vs velocity ($\lambda = 0.2$)

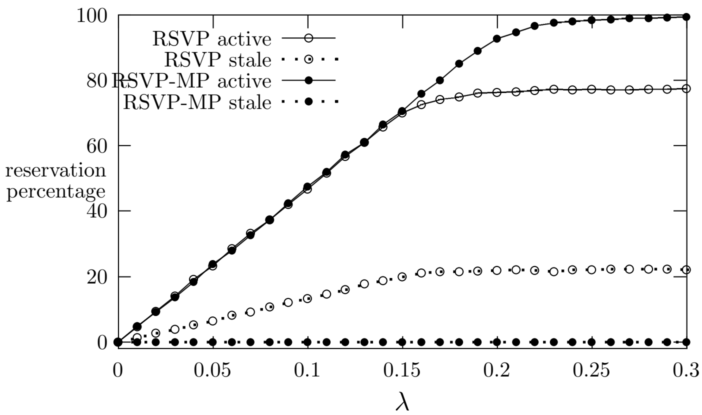

Fig. 5. Active and stale reservation percentage (256 channels) in the link between the edge and the core router vs new arrivals λ ($v = 1m/sec$)

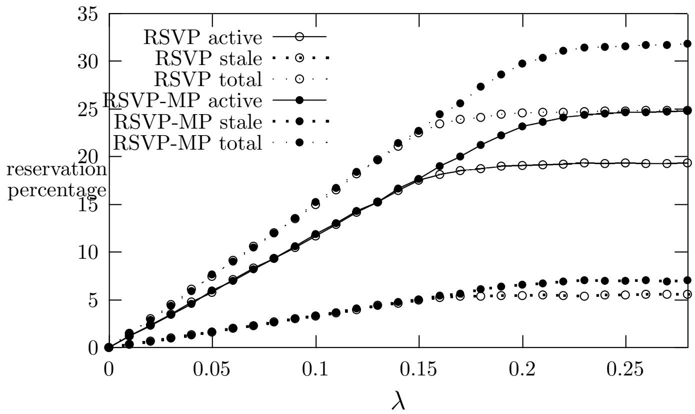

Fig. 6. Active and stale reservation percentage (1024 channels) in the internal interfaces of the edge router vs new arrivals λ ($v = 1m/sec$)

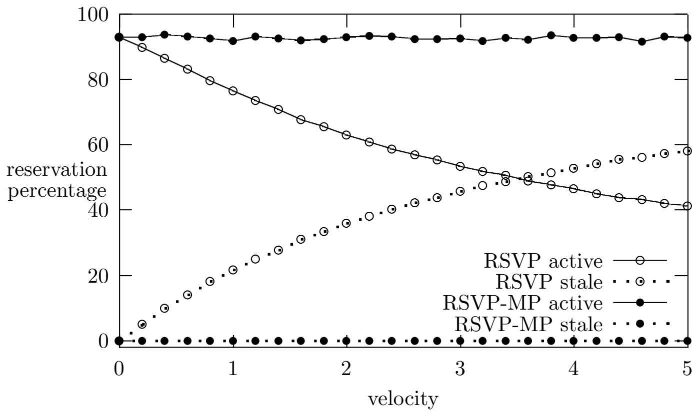

Fig. 7. Active and stale reservation percentage (256 channels) in the link between the edge and the core router vs velocity ($\lambda = 0.2$)

bility. RSVP-MP is obviously not affected at all from the user mobility, maintaining the same service as it did without any mobility. In the current scenario, for which $\lambda = 0.2$, the difference in performance scales to a tenfold increase in $P_{b,2}$, when velocity increases. If we consider smaller arrival rates, the difference in performance is even greater in favor of RSVP-MP.

We should note that the simulation curves represent blocking rates for new arrivals in both protocols. The handoff blocking probability is non-measurable in the RSVP-MP case, whereas in the RSVP case, the handoff blocking probability is the same as the new arrival blocking probability.

In Fig. 5, the reservation occupancies at the link between the edge and the core router are illustrated as a fraction of the total bandwidth of the link. RSVP-MP does not create any stale reservations on that link, while RSVP keeps approximately 20% of the link bandwidth unnecessarily occupied due to the stale sessions it maintains. One further note is that the stale-active ratio in the RSVP case does not seem to depend on the new traffic arrival rate. Both active and stale reservations increase linearly until their sum reaches the total bandwidth of the link. In the RSVP-MP case, the full bandwidth of the link is available to active connections.

Similar behavior can be observed in Fig. 6, where the reservation percentage at the internal routers of the access network is displayed. The actual number of active reservations is the same as in Fig. 5, but this time it represents a smaller fraction of the total bandwidth, since we assumed a network topology with a large bandwidth in the access network. RSVP-MP does show stale reservations in the internal network, and in fact in greater numbers than plain RSVP. The ratio between active and stale reservations remains constant when the MHs' velocity is kept constant. Since RSVP-MP allows for more active reservations, it will have to maintain more stale connections in the internal network.

In Fig. 7, the reservations at the link between the edge and the core router are displayed in a relation to MHs' velocity. The total number of reservation (active + stale) remains con-

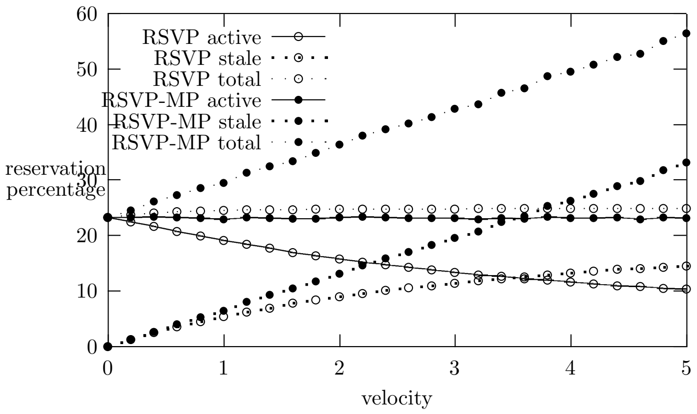

Fig. 8. Active and stale reservation percentage (1024 channels) in the internal interfaces of the edge router vs velocity ($\lambda = 0.2$)

stant and constrained by the link's bandwidth in the RSVP case. This leads to the phenomenon that the percentage of stale reservations increases as the users' velocity increases, whereas the active reservations face a continuous deterioration. In the RSVP-MP case, on the other hand, the full bandwidth in the link is utilized by active connections, while the stale reservations percentage is kept to zero.

The internal access network utilization with variable MHs' velocity is shown in Fig. 8. The under-utilization of the internal network is a first observation, since both protocols occupy only a fraction of the available bandwidth. In the RSVP case, a quarter of the total bandwidth for both types of reservations is occupied. In the RSVP-MP case, the number of active reservations is a constant quantity and constrained by the bandwidth limitation on the access-core link. Stale reservations inside the access network are allowed by the RSVP-MP architecture and their number increases linearly with the MHs velocity increase. Using the RSVP-MP architecture, the access-core link is always occupied with active reservations only, while stale reservations in the internal access network can increase, given the extraneous bandwidth available.

IV. Conclusions and Future Work

We have presented a scheme that for the efficient interoperation between Mobile IP and RSVP. Our main goal is to achieve this while keeping the required modifications on existing protocols and network components to a minimum.

Using a simulation model, we have demonstrated that with the introduction of RSVP-MP, the blocking probability in the link between the upstream ISP and the access network is greatly reduced, and stale reservations are avoided, leading to enhanced resource usage efficiency. Our scheme also reduces the period, during which, moving users experience QoS deterioration, by keeping the required signaling for the re-establishment of an end-to-end QoS supported session inside the access network. Finally, our scheme works without any modifications to network components other than the edge RSVP router.

We acknowledge that RSVP-MP should be developed in cooperation with any advances in hierarchical mobility management schemes. These schemes are still at a research stage, thus, major or minor modifications are expected. The enhanced functionality of RSVP-MP imposes also a complexity burden on the access network edge router.

In our future work, we consider the addition of multiple RSVP-MP edge routers in an access network to distribute the processing load . A hierarchy of RSVP-MPs and its applicability to current access networks will also be researched.

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