M-YESSIR: A Low Latency Reservation Protocol for Mobile-IP Networks

Hormuzd Khosravi, Daniel Reininger, Maximilian Ott, Manish Parashar

Abstract—**Advanced network and media applications such as multimedia streaming and Internet telephony are becoming an integral part of the Internet. Reservation protocols, such as RSVP have been defined, to provide the necessary Quality of Service (QoS) guarantees. A significant drawback of RSVP is its implementation complexity and high end-to-end reservation delay. Pan et. al. proposed a simpler reservation protocol, called YESSIR, which is sender-initiated and tightly integrated with RTP. This paper proposes an extension to YESSIR, called M-YESSIR, to cover the special needs of mobile applicatons.**

This paper describes the design of M-YESSIR and also provides an extensive comparison with other similar protocols. We also propose a Mobile Call Admission Control(M-CAC) scheme to preserve key M-RSVP functionality with lower protocol overhead. Experimental results of a prototype implementation are also presented.

Keywords—**Resource reservation protocol, YESSIR, Mobile IP, sender-initiated, mobile call admission control**

I. Introduction

Research efforts in the area of mobile computing have been focused on enabling mobile users seamless access to the Internet. There has been a lot of work on extending existing network and transport protocols so that applications are transparent to the mobility of hosts. The Mobile IP[2] specification by the IETF is an example of extending the IP protocol to mobile hosts.

Advanced network and media applications such as multimedia streaming and Internet telephony are becoming an important part of the Internet. Such applications require certain Quality of Service (QoS) guarantees from the network. In the Integrated Services model, QoS is achieved through resource reservation protocols such as RSVP[6]. There have also been several proposals for extending RSVP for mobile hosts in the Internet[8]. A significant drawback of RSVP is its implementation complexity and high end-to-end reservation delay.

This paper presents the design, implementation and performance evaluation of a low-latency resource reservation protocol for mobile networks. This reservation protocol is based on YESSIR[4]. YESSIR is a sender-oriented resource reservation protocol based on RTP, that offers significantly lower code and run-time complexity compared to RSVP. Results show that the main advantages of extending YESSIR for mobile networks is that, being in-band and sender oriented, its latency of reservation setups during handover can be significantly lower than for RSVP. Other design goals of the M-YESSIR protocol are to provide soft-QoS guarantees by inter-working with a mobile call admission control[9], and enhance reliability and robustness of the reservation mechanism by minimizing signaling complexity.

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The outline of the paper is as follows. In Section 2, we discuss the YESSIR protocol on which our work is based and other related protocols. In Section 3, we discuss the design objectives for M-YESSIR. Section 4 presents the protocol design and description. In Section 5, we present a protocol analysis and experimental results obtained. Finally, Section 6 summarizes key issues of our approach and gives directions for future work.

II. Background and Related Work

In this section, we first describe the YESSIR protocol. We then discuss two reservation protocols that have been proposed for Mobile-IP. Namely, an extension to RSVP and one using pre-configured RSVP tunnels.

A. YESSIR: Extending RTP to support QoS

The complexity concerns associated with the wide deployment of RSVP, coupled with the fact that a large fraction of continuous media applications are already based on RTP[1], motivated P. Pan and H. Schulzrinne to develop YESSIR[4], a simple reservation mechanism leveraging RTP's control mechanism.

YESSIR is an in-band, sender-oriented protocol based on RTP, with significantly lower code and run-time complexity. YESSIR and RSVP can operate side by side in the same network without effecting the guarantees offered to applications. The protocol relationships are shown in Figure 1. The YESSIR reservation messages are added to the RTCP sender report messages. In addition, the IP Router Alert option[5] is enabled for these messages.

The key features introduced by RSVP, such as robustness (using soft state to maintain reservation states), advertising network resource availability and resource sharing among multiple senders (using different reservation styles), are supported by YESSIR. YESSIR also extends the all-or-nothing reservation model to support partial reservations that improve over the duration of the session.

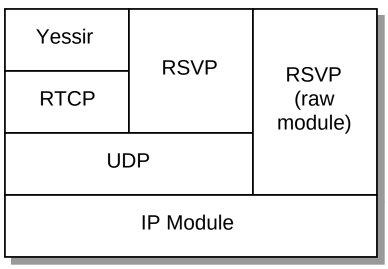

Fig. 1. Protocol Relationships.

B. MRSVP : Mobility support for RSVP

MRSVP[8] extend the signaling capabilities of RSVP to enable advanced resource reservation. MRSVP introduces the concept of active and passive reservations. A mobile host makes an active reservation for its current location and passive reservations for all other locations listed in its Mspec. MRSVP extends the PATH and RESV messages of RSVP by adding Active and Passive types to these messages to distinguish active and passive reservations. On a link, active and passive reservations for a flow are merged. To improve link utilization, bandwidth of passive reservations of a flow may be used by other flows requiring weaker QoS guarantees. However, when a passive reservation becomes active, these flows may be affected.

In MRSVP, the mobile host uses proxy agents to make reservations on its behalf along the currently passive paths defined in the Mspec. Thus MRSVP further increases the complexity of RSVP by adding new messages and extending the functionality to support advance reservations. Also the assumption that the mobile host can accurately determine its Mspec, on which this protocol is based, may not be applicable for many mobile applications.

C. Simple RSVP based Protocol for Mobile Hosts

The protocol described in [7] combines pre-provisioned RSVP Tunnels with Mobile IP. It strives to minimize the changes neccessary to to RSVP, while minimizing service disruption during handover. The protocol proposes the addition of a Q-bit to the Agent Discovery and Registration requests used in Mobile IP to indicate whether the care-of-address can handle QoS requests.

When a receiver changes its location, the Home Agent(HA) initiates a RSVP ”tunnel” session between itself and the Foreign Agent(FA), if one does not already exist. In case the mobile is a sender, it initiates a reverse tunnel[3] from the FA to HA. For the multicast scenario no changes are required to the reservation protocol.

The protocol proposes the use of pre-configured tunnels between the Home Agent and the Foreign Agent to reduce the latency of reservation setup during handover. However, this could easily lead to over provisioning of valuable resources.

III. M-YESSIR: Design Objectives

In this section we describe the main design principles on which the M-YESSIR protocol is based. They are as follows :

Minimal service disruption during Handover. Obviously, this is a key requirement for any reservation protocol. We are considering two important factors, availability of resources, and latency in establishing the reservation along the new path.

Support for Soft-QoS guarantees. As hard QoS guarantees are difficult to provide over wireless channels, soft-QoS principles provide a meaningful compromise. Especially for application frameworks that can adapt to changes in resource availability[12].

Minimum changes to YESSIR. M-YESSIR is an extension of YESSIR and changes to the base protocol should be kept to a minimum.

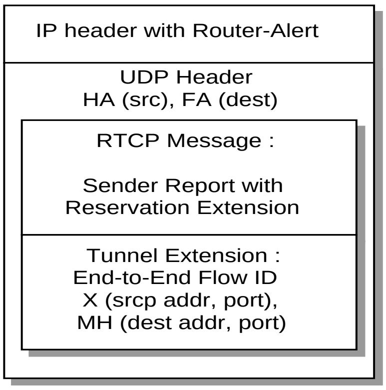

Fig. 2. Reservation SetUp Message Format.

Keep important YESSIR features. Features of YESSIR, such as sender-initiated reservation, low protocol and processing overhead should be maintained. Newly added functionality should not change the characteristics of the base protocol.

Decouple protocol from algorithms. Decoupling the reservation protocol from the bandwidth management algorithm will reduce implementation complexity and future-proof the protocol.

IV. M-YESSIR: Protocol Description

In this section, we describe the proposed modifications to Mobile IP and YESSIR. We also describe the Mobile Call Admission Control (M-CAC) scheme used along with the proposed Flow Specification.

A. Modification to Mobile IP

Similar to the modifications proposed in [7], we require two small additions to the Mobile IP[2] protocol for detecting QoS support in a heterogeneous environment.

As part of the Agent Discovery mechanism, base stations advertise their capabilities to mobile hosts by sending Agent Advertisement messages. We propose a Q bit in the Advertisement message to add QoS support to the capability list. When the mobile host moves to a new cell, it can learn if the new agent supports QoS reservations and accordingly inform the other end.

As in the case of Agent Discovery, we have added a Q bit in the Registration Requests which signifies that the care-of-address can handle QoS requests and therefore the Home Agent should forward them.

B. Reservation Set-Up Over IP Tunnel

Identical to YESSIR, the reservation setup takes place by adding a reservation request to the RTCP Sender Report (SR). To extend the reservation to the IP tunnel between the Home Agent(HA) and the Foreign Agent(FA), or the mobile host (in case of co-located address), we use a mechanism similar to that proposed for RSVP over IP tunnels[7].

The end-to-end session reservation is converted to a ”tunnel” reservation over the IP tunnel between the HA and the FA or mobile. Inside the tunnel, the data packets are UDP encapsulated at the HA with the HA address and care-of-address as the source and destination address, respectively. A unique source

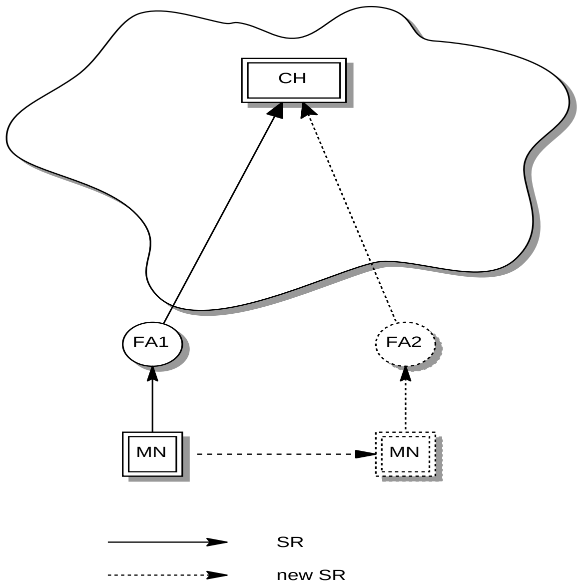

Fig. 3. Reservation Messages during Handover: Mobile is Sender

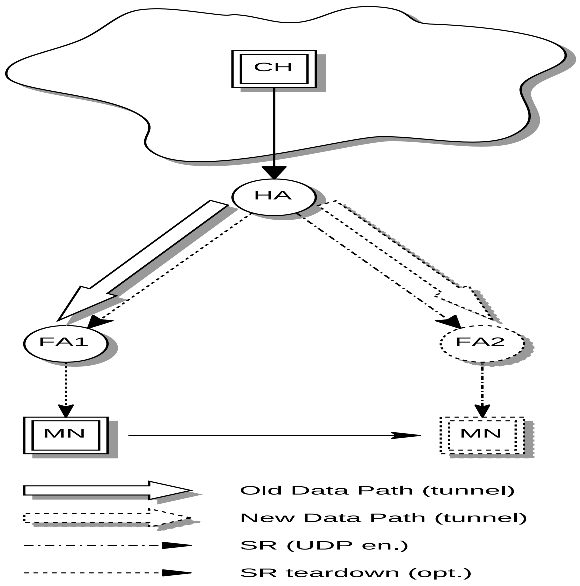

Fig. 4. Reservation Messages during Handover : When Mobile is Receiver

port number not only support de-muxing at the FA or tunnel exit point, but also allows the intermediate routers to distinguish the individual flows inside the tunnel.

The IP and UDP headers of the control packets (SR) are replaced with new headers containing the HA address and care-of-address as the source and destination address, respectively. Following the RTP convention, the port number is adjacent to the tunneled data stream. This allows the YESSIR reservation daemons on the intermediate routers to function correctly without any changes.

A ”tunnel extension” is appended to the SR containing the Flow Id of the end-to-end session allowing the tunnel end point to reconstruct the data flow. The message format of the tunneled SR is shown in Figure 2.

C. Reservation for Unicast Flows during Handover

We consider two scenarios for handover.

C.1 The mobile host is a Sender

In the scenario shown in Figure 3, the mobile host will send a SR message along the new path to initiate the reservation setup. The reservation along the old path could either be timed out, or an explicit cancellation message could be sent to the previous Foreign Agent(FA). This explicit cancellation message could be a RTCP BYE packet sent to the previous FA with the Router Alert option set[1]. This packet needs to be consumed by the old FA as the end host would terminate the RTP session when receiving a BYE packet. While immediate reservation cancellation clearly improves resource utilization, bending the semantics of the BYE message is problematic to say the least.

C.2 The mobile host is a Receiver

In the scenario shown in Figure 4, the mobile's Home Agent(HA) will send a reservation message along the new path whenever a mobile host registers a new care-of-address with the Q-bit set in the registration request. The use of the HA to setup the reservation along the new path reduces the path along which the reservation needs to be re-established.

The reservation message that the HA sends to setup the reservation along the new path is similar to that described in IV-B except that all the fields of the SR, other than the reservation extensions, are null. The ”tunnel extension” will contain a Flag to indicate that the SR must be dropped at the tunnel exit point and not forwarded to the RTP daemon running on the mobile. This approach does not require any changes in the YESSIR reservation daemon running on the intermediate routers nor does it require any changes in the end host RTP module.

The HA could optionally send an explicit cancellation message in the form of a Sender Report with ”reservation teardown” flag set to the previous FA to remove the old tunnel reservation. Again this packet should be discarded by the previous FA and not forwarded to the HA.

D. Reservation for Multicast Flows

We consider the two roles a mobile host can play in a multicast session. A similar analysis was also carried out in [7].

D.1 The Mobile Host is a Sender

As in the unicast case, a mobile host that is acting as a sender to a multicast group has two different options. It can either send packets using usual routing at the foreign subnet or it could reverse tunnel its packets back to its home network. Depending on the choice of forwarding, the reservation is done in the same way as described for the unicast scenario.

D.2 The mobile host is a Receiver

A mobile host that wishes to receive multicast packets has to register via IGMP[14] messages. It can either do so via a multicast router on the foreign subnet or it may join groups via

[1] The Flow Id (address of mobile) is implicitly contained in the UDP header of the BYE packet.

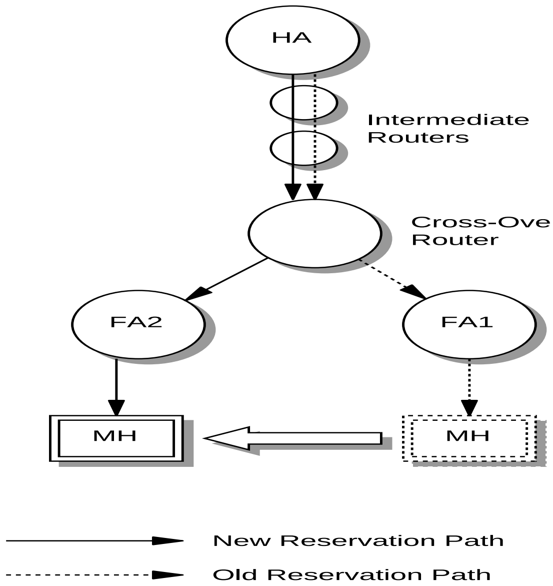

Fig. 5. Reservation paths during Handover: Mobile is a Receiver.

bidirectional tunnel [2] to its Home Agent. In the first case, existing reservations should get rerouted over the new path. In the second case, the HA would receive the multicast packets on the mobile's behalf and encapsulate them and deliver them to FA which would send it to the mobile. The reservation would be done in the same way as described in the unicast case.

E. Flow Specification

We are proposing a FlowSpec that includes the maximum and minimum bandwidth requirement of the application. These requirements would reflect the adaptiveness of the application to changes in the bandwidth. The Call Admission Control (CAC) scheme would make a decision on bandwidth allocation based on the available bandwidth and the individual flows' FlowSpec reservation. A similar FlowSpec definition has also been used in INSIGNIA[11] which supports QoS in mobile ad-hoc networks.

F. Mobile Call Admission Control

A significant drawback of the MRSVP protocol is the complexity that results from integrating the reservation protocol with bandwidth management. Our approach to support QoS in the mobile scenario is to decouple the two functionalities by providing clean and comprehensive interfaces.

The provision of quality-of-service (QoS) for mobile multimedia applications requires a certain level of continuity in resource availability along a terminal's path. Given the difficulties in predicting a terminal's path, and that multimedia traffic is non-stationary, an efficient method for admission and bandwidth allocation is needed to meet consistent QoS expectations during a session. In [9], we describe a mobile call admission control algorithm (M-CAC) for mobile multimedia terminals roaming within coverage areas consisting of multiple microcells. The method targets consistent soft-QoS for admitted connections with high utilization of radio resources, exploiting both temporal and spatial statistical multiplexing that maintains soft-QoS[10] and high utilization of radio resources leading to reduced service blocking probability.

G. Optimization

During the reservation handoff procedures described in IV-C, two separate reservation pipes are setup for a short period of time for the same flow as shown in Figure 5. An optimization could be done if the reservation is performed based on a global Flow ID rather than the source and destination address. The global Flow ID can be the 4-byte RTP synchronization source identifier (SSRC)[3]. This ID should be able to uniquely identify a flow independent of the mobile's current location. In case of the mobile receiver, reservation requests towards the new FA should result in an update of the state in routers where it already exists for this flow. New state will be created only in routers that previously did not have the flow state, typically only from the "crossover point" i.e. the point at which the flow has to diverge to go to the new FA. The crossover point would be closer to the current and new Foreign Agents, implying that the new state information needs to be setup only in a few routers. Thus it would reduce over provisioning of resources and also improve the chances of the reservation being successful over the new path.

V. Protocol Analysis and Experimental Results

In this section, we compare the overhead of our protocol with other protocols such as MRSVP[8], and RSVP over Mobile IP[7]. We also describe the experimental results obtained from our prototype implementation.

A. Protocol Overhead

The protocol messages generated in events of reservation establishment and handoff (for the unicast case when the mobile is the receiver) have been compared in Tables I & II for M-YESSIR, RSVP over Mobile IP and MRSVP. 'M' denotes the number of proxy agents the mobile host discovers according to its mobility specification in case of MRSVP. We do not consider the overhead of the "Proxy Discovery Protocol" in case of MRSVP.

In Table I, in case of RSVP, the messages generated during reservation establishment are considered for the case when the tunnel reservations are dynamically created between the Home Agent and Foreign Agent for an end-to-end session and not preconfigured. In case of MRSVP, the JoinGroup and Spec messages are sent by the mobile receiver to the proxy agents (assuming they are the same as Foreign Agents) and the MSpec message is sent to the Home Agent. In Table II, in case of MRSVP the messages generated are for turning the old reservation to passive mode and the new reservation to active mode. In case of RSVP, we have again considered the case without a pre-configured tunnel reservation. In case of M-YESSIR, the SRtd (teardown) message is optional.

From Tables I & II we can see that the protocol overhead for M-YESSIR is less than that for MRSVP or RSVP in case of

[2]The mobile host tunnels IGMP messages to its HA which in turn forwards multicast datagrams down the tunnel to the mobile host.

[3]Even though the SSRC is only unique within each RTP session, the probability of duplication is low. Using the SSRC would also reduce the state maintenance overhead in the routers.

TABLE I
PROTOCOL OVERHEAD FOR RESERVATION ESTABLISHMENT.

Protocol	CH↔HA	HA↔FA(s)	FA(s)↔MH
M-YESSIR (receiver)	SR	SR(UDPen)	SR
RSVP (receiver)	PATH +RESV	PATH +RESV(tunl)	PATH +RESV
M-RSVP (receiver)	PATH +RESV	MSpec +PATHac +RESVac +M∗(PATHpa +RESVpa)	MSpec +Spec +JoinGroup +PATH +RESV

TABLE II
PROTOCOL OVERHEAD FOR RESERVATION HANDOVER.

Protocol	HA↔FA(s)	FA(s)↔MH
M-YESSIR (receiver)	SR(UDPen) +SRtd(opt.)	
RSVP (receiver)	PATH+RESV(tunl) +RESVConf	PATH+RESV
M-RSVP (receiver)	RESVac+RESVpa	RESV

reservation establishment and handoff. A similar analysis can also be done for the case when the mobile is a sender.

B. Experimental Evaluation of M-YESSIR Protocol

We implemented both the YESSIR and M-YESSIR protocols to obtain a direct measure of the processing overhead at the router and to compare the additional overhead of the M-YESSIR extensions. The experimental evaluation of M-YESSIR protocol consisted of two parts. In the first part, the processing overhead for a YESSIR setup message (first message) and the overhead of the following refresh messages was calculated at the router. In the second part, the processing overhead to trigger a M-YESSIR message with tunnel extension at the Home Agent (router) and the overhead to process and tunnel the following refresh messages was calculated.

The experimental testbed for testing M-YESSIR consisted of

TABLE III
PROCESSING OVERHEAD FOR YESSIR SETUP MESSAGE

Code Section	Time (μs)	%
YESSIR entry creation & Update	160±5	42%
Network Interface query	91±5	24%
CAC Response Time	61±5	16%
Forward YESSIR downstream	68±5	18%
Single YESSIR flow setup overhead	380±20	100%

TABLE IV
PROCESSING OVERHEAD AT HOME AGENT TO TRIGGER M-YESSIR MESSAGE

Code Section	Time (μs)	%
YESSIR entry look-up	75±5	34%
Create M-YESSIR message	75±5	34%
Forward YESSIR downstream	70±5	32%
Single M-YESSIR trigger message overhead	220±15	100%

TABLE V
PROCESSING OVERHEAD FOR YESSIR AND M-YESSIR REFRESH MESSAGE

Code Section	Time (μs)	%
YESSIR entry look-up & Update	150±5	62.5%
Forward YESSIR downstream	70±5	29.5%
Single YESSIR flow refresh overhead	220±10	92%
Additional Mobility overhead	20±5	8%
Single M-YESSIR flow refresh overhead	240±15	100%

PCs running Linux (kernel version 2.2.2) that were configured as routers. The router PCs contained Intel Pentium II processors clocked at 450 MHz. The processing times were calculated using the "gettimeofday" linux system call. The application scenario consists of a home-grown video server[12] sending video through an RTP connection to an MpegTV based client.

The results for the first part have been shown in Tables III & V. The processing time for the YESSIR refresh messages is about 42% less than for the YESSIR setup message. This can be attributed to the fact that about 40% of the processing time for the setup message is attributed to the Network Interface Query and CAC response time. This is not the case for the refresh messages[4].

In the second part, the functionality of M-YESSIR at the Home Agent and Foreign Agent was tested. The M-YESSIR reservation daemon executing on the Home Agent can trigger a M-YESSIR message with a tunnel extension when it received a Mobile IP Registration message with the Q-bit set[5].

The results for the second part have been shown in Tables IV & V. As can be seen, the overhead of tunneling the M-YESSIR refresh messages is about 9%. Also the overhead for triggering a M-YESSIR message at the Home Agent when the mobile registers with a new Foreign Agent is about the same as that of a refresh message and thus less than that of the setup message. Thus we can conclude that the extensions to YESSIR for Mobile IP support have added a very small processing overhead to the base protocol.

[4] The CAC was running as part of the same process as the Reservation Daemon.

[5] The Mobile IP code in the kernel was not modified to support UDP encapsulation. This was done by a daemon running in user space.

VI. Summary and Future Work

This paper presented the design, implementation and evaluation of the M-YESSIR protocol. M-YESSIR extends the YESSIR protocol to support Mobile-IP. The M-YESSIR protocol has the advantage of lower control message processing time because of sender initiated reservations and thus reduced latency of reservation set-up during handover in mobile scenarios. Additional design goals included support for Soft-QoS[10] guarantees and keeping the changes to the YESSIR protocol at the end hosts and also at the routers to a minimum. The reliability and robustness of the protocol is also improved by reducing the control messages generated for setting up reservations and by using soft state at the routers.

Decoupling the bandwidth management algorithm from the reservation protocol has helped in keeping the protocol simple. In addition, using the M-CAC[9] has helped in preserving the key functionality proposed in MRSVP. Optimizations, such as the use of the 4-byte RTP synchronization source identifier (SSRC) as an alternative generic Flow ID, not only reduce the latency of reservation setup during handover but also increases the probability of full resource availability along the new path. The results from the experimental evaluation of the M-YESSIR prototype show that the mobility extensions add little processing overhead.

While sender-initiated protocols may not have the massive scalability properties of receiver-initiated protocols, the simplicity of M-YESSIR makes it an attractive alternative for many of today's mobile application scenarios.

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