Resource Reservation Protocol for Mobile Satellite Communication

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Abstract

The *Internet Engineering Task Force* is working on extending the traditional TCP/IP model for supporting multimedia and real-time applications on the Internet. Thus, new protocols have been developed such as the *Resource Reservation Protocol*. With the rapid growth of mobile networks, the IETF is also working on creating and extending the existing protocols to support mobile users. This has led to the development of Mobile IP. At the same time, there has been a growing interest in using *Low Earth Orbit (LEO)* satellites. LEO satellites are well suited to providing services to mobile users. In the near future, mobile users will be able to access multimedia and real-time applications, so the new TCP/IP with real-time and mobile support will be needed to work over LEO satellite networks. This paper surveys the networking issues related to RSVP over (mobile) LEO satellite networks. It also describes different approaches for extending RSVP for supporting mobile satellite users.

Keywords: Resource Reservation Protocol (RSVP), receiver-oriented paradigm, soft-state, Mobile IP, Low Earth Orbit (LEO) Satellites.

1. Introduction

Communication satellites may be categorised according to their orbit [6] into *Geostationary (GEO)* and *Non-Geostationary Earth Orbit (NGSO) satellites*. GEO satellites orbit at the same angular speed of the earth and hence their coverage of the earth (the footprint) is constant over time. The disadvantage is the quarter of a second round trip delay. An alternative is to use a NGSO satellite such as a *Low Earth Orbit (LEO) satellite,* where the delay is greatly reduced, but the satellite's footprint is constantly moving across the earth. LEO satellites are deployed in circular or elliptical orbits at altitudes of 500-2000 Km.

Today, there are several projects [5, 8, 15] for using LEO satellites for a wider range of applications - from low-bit-rate applications such as store-and-forward messages to high-bit-rate applications such as multimedia and real-time services. LEO satellites are well suited to providing services to mobile users. In the near future, mobile satellite users will be able to access multimedia and real-time applications over the Internet[1].

The *Resource Reservation Protocol (RSVP)* is a proposal of the IETF for setting up reservation state information for data flows along the communication paths [3,14]. It is intended to support real-time and multimedia applications, which require some *Quality of Service (QoS)* guarantees from the network.

In this paper, different networking issues related to RSVP in mobile LEO satellite networks will be examined. Since RSVP was developed for working over fixed networks, there are

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[1] See Teledesic project at *http://www.teledesic.com/*.

some problems which arise from incorporating user mobility. However, there are several options for solving these problems. In this paper, several proposed approaches are classified according to different options.

This paper is organised as follows. Section two presents an overview of RSVP. In section three, a description of the routing extension for Internet mobile users is outlined. The options and issues for RSVP over Mobile Satellite Networks are described in section four. Section five outlines the approaches for overcoming the problems described in section four. Finally, section six concludes this paper.

2. RSVP Overview

The RSVP is a signalling protocol developed to create and maintain reservation state information within routers along communication paths [3,14]. The main characteristics of RSVP are summarised as follows:

- **Flow oriented:** RSVP reserves resources on a flow basis. A flow is a sequence of packets flowing between a source and one or more destinations. It may be defined by the source and destination ports, IP source and destination addresses, and priority and flow label field in the IPv6 header.
- **Receiver orientation:** receiver initiates resource reservation in an attempt to reserve appropriate resources.
- **Soft-state allocation:** reservations along communication paths are considered non permanent, so they must be refreshed periodically.

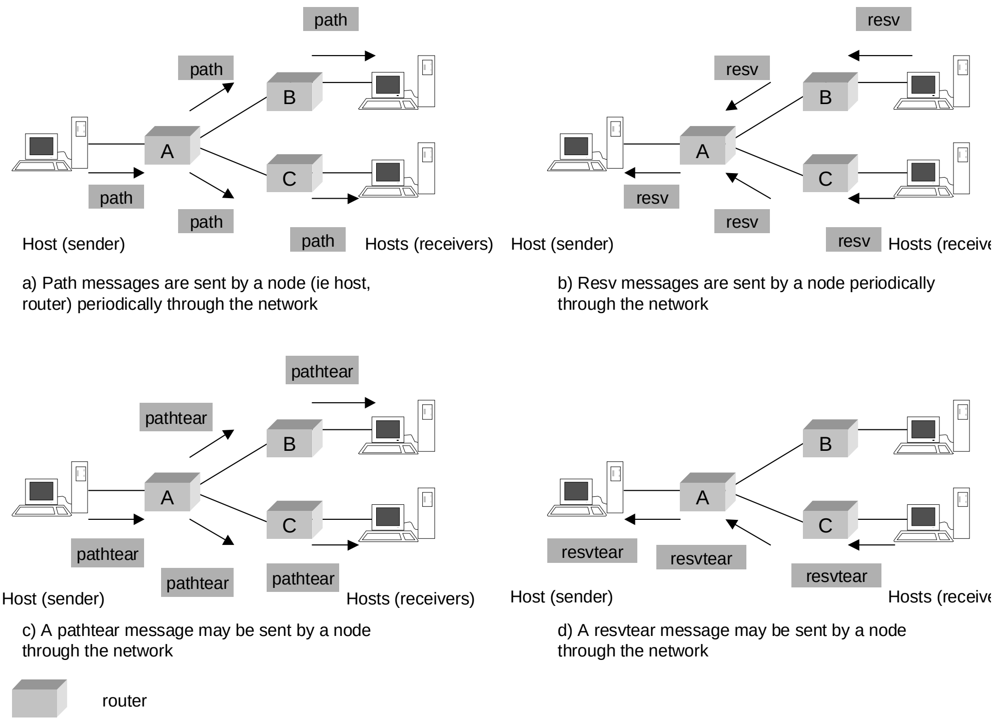

Figure 1: RSVP message flows.

- **Unidirectional:** RSVP reserves resources in one direction (i.e. data flow direction).
- **Support of multicast session:** resources may be reserved for both unicast and multicast applications.

2.1 RSVP Operation

A sequence of packets with a particular destination and transport layer is considered a *session* [3], so it may include several data flows. RSVP treats each session independently. Figure 1 shows several RSVP message flows. The receivers are members of the same multicast group[2].

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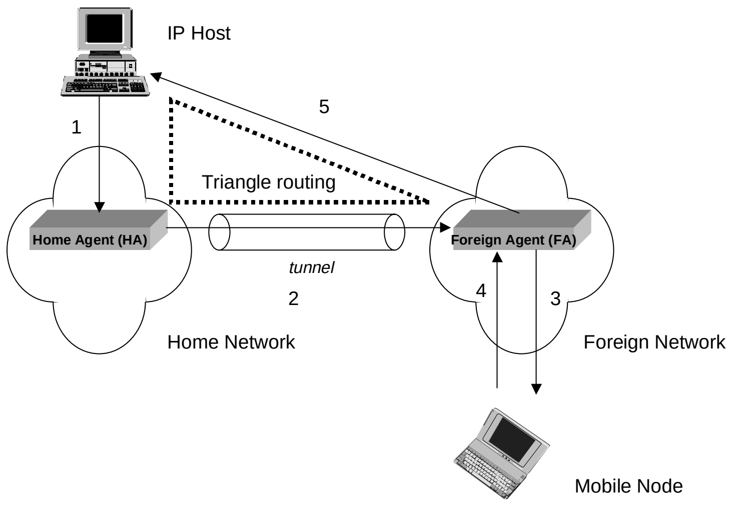
[2] A multicast group may be defined as a set of hosts identified by the same IP destination address.

A sender, which participates in a RSVP session, sends *Path messages* periodically (fig. 1(a)) to the receiver(s). A path message creates and maintains path state information (eg the IP address of the previous node) in each node along the communication path. Once a receiver receives the first path message, it may initiate sending *Resv messages* upstream to the senders (fig. 1(b)). The *Resv message* creates and maintains reservation state information (eg bandwidth, buffers) in each node along the route.

Both reservation and path states only exist for a predefined period of time (the *cleanup timeout interval*), so if they are not refreshed (by sending periodic resv and path messages, respectively), they will be cancelled. An end system or a router may trigger teardown requests to accelerate the removal of path and reservation states when the route changes or the application is finished. Teardown requests may be also generated if no refresh message arrives before the expiration of the cleanup timeout interval. *PathTear messages* travel downstream to the destinations and delete path state and all dependent reservation states along the route (fig. 1(c)). *ResvTear messages* delete reservation states and travel upstream from the point of initiation (fig. 1(d)). Error handling messages and procedures are also defined by RSVP [3]

3. Mobile IP

The IETF has worked on extending the original IP protocol for routing IP packets to mobile nodes in the Internet [9, 12]. This paper will refer collectively to these extensions as *Mobile IP*. Mobile IP operation is shown in figure 2. A *mobile node* (host or router) may connect to the network from different points using its long-term constant IP address (*home address*). The



1: IP host sends a packet to HA
2: HA tunnels the packet at the care-of-address(eg FA's address)
3: FA sends the packet to the mobile node
4: The mobile host sends a packet to FA
5: FA sends the packet to IP host

Figure 2: Mobile IP packet flow.

mobile node must be registered in the *home network*. A *home agent* which resides in a home network serves one or more mobile nodes. The home agent maintains the current location of the mobile nodes which it serves. When the mobile user moves to another network, called the *foreign network*, it obtains a temporary address, called the *care-of-address*. The mobile user must register its care-of-address with its home agent, possibly through a foreign agent [12].

The home agent will intercept the IP packets sent to a mobile address (fig. 2, step 1), which is away from the home network. In turn, the home agent will send the IP packet to the foreign agent using the care-of-address as the destination address. The home agent *tunnels* all the packets sent to its care-of-address (step 2). *Tunnelling* [12] is the forwarding mechanism for routing packets from the home agent to the foreign agent. Thus, IP packets are encapsulated by the home agent which acts as the initiation point of the tunnel, and are decapsulated by the foreign agent which is the termination point of the tunnel. Indeed, IP packets seem to travel along a tunnel. Several encapsulation techniques have been proposed [12] such as IP-within-IP (default one) [10] and minimal encapsulation [11]. After decapsulating the packet, the foreign agent sends it to the mobile user (step 3). In the reverse direction, packets sent by the mobile user are delivered to the destination point using standard IP routing mechanisms (steps 4,5).

Since all the packets destined to a mobile node are routed through its home agent, and packets from the mobile node to an Internet node are routed directly to their destination, it is referred to as *triangle routing*.

4. Networking Issues of RSVP for Mobile LEO Satellite Communication

This section presents the main networking issues related to RSVP over (mobile) LEO satellites.

4.1 Receiver orientation

RSVP's receiver orientation is particularly favourable for mobile satellite networks, since mobile users may adapt their reservation requests to the different possible heterogeneous environments they visit. For example, a mobile user may move from a slower satellite network which limits the data rate to 16 kbps to a faster satellite network providing a data rate of 64 kbps.

The main disadvantage is that there may be a long path setup delay. Firstly, refresh path messages will arrive at the new foreign network via the home agent, which may be far from the optimal [12], such as when the mobile node is very close to the correspondent node. Secondly, a sender host will send a refresh path message only after a refresh time out has expired (default 30 sec.).

4.2 Soft Reservation States

RSVP uses the notion of soft state allocation (section 2). Therefore, user reservations are adapted automatically to topology and routing changes. Since reserved resources may be freed some time after a user has moved to another cell, users requiring new reservations may use those resources. Thus, RSVP's procedure are well suited to catering for mobility.

However, refresh messages, which are generated to maintain reservation states, increase resource consumption. In addition, RSVP relies on periodic refresh messages from nodes to maintain current reservations and handle possible loss of packets. Satellite transmission links introduce multiple bit errors, which may be caused by noise, intermittent connectivity, and interference. Multiple bit errors may cause packet loss. If successive Resv messages are lost, some useful resources could be released, and hence real-time communication could be interrupted. Also, RSVP teardown messages accelerate the removal of reservation states. If they are lost, resources will not be freed for a longer period than is necessary.

Problem (section)	Proposed approach (section)
Long path setup delay (4.1)	Route optimisation (5.5) Staged refresh (5.2)
Refresh messages (4.2)	Error Control and channel coding schemes (5.2) Staged Refresh (5.2) Dynamic reservation, fixed reservation, or middle approach (5.1)
Size of RSVP messages (4.3)	Header compression (5.3)
RSVP/Mobile IP integration: tunneling (4.4)	RSVP operation over IP tunnels (5.4)
RSVP/Mobile IP integration: triangle route (4.1,4.4)	Route optimisation (5.5)

Table 1: Problems of RSVP over mobile satellite networks and their proposed solutions.

4.3 Size of RSVP messages

RSVP messages are encapsulated in IP packets. There is substantial bit overhead associated with the IP protocol [4]. Long packet sizes may result in data loss, long transmission delays, and high link capacity consumption.

4.4 RSVP/Mobile IP Integration

Some problems arise when integrating RSVP and Mobile IP. Firstly, since IP packets are tunnelled, intermediate nodes along a tunnel will not be able to process RSVP messages [13]. Secondly, as mentioned before, triangle route may be far from the optimal [12].

5. Approaches for supporting RSVP over LEO satellite networks

Solutions of the problems, which arise from using RSVP in mobile satellite environments, have been proposed [1,2]. Most of them are also applicable for other wireless communication systems. Table 1 summarises these problems and the possible approaches which may solve one or more of them.

5.1 Reservations

Several authors [1,2] have proposed mechanisms to deal with reservations over mobile networks. The approaches may be classified as dynamic reservation, fixed reservation, and an approach that lies in between these two extremes known as middle approach.

5.1.1 Dynamic Reservation

A mobile user will send a refresh reservation request any time it enters to a new cell. The user may adapt the reservation request to the new environment. This approach does not require any changes to the RSVP specification more than the ones related to RSVP over IP tunnelling (see section 5.4).

Dynamic reservation includes some disadvantages. For example, there may be a long path setup delay as outlined in section 4.1. Also, there is the burden associated with the reservation requests sent any time the mobile changes its position. In addition, network resources required by the mobile user at the new location may not be available.

5.1.2 Middle Approach

Under the middle approach, network resources may be pre-reserved within an area (eg neighbourhood area, determined group of cells) on a pre-emptive basis. Network resources pre-reserved for a user which no longer uses them (eg. because the user has moved to

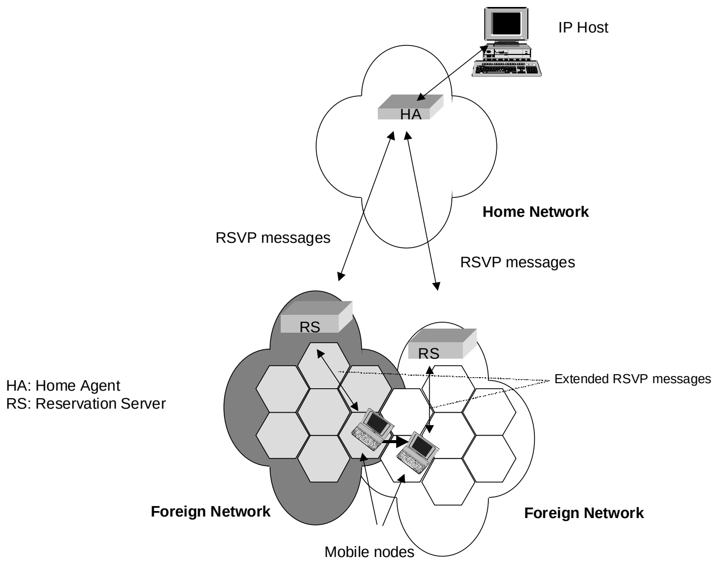


Figure 3: Reservation Servers in a Mobile IP network.

another cell) may be temporarily assigned to another user. However, if the user requires its pre-reserved resources, it may obtain them.

Resources may be reserved within the cells, which the user will more likely visit. So, some user location estimations are required. For example, Awduche et al [2] propose a mobility prediction mechanism based on the sequence of cells which have been visited by the mobile user for whom the resources have been or will be reserved. Also, resources may be allocated over pre-established fixed areas.

RSVP makes reservations which take effect immediately. In addition, all reservations must be processed by the receivers. With RSVP, applications must also run the entire time the reservation is active. Under the middle approach, reservations need to be set up in advance.

In order to support advanced reservation, a reservation server may act on behalf of the mobile clients as shown in figure 3. A server may serve mobile nodes on a determined area. It will receive path messages from the sender, and in turn send resv messages to the sender. They will include the mobile user's QoS requirements. Servers and mobile users may exchange RSVP messages. However, RSVP may be extended to support pre-reserved resources. For example, in order to allocate temporal pre-reserved resources to other mobile users, a server needs to communicate with the client by using some kind of temporal path and reservation messages as proposed in [2].

5.1.3 Fixed Reservation

Network resources may be pre-allocated in cells within a neighbourhood area for a fixed permanent period of time. As explained for the middle approach, RSVP may be extended to support advanced reservations, and some centralised servers may be used for advance reservation setup.

5.2 Multiple bit errors

Approaches for dealing with the multiple bit errors on satellite links are summarised as follows:

a. RSVP messages are sent without any delivery guarantee using IP. A number of advanced error correction and channel coding schemes have been developed. They work at the physical layer and may improve the error performance of satellite links [6] and hence minimise the error rate.

b. RSVP may be extended to deal with possible message loss. For example, Pan et al [7] propose RSVP extensions to deliver messages more reliably over lossy networks. They are based on staged refresh timers and echo request and replies. The latter acts as acknowledgments of RSVP messages. While waiting for a RSVP echo message reply, the sender will send the RSVP message every certain period of time (staged refresh interval). Unlike the current specification of RSVP where the refresh timers are fixed, a staged refresh interval may change dynamically. Pan et al [7] compare the RSVP message loss probability using both fixed refresh and staged refresh timers. The results show than staged refresh mechanism reduces the RSVP message loss probability.

5.3 Header Compression

The objective of header compression is to reduce packet overhead, allowing smaller packets to be used for delay sensitive low data-rate traffic, improving interactive response time, and reducing packet loss rate.

Header compression is based on the analysis of packet header fields (e.g. TCP/UDP/IP header). The header fields belonging to the same packet flow may be classified according to how they are expected to change. If the value of a field does not change or seldom changes or may be inferred from other values, it does not need to be transmitted. Otherwise, if the field changes with small values, the packet may only include the change from the previous value. If the field changes randomly, it must be included in the compressed header. Thus, a packet with a full header is only sent occasionally. The following packets, belonging to the same flow, will be transmitted as compressed header packets. Degermark et al [4] describe in more detail a TCP/UDP/IP header compression method. A similar mechanism may be applied to the RSVP header.

5.4 Tunnelling

The RSVP Work Group (WG) has proposed a mechanism for RSVP operation over IP Tunnels [13]. RSVP sessions are classified as *end-to-end* and *tunnel*. The former is the original RSVP session existing between one or more senders and one or more mobile users. The second is defined in order to allow RSVP to operate over IP tunnels. It exists between the entry and exit point of the tunnel and is defined as a simple unicast fixed-filter[3] RSVP session. *Path and Resv tunnel messages* flow between the end-points of the tunnel. They create and maintain path and reservation information, respectively, along the tunnel.

End-to-end session parameters must be mapped end-to-end into tunnel sessions. Either an end-to-end session may be mapped into an existing tunnel RSVP session or a new RSVP session may be created for each end-to-end session. In both cases, a new RSVP object[4] may be attached to the end-to-end path message [13]. The object will have the necessary information to bind the end-to-end session and tunnel session. Another option is to create a new RSVP message which will include binding information.

[3] Under the fixed-filter option, each sender in the same session will obtain a different resource reservation. This reservation will not be shared with any other sender [3].
[4] A RSVP message body consists of a number of variable-length "objects" [3].

Although RSVP will operate over mobile IP networks using tunnelling, there is an increase in network traffic due to the number of RSVP tunnel messages. Also, RSVP packets may need to carry additional binding information.

5.5 Route Optimisation

Route optimisation is a proposal to eliminate the triangle routing problem [12]. The basic idea underlying route optimisation is that the host node (fig. 2) sends encapsulated packets directly to the care-of-address of the mobile node, so the packets do not need to be intercepted by the home agent. Route optimisation is based on providing mobility binding information (eg care-of-address of mobile nodes) to correspondent nodes (eg host nodes).

A home agent may send a *binding update* which includes the care-of-address of the mobile node to the correspondent node. For example, a home agent may send a binding update after intercepting a packet addressed to the mobile node. The home agent may request *a binding acknowledge* from the recipient of the binding update. In addition, a *binding warning* may be sent to the home agent indicating that a host node may benefit from a care-of-address. The host node may also send a *binding request* to the home agent to obtain the care-of-address.

A problem could arise if the packet addressed to a mobile node is dropped because the node had moved to another cell. To overcome this problem, the current foreign node may register the care-of-address of the mobile node with the previous foreign node. If a foreign node received a packet addressed to a node which had left the network, it may encapsulate it and send it to the current care-of-address.

6. Conclusions

Some of RSVP's features are beneficial in mobile LEO satellite networks. For example, the mobile user may adapt reservations to different environments, user reservations may be adapted automatically to routing changes due to user mobility, and reserved resources may be removed automatically after the user has left the network.

However, there are some limitations of RSVP over mobile networks. For instance, there may be a long path setup latency due to the existing triangle route and refresh time out interval, RSVP messages may be lost because LEO satellites may delay reservation setup or resources removal, and RSVP messages are encapsulated, preventing them being be processed by intermediate nodes.

Some ways of mitigating these limitations have been outlined. Future work may consider integration of these solutions into an Internet Mobile Network with real-time and multimedia support.

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