# Mobile Extensions to RSVP

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**Abstract**

*RSVP is a receiver oriented resource reservation setup protocol targeted for Integrated Services Packet Networks (ISPNs). RSVP has a number of desireable attributes which make it a leading candidate for Internet standardization. These attributes include flexibility, robustness, and scalability. However, RSVP does not adequately address the issue of resource reservation for mobile hosts. This paper highlights the limitations of RSVP in mobile environments and proposes extensions to obviate these deficiencies. The basic characteristics of the proposed augmentations include: (1) quiescent resource reservations, (2) virtual receivers, (3) intelligent pre-allocation of resources based on analysis of user mobility patterns, and (4) predictive lookahead dynamic dormant multicast trees.*

## 1 Introduction

Resource reservation is essential for Quality of Service provisioning in Integrated Services Packet Networks (ISPNs). Because conventional Internet protocols are best effort, offering limited service guarantees to network clients, a number of resource reservation setup protocols have been proposed to remedy this deficiency [4, 6, 10, 15, 18]. Amongst these, RSVP has attracted significant attention in recent times because of its desirable attributes [4, 18]. RSVP is a receiver oriented protocol which satisfies the fundamental requirements for good reservation protocols, namely [6, 18] (1) suitability for multicast sessions, (2) support for heterogeneous receivers, (3) flexibility, (4) robustness, (5) scalability, and (6) support for service preemption. RSVP also incorporates a set of reservation styles that determine how multiple reservation requests from a given multicast group are coalesced at intermediate switches.

Despite its positive attributes, RSVP appears biased towards static networks infrastructures and does not adequately address networking scenarios with mobile hosts. Given the prevalence of portable computing devices, and the current trend towards ubiquitous mobile computing, it has become increasingly manifest that ISPN protocols must incorporate explicit mechanisms to accommodate the needs of mobile clients. This realization is evidenced by recent efforts to extend legacy network protocols to mobile environments [5, 8, 14, 13].

This paper highlights the characteristics of RSVP as they pertain to networks with mobile hosts and proposes extensions to enhance its applicability to such environments. In such environments, mobile stations typically establish network access through a wireless interface. The key characteristics of wireless mobile networks include limited bandwidth, mobility, constraints on battery life, and non-deterministic operating conditions. The approach which we suggest to extend RSVP to such environments has the following main characteristics: (1) Quiescent resource reservations, (2) Predictive preallocation of resources based on analysis of user mobility patterns, (3) Predictive lookahead dynamic dormant multicast trees, (4) Virtual Receivers, (5) Fulcrum Nodes, (6) Mobility Management Agents, and (7) Extended RSVP Messages.

The remainder of this manuscript is organized as follows. In Section 2, an overview of the RSVP protocol is presented. Section 3 describes the attributes of RSVP as they pertain to mobile environments, highlighting the positive aspects as well as the limitations. In Section 4, the proposed extensions to the RSVP protocol are presented. In Section 5 a brief review of prior work in the literature pertinent to this endeavor is presented. Finally, Section 6 contains our concluding remarks.

## 2 Overview of RSVP protocol

RSVP [4, 18] is a unidirectional receiver oriented Internet Control Protocol which is used to request Quality of Service from the network and to "establish and maintain state" to ensure that the requested service is provided [4]. The RSVP "reservation" message propagates in the reverse direction along the path through which data will eventually flow. As the reservation message propagates from the receiver to the sender, resources are reserved at intermediate nodes (router or host) along the datapath. An RSVP request is characterized by its "flow descriptor" which is comprised of a "flow spec" and a "filter spec." The flow spec indicates the required QoS while the filter spec specifies the flow or set of packets to receive the requested QoS.

RSVP employs the concept of "soft states" in which resources are reserved only for a predefined interval of time. Periodic refresh messages are required to maintain state and guarantee that resources remain reserved. If a refresh message is not sent after a predefined interval of time, the "state" becomes stale and reserved resources are reclaimed for other applications.

# 3 RSVP in Mobile Environments

An interesting aspect of resource reservation in wireless mobile environments concerns maintenance of QoS guarantees following cell transition events. A brute force application of RSVP's receiver oriented paradigm would require a receiver to initiate fresh resource reservations each time it enters a new cell. On the other hand, fixed pre-allocation of resources in cells within a given neighborhood system of a mobile user's current location would deny other clients access to network resources, thereby resulting in low resource utilization. These considerations are well known and a number of techniques have been proposed for a variety wireless architectures [1, 8, 12, 16, 17]. The approach which we describe in this paper would help resolve this problem at low cost.

Because RSVP employs the notion of soft reservation states, signaling messages associated with state maintenance increase bandwidth consumption on the wireless segments of the network. An important attribute of mobile environments is limited battery life, hence the need to conserve power utilization. Power saving techniques often involve running hardware in sleep mode or intermittently reducing the power level of portable devices. Such techniques can impact on the performance of protocols like RSVP that require periodic refresh messages to maintain reservation state.

An important characteristic of RSVP is that it is dependent on other Internet protocols for its operation. For example, it depends on IP for route selection during the resource reservation setup process. Furthermore, because of the requirement that reservation messages should propagate in a reverse direction along the same path through which data will eventually flow, it might be difficult to achieve compatibility with route optimization strategies (see [11]) suggested for mobile IP. The proposed "RSVP Operation Over IP Tunnels' by Krawczyk, Wroclawski, and Zhang [7] should aid in partially resolving this problem.

Through the use of multiple reservation styles, RSVP permits aggregation of traffic at intermediate routers. This can be exploited in a mobile environment by establishing "virtual root fulcrum points" from which dynamic lookahead pre-reservation dormant multicast subtrees can be constructed to facilitate fast re-establishment of reservations after handoff events.

Some of the seemingly unfavorable aspects of RSVP can actually be put to good use in wireless mobile networks. First, because of RSVP's Receiver-oriented paradigm, each receiver can submit flow specifications appropriate for its ambient circumstance. Consequently, reservations can be readily and efficiently adapted as the receiver roams between heterogeneous and highly disparate environments. In this way, adaptive topology dependent reservation policies that respond to the dynamics of receiver motion can be easily devised. Another attribute of RSVP that can be put to good use is the concept of soft states, which can be used to reclaim reserved resources when a mobile station is disconnected from the network over some interval of time.

# 4 Mobility Extensions

In this section, we describe a number of extensions that enhance the applicability of RSVP to mobile environments in a cost effective manner. These proposed extensions are based on the following core abstractions: (1) extended reservation classes, (2) virtual receivers, (3) mobility prediction, (4) dynamic lookahead multicast trees, (5) fulcrum nodes, (6) mobility management agents, and (7) extended RSVP messages.

## 4.1 Extended Reservation Classes

The proposed extensions distinguish between three main classes of reservations, namely (1) committed reservations, (2) quiescent reservations, and (3) transient reservations. These extensions imply that RSVP messages will also have to be expanded to accommodate the new classes. In the following paragraphs, we elaborate on the basic properties of these reservation classes.

### 4.1.1 Committed Reservations

Committed reservations correspond to the current RSVP service model in which a reserved resource is set aside for the exclusive use of a specific set of traffic streams. Not much needs be said about this reservation class as it will operate according to the current RSVP specifications [4].

### 4.1.2 Quiescent Reservations

As the name implies, a quiescent reservation is one in which resources are reserved but not allocated. Specifically, while in the quiescent state, reserved resources can be temporarily allocated to other clients, but those allocations can be preempted when the reservation becomes activated. A quiescent reservation can be likened to an indication of "strong interest" in the resource to be reserved without firm commitments. When a mobile client enters a cell in which a quiescent reservation has been made for it a priori, the reservation is activated. If some other service was accorded temporary use of the quiescently reserved resources, those services will be preempted.

### 4.1.3 Transient Reservations

A transient reservation occurs when a resource which was quiescently reserved is made available for temporary use of another traffic stream. Transiently reserved resources can be preempted when activated by the client for which it was quiescently reserved. Since a station can be in at most one cell at a given instant in time, the combination of quiescent and transient reservations facilities QoS provisioning for roaming stations while at the same time enabling efficient resource utilization.

Within the wireless domain, transient reservation of link resources are given only on a cell by cell basis. A station accorded transient reservations which migrates to a new cell will have to renegotiate for new reservations.

A transient reservation can occur through either an explicit request by a client or through an implicit decision by the network during the admission control process. An explicit transient reservation request occurs when a client solicits for and is granted a transient reservation. An implicit transient reservation eventuates when a network client requests for a committed reservation but instead, the network offers it a transient reservation. If a network client which desires committed reservations is offered transient reservations, it can either reject or accept the offer.

## 4.2 Virtual Receivers

A virtual receiver is an entity that acts as a proxy for a mobile receiver under our extended RSVP model. Virtual receivers will typically reside on base stations or Access Points. A mobile station can have many virtual receivers. Virtual receivers are used to quiescently pre-reserve resource on behalf of mobile clients in cells to which the client are most likely to migrate. This is necessary because under the RSVP model, reservations are incepted by receivers.

Virtual receivers can also be used to reduce bandwidth consumption on the wireless links associated with maintenance of soft states in RSVP. Maintenance of soft states requires periodic refresh signals from the receiver which can be wasteful of wireless bandwidth resources. A virtual receiver on the wired network can generate refresh messages on behalf of mobile clients, so that with this clear dichotomy, refresh messages can be generated at different rates in the wired and wireless segments of the network. For example, a wireless station which is not highly mobile can reduce its refresh rate and mandate the virtual receiver in its current cell to generate most of the refresh messages for maintenance of reservation states in the wired components of the network.

## 4.3 Mobility Prediction

Mobility prediction refers to a procedure used to estimate the most likely future locations of a mobile user based on known prior movement patterns of the target. Mobility prediction need not be an integral component of RSVP. Instead, it can be implemented as specialized mobility control functions which are used as auxiliary services by RSVP. Mobility predictions consist of time dependent discrete location probability measures whose domain is the set of wireless cells in the network. Each location probability quantifies the likelihood that a mobile station will be in a given cell at a particular instant in time (see eg., [2, 3] ).

The basic idea is to keep track of the sequence of cells visited by the target station for whom resources are to be reserved. Each datum of mobility history information consists of a tuple whose elements include the identity of the mobile station, the identity of the cell visited, and a timestamp indicating the time at which the mobile terminal entered the cell. Based on this historical data, an estimate can be made as to the most likely future trajectory of the mobile client. This knowledge can then be used for intelligent preallocation of resources.

## 4.4 Dynamic Lookahead Dormant Multicast Trees

Lookahead dormant multicast trees are formed by virtual receivers resident on base stations in the cells to which a mobile station with committed RSVP reservations is likely to migrate based on the outcome of mobility predictions. The mobility management agent which performs predictions sends control signals (through the wired network) to virtual receivers on base stations in the cells to which the station is likely to migrate. Each virtual receiver that receives this control signal joins the RSVP multicast tree to which the target user currently belongs. This process is termed *dynamic lookahead multicast tree extension.* The multicast tree so constructed is said to be dormant because resources along the tree branches are reserved but not committed. In other words, resource reservations along tree arcs are quiescent; except for the branch whose leaf terminates in the cell in which the mobile station is situated. This path is called the "active path" of the dormant multicast tree and resources along such a path are committed.

### 4.5 Fulcrum Nodes

A "fulcrum" is a node in the wired network from which lookahead multicast trees are extended to virtual receivers in base stations. A fulcrum acts as the effective local root of the dormant multicast tree. The fulcrum is the point where resource reservations from lower branches of the tree are aggregated using an appropriate RSVP reservation style*. Packets bound for the mobile station are first sent to the fulcrum whence they are then dispatched to the mobile station through a committed branch of the dormant multicast tree. Under the mobile IP model [13] a fulcrum could be a Foreign Agent – if the mobile station is situated in a foreign subnet, or a Home Agent – if the mobile station is situated in its home subnet. A fulcrum could also be any router specifically selected by mobility management agents within a given subnet to act as an aggregation point for dormant multicast trees for a given RSVP session. In some networks, the fulcrum might simply correspond to the source station.

### 4.6 Mobility Management Agents

To support the mobile extensions to RSVP described hereto, mobility management agents (MMA) are required. Mobility management agents are used to manage resource reservations and other mobility related tasks on behalf of mobile stations located within a given administrative area. A mobility management agent maintains information on a subset of mobile stations. This information includes a "mobility profile" which consists of data on frequency of handoffs and prior known mobility history of the target stations. Mobility profiles are used to predict the most likely future locations of mobile stations. The mobility management agent is responsible for sending signals to virtual receivers for establishment of lookahead quiescent reservations. In a sense, mobility management agents are similar to supervisor nodes described in [16]. However, here, mobility management agents are mapped to mobile users rather than to subnets. It is anticipated that such mobility management agents will be required to provide a plethora of services for mobile clients as the vision of ubiquitous computing continues to crystallize.

*See [4] for a definition of RSVP reservation styles.

### 4.7 Extended RSVP Messages

Presently, RSVP supports two generic types of messages, namely *Path* and *Resv* messages [4]. The former is originated by senders whereas the latter is generated by receivers. Both message types travel through the same path but in reverse directions. Path messages are used to distribute path state which includes sender data characteristics as well as routing information. Resv messages are used for resource reservation as well as maintenance of soft reservation states. The generic message types have a number of derivatives namely: error messages - *PathErr* and *ResvErr*; confirmation messages - *ResvConf*; and finally tear down messages - *PathTear* and *ResvTear*.

To accommodate our expanded reservation classes, we propose the following additional RSVP message types: *PathCom*, *ResvCom*; *PathQui*, *ResvQui*; *PathTra*, *ResvTra*. These will be used for committed reservations, quiescent reservations, and transient reservations in an obvious fashion. Each of these expanded message types will in turn have their derivatives for error handling, confirmation, and tear down. Note that the committed reservation messages (*PathCom*, *ResvCom*) will function exactly as the current RSVP *Path* and *Resv* messages.

## 5 Related Work

There are many recent papers that deal with QoS provisioning in wireless networks (see eg., [9, 1, 8, 16]). The shadow cluster concept of Levine, Akyildiz, and Naghashineh [9] is targeted towards wireless ATM networks, and aims to enhance QoS provisioning by reducing the number of dropped calls resulting from handoffs using mobility prediction. The shadow cluster concept builds on the "virtual connection trees" of Acampora and Naghashineh [1] which is also a method for resource management in wireless ATM networks. Virtual connection trees [1] employ multiple ATM virtual connections in a tree structure. The leaves of the virtual connection trees consist of base stations in cells within a neighborhood system of the location in which a mobile station initiating connection setup is situated. In contrast to the virtual connection tree and shadow cluster concepts which use hard pre-reservations, our approach which depends on quiescent reservations should lead to more efficient utilization of network resources.

Lee [8] proposed a scheme that establishes branch connections in anticipation of mobile handoffs. Resources are not allocated to branch connections except after actual handoff occurs. This is somewhat similar to the notion of quiescent reservations described here. Under Lee's framework, mobility prediction is not employed and branch connections are established in cells adjacent to the location in which a mobile station is situated.

Brown and Singh [5] have proposed mobile extensions to the Real-Time Protocol (RTP) and its control protocol – the Real-Time Control Protocol (RTCP). The primary focus of their paper was to reduce bandwidth consumption in the wireless links by limiting the volume of signaling traffic. In another paper which is of interest, Singh [16] has addressed a variety of issues pertaining to QoS provisioning in mobile computing environments.

## 6 Conclusion

In this paper, we have proposed some augmentations to enable the RSVP reservation setup protocol operate effectively in mobile environments. One basic idea of the proposed enhancements is an expansion of the semantics of RSVP reservation messages to include committed, quiescent, and transient reservations. Other key ideas of the proposed mobile extensions to RSVP include virtual receivers and predictive quiescent pre-reservation of resources through dynamic lookahead dormant multicast trees. The combination of soft states, receiver orientation, and heterogeneous reservations (which are already part of the RSVP specifications), as well as the extensions discussed herein should increase the capability of RSVP to operate in mobile environments without imposing excessive burden on network resources.

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