Extension and Evaluation of the RSVP version 2 Protocol in Infra-Structured Mobile Networks

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Abstract. In order to optimize the operation of the RSVPv2 protocol in mobile infra-structured networks this paper proposes a set of extensions. The proposed extensions are: employment of the reservation message to quickly create reservation states after a handoff is performed; utilization of teardown message in order to explicitly remove the reservation states from the old path; extension of the mobile IP message in order to carry reservation acknowledgement information. The Network Simulator NS was employed to evaluate the RSVPv2 protocol and the suggested extensions. Simulation analysis have shown that the utilization of the proposed extensions is able to efficiently manage the reservation states in different mobile networks scenarios.

1 Introduction

As portable computers are increasing process power, increasing portability and the wireless access technology is rapidly evolving, mobile users are starting to demand Internet services in the same way as fixed users. However, to guarantee data continuous accessibility it is necessary to use the mobile IP protocol, where mobility agents are responsible for the correct packets forwarding to the current location of the mobile node. In addition to offer data continuous accessibility and support real time applications it is still needed to offer a differentiated treatment to QoS (Quality of Service) sensible applications. Besides, the current Internet packets forwarding model does not provide any kind of special treatment. For instance, Voice over IP packets are treated in the same way as FTP application packets. Then, one way to have QoS guarantees is to use specific architectures as the IntServ [1] and DiffServ [2] architectures.

The main elements of a communication system able to offer QoS over the Internet are the packets scheduler, the admission control and the signaling protocol. According with Fu [3], a QoS signaling protocol is responsible for the establishment, maintenance and removal of the reservation states in the network nodes and is essential for end-to-end QoS delivery. The applications use the signaling protocol to inform network nodes which flow will have a special treatment and how this going to be.

The most used QoS signaling protocol is the RSVP (Resource reSerVation Protocol) [4]. However, it is notorious that this protocol presents problems like: low scalability, high complexity and lack of integration with the mobile IP protocol. The main mobility RSVP related problems are:

- Alteration of the RSVP session identifier: an RSVP session is defined by the triple: destination IP address, IP protocol identifier and destination port. After a handoff, the mobile node IP address is changed by the mobile IP protocol. That way, the RSVP session identifier value is also changed and the reservation states need to be reestablished in the whole end-to-end path, instead of only being established in the new part of the data path.
- Temporary absence of the reservation states in the new data path: when a mobile host roams to another subnet, the path between sender and receiver is changed. The reservation states have to be reestablished along the new path. Since resources may be unavailable in the new path, it will lead to possible degradation or disruption of QoS services.
- Removal of the reservation states from the old data path: after a handoff, the reservation states from the old path need to be quickly removed. If this process is slow, then new reservation sessions may have its creation denied by lack of resource.

Several works have indicated extensions to solve RSVP mobility problems, for instance the MRSVP protocol [5] and the work of Chen and Huang [6], however, these works still presents the same complexity and scalability problems of the RSVP protocol. As part of the IETF NSIS working group (Next Steps in Signaling), Brunner *et al*. have proposed the RSVPv2 protocol [7], which presents a lower complexity and a higher scalability compared to the RSVP protocol. In order to optimize the RSVPv2 operation in mobile networks scenarios a unique reservation identifier is utilized. A RSVPv2 prototype was created and a comparison with the RSVP were made. However, these tests were made only in a fixed network topology.

Although the author has indicated the utilization of the unique reservation identifier in order to make the signaling protocol efficient in mobile networks, it is still needed to specify other aspects related to the creation and maintenance of reservations in mobile environments.

This work evaluates the RSVPv2 protocol mobility support and proposes a set of extensions responsible for the optimization of the protocol in mobile environments. The proposed extensions are:

- Employment of the reservation message FAST_RESV to quickly create reservation states, after the handoff is performed, in the new part of the data path.
- Utilization of the RESV_TEAR message, sent from the crossover router, in order to explicitly remove the reservation states from the old path.
- Extension of the mobile IP Agent Advertisement message in order to carry reservation acknowledgement information. This extension is able to reduce the reservation set up delay when the mobile node is located far away from its home agent.

This article has the following structure: The section 2 shows the related works on QoS signaling protocols in mobile networks. The section 3 presents the main characteristics of the RSVPv2 protocol. The section 4 introduces the proposed extensions and also shows the main implementation aspects in the network simulator

NS. The section 5 presents the simulation results. Finally, the section 6 makes the final considerations and offer ideas for future works.

2 Mobile Networks QoS Signaling

Originally, the QoS signaling protocols were designed for fixed networks, for instance the RSVP protocol and the YESSIR protocol [8]. However, in the last years, several works [5,6,7,9], that make adaptations in the reservation signaling protocols, have been proposed. With these modifications, the reservation protocols are able to operate properly in mobile scenarios.

The mobile networks have special characteristics, which must be considered in the design of a QoS signaling protocol. Examples of these special characteristics are: mobility of the node, reservation readaptation after a handoff, some wireless communication particularities, like high error rate and low bandwidth.

The mobile networks QoS signaling protocols use two strategies to manage the alteration of the data path caused by a handoff:

- Use of reservations in the set of locations where the mobile node will visit in its connection lifetime. This strategy is used by the MRSVP protocol [5] and in work proposed by Chen and Huang [6].
- Creation of reservations dynamically as the mobile node roams between networks. This strategy is employed in the RSVPv2 protocol [7] and in the work proposed by Terzis *et al*. [9].

The utilization of reservation states in several locations is based in the mobility specification, where the set of locations are defined. Although, this method eliminates the session establishment delay, its major problems are: how to obtain the mobility specification precisely in advance and the network resource waste caused by the creation of reservation in several different sub-networks.

The creation of reservations dynamically presents an increase in the session reestablishment delay, but a better network resource sharing is obtained, because the reservations are only created in the current location of the mobile node.

In order to provide a good performance to the mobile networks signaling protocols, an interaction between the mobility manager protocol and the reservation protocol is necessary. According with López *et al*. [10], the collaboration degree between these two protocols can be classified in one of the three levels:

- Not coupled: this is the current state of the RSVP protocol and the Mobile IP protocol, where both protocols are unaware about each other.
- Loosely coupled: the beginning of some action results in a exchange of information between the protocols.
- Strongly coupled: in this strategy both QoS and mobility information are carried together in the same message. As an instance, the work proposed by Chaskar and Koodli [11], where QoS related information is added to the Mobile IP protocol (version 6) Binding Update message.

3 General View of the RSVPv2 Protocol

Brunner *et al*. [7] proposed a new version of the RSVP protocol. The main objectives of this protocol are: greater scalability (through the reduction of reservation related information, stored in each network node) and complexity reduction of the protocol (RSVPv2 uses a lower number of messages, compared with RSVP protocol) and a more efficient mobility support.

The capacity of a QoS signaling protocol to accommodate multicast groups is very important (due to the diversity of receiver characteristics). In this protocol, the multicast support is regarded as an extension to the base protocol.

The RSVPv2 protocol is sender oriented, i.e the reservation request is sent from the sender node through the RESV message. In that way, it is possible to reduce the protocol complexity and the session establishment delay. However, the receiver is not allowed to choose the traffic characteristics. This approach was defined from the fact that the receiver will, in most cases, simply request the traffic characteristics indicated by the sender.

The RSVPv2 is a soft state protocol, which means that reservation information are temporally stored in the nodes along the communication path. In order to improve the performance of the protocol, only end points are able to send refresh messages. In this way, the load in the intermediate routers is reduced. Although the soft state paradigm does not need any reservation explicit removal mechanism, this characteristics can be really useful, especially in high mobility environments.

After a reservation request is desirable to inform the sender node about the request success or not. The RSVPv2 protocol sends acknowledgement reservation request message (RESV_ACK) in order to inform the sender node. If the message indicates a error in the attempt to establish the reservation state, the message will inform the sender about the location (which router) where occurred the fail and which was the cause, responsible for the error.

The RSVPv2 protocol uses different information to distinguish between a flow and a reservation. Each RSVPv2 message carries a reservation identifier and one flow identifier that allows to match data with reservations previously set. This mechanism is especially used in mobile networks.

4 Proposed Extensions and RSVPv2 Protocol Implementation

The RSVPv2 prototype was developed in the Network simulator NS and presents the following functions:

- Integration between the reservation protocol and the mobility manager protocol (mobile IP version 4) [14], through the utilization of messages that carry information about the current Base Station and the handoff event.
- Creation of mechanism capable of quickly send the reservation message RESV, in order to build the reservation state in the new part of the data path.

- Identification of the RSVPv2 session thought the utilization of an unique reservation identifier, generated randomly.
- Detection of the crossover router and dispatch of the RESV_TEAR message, in order to remove the reservation from the old path.
- Creation of the RESV_ACK message, used to inform the traffic sender about the reutilization of a reservation previously set.
- Use of the mobile IP Agent Advertisement message as transport form for the reservation establishment acknowledgement information.
- Implementation of mechanism responsible for creation and management of a tunnel RSVPv2, used when the mobile node is receiver of the data flow.

The network simulator NS [12] is kept by the project VINT (Virtual InterNetwork Testbed). It uses two programming languages: C++ and Otcl. The C++ is utilized in the protocol core development, while the Otcl is used in the creation and configuration of the simulation scripts.

In the NS, agents are abstractions that represent endpoints where network-layer packets are constructed or consumed and provide some helpful functions in developing transport-layer and other protocols. Any new protocol, created in NS, will have some of its classes derived from the Agent class.

In the Fig. 1 is presented the partial NS classes diagram, extended with the RSVPv2 protocol (represented in black) and the extended Mobile IP classes (shown in gray).

The RSVPv2Agent class extends the Agent class and is responsible for the following functions:

- RSVPv2 messages processing (RESV, RESV_ACK, RESV_TEAR and HANDOFF_WARN);
- reservation states creation, renovation and removal;
- soft state maintenance;
- admission control query.

The RSVPv2Checker class extend the Connector class and is responsible for the RSVPv2 messages forwarding from the object RSVPv2Link to the RSVPv2 Agent. This class simulates the behavior of packets which the IP router alert option [13] is set.

The RSVPv2Link class is compound of the objects of type duplex-intserv-link and with the object from the type ADC (Admission Control) and the packet scheduler object from the type WFQ (Weighted Fair Queuing).

The class MIPMHAgent extends the class agent and presents the function of detecting the handoff happening and warn the reservation module about it. Besides, this class is responsible to inform the signaling protocol about the address of the actual mobile node base station. The MIPBSAgent class is responsible for the initiation of the RSVPv2 tunnel.

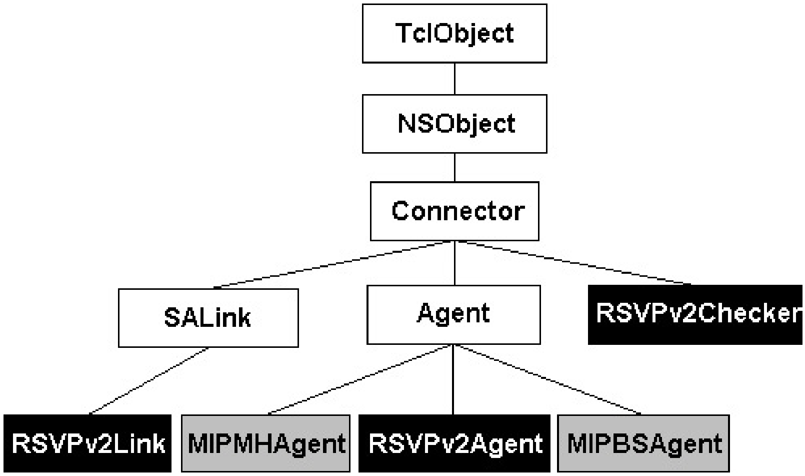

Fig. 1 Partial NS diagram class

The implemented messages in NS are:

- RESV: this message is responsible for the reservation states creation and it is used by the sender in two situations. In the first situation, the message is sent periodically (each 30s), in order to renew the reservation states (soft state mechanism). In the second condition, the message is used to rapidly create the reservation sates in the new part of the data path, when used in such situation, the message is called of FAST_RESV.
- RESV_ACK: message which has the objective to inform the sender about the reservation creation/reuse attempt status;
- RESV_TEAR: this message removes the reservation states of a specific data path. In mobile networks the use of this message is useful because when a handoff is performed, resources got allocated in the old path. So it is imperative to employ some technique in order to release this resources;
- HANDOFF_WARN: this message is responsible to inform the reservation module about a handoff event. It is generated and sent from the mobile node.

5 Simulation Results

This section presents the simulation results of the RSVPv2 protocol, in some mobile network scenarios.

The experiments objectives are:

- Evaluate the effectiveness of the use of the RESV_TEAR message, in order to remove the reservation states from the old path (experiment 1).
- Evaluate the reservation establishment delay when the mobile IP is extended with reservation acknowledgement information (experiment 2).

The network topology used in experiment 1 is represented in the Fig. 2. The simulation has, initially, four mobile nodes (one per base station) sending data to the node W0. The number of mobile nodes is increased up to 120 (30 per base station). Each one establishes a 64 Kbps reservation session. The access networks bandwidth are proportional to the current number of mobile nodes in each base station. This is done in order to create a bandwidth contest situation by the mobile nodes, where the creation of some sessions might be denied by lack of resources.

Initially, the mobile nodes establish their sessions from the simulation time 0 to 30s. From the time 50s and on, the mobile nodes start to move (with a speed of 10 m/s) and they might perform up to two position displacements.

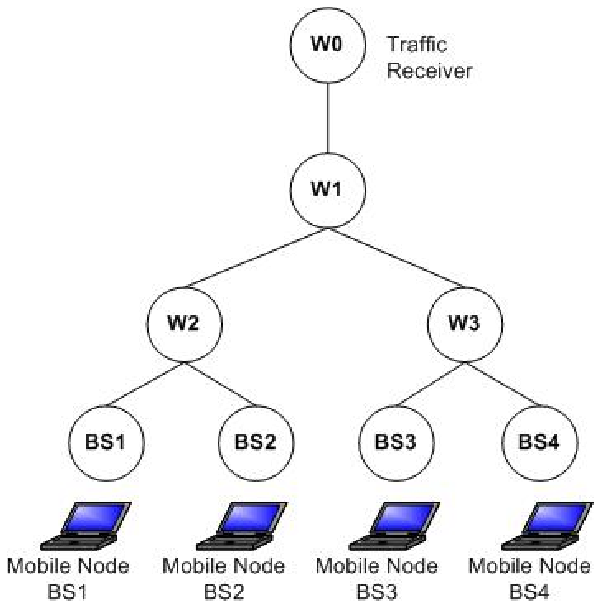

Fig 2. Network topology used in experiment 1

Initially, no removal reservation message is used and the reservations are only removed by the soft state expiration. After that, it is used the RESV_TEAR message, sent soon after the handoff event. Testing this two methods, it is possible to determine which one provides the better utilization of the network resources. The results from experiment 1 are shown in the Fig. 3. Analyzing the Fig. 3, it is possible to conclude that the use of RESV_TEAR message is efficient to increase the total sessions number that a networks is able to support.

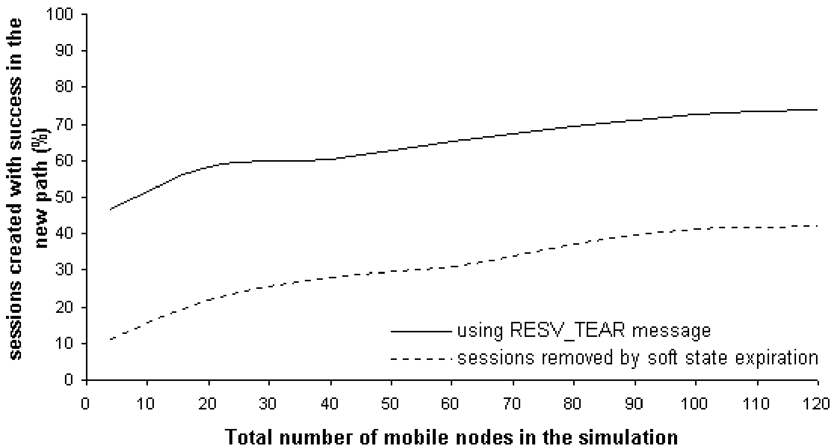

Fig 3. Results from the Experiment 1

The experiment 2 was performed with intent to observe the reservation session establishment delay, in a large topology, where the mobile node can located far away from its home agent. In order to do that, the topology used is represent in the Fig. 4. In the represented network the links have a 10 ms transmission delay. This simulation consists of the mobile node displacement from the base station 1 (BS1) until the base station 10 (BS10), where nine handoffs are performed by the mobile node.

The extension of the Agent Advertisement message, with acknowledgement related information, it was proposed for situations when the mobile node is located far from its home agent. In this case, the RESV_ACK message must go until the mobile node home agent, and after that, the message is sent through the tunnel between the home agent and the current mobile node base station. This process can present a high delay and it is proportional to the distance between the crossover router and the home agent and also to the RSVPv2 tunnel length.

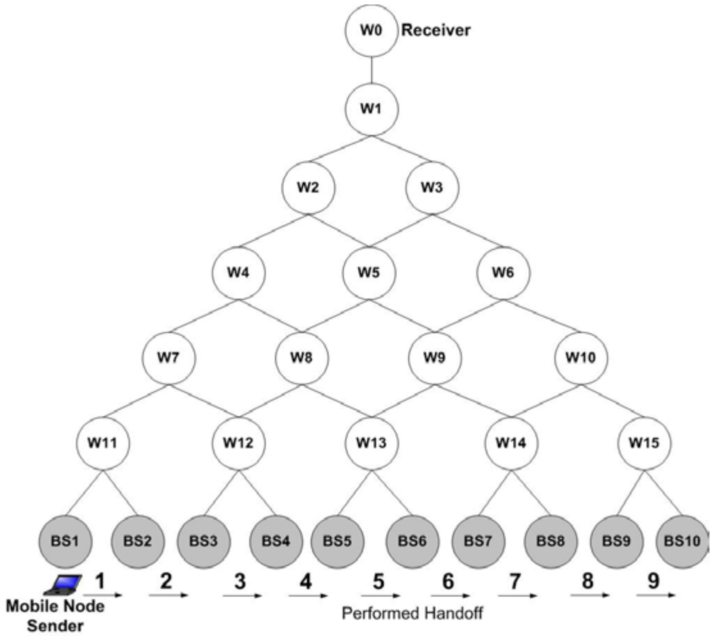

Fig 4. Network topology used in experiment 2

In the experiment 2, the mobile node is traffic sender and the total session reestablishment delay was measured through the difference between the time that the FAST_RESV was sent and the time that the RESV_ACK was received in the mobile node. After that, the delay of the use of the Agent Advertisement extended with acknowledgement information was measured. The total reservation reestablishment delay was calculated through the difference between the time that the FAST_RESV was sent and the time that the Agent Advertisement message was received by the mobile node.

In the Fig. 5 is possible to note that the session reestablishment delays, from the occurrence of the first handoff, have nearly only 10 ms difference (considering both methods: 29 ms using RESV_ACK message and 39 ms using mobile IP protocol extend message). This small difference is given by the small distance (one hop) between the crossover router (node W11) and the home agent (located in BS1). In the second handoff, the distance between the crossover router (node W7) and the home agent is of two hops. That way, the RESV_ACK message will hop seven times, since was sent, until reaches the mobile node (with a session delay of 70 ms), while the Agent Solicitations and Agent Advertisement will hop only three times (with a 52 ms session reestablishment delay). Analyzing the subsequent handoffs is possible to clearly note the advantage of the use of Agent Advertisement message enhanced with acknowledgement information compared to the use of RESV_ACK message.

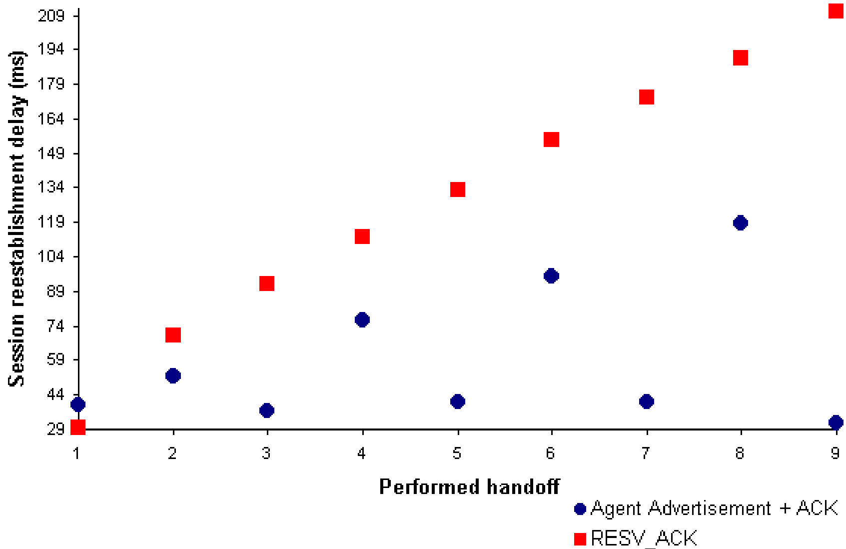

Fig 5. Results from experiment 2

6 Conclusions and Future Work

In this paper we have presented the evaluation of the RSVPv2 protocol mobility support and the suggested extensions, which are used to optimize the RSVPv2 protocol reservation states management, in mobile network scenarios. The first proposed extension was the use of the FAST_RESV message in order to quickly create the reservation states in the new path. The second extension consists in the utilization of the RESV_TEAR message in order to remove the reservation states from the old path, after a handoff is performed by the mobile node. The simulations on this extension, have shown that the use of a explicit removal message increases the total number of sessions that the network can support simultaneously. The third extension uses the mobile IP protocol Agent Advertisement message to carry the reservation reestablishment acknowledgement information. Simulations results have indicated, when the sender mobile node is located far away from its home agent, a reduction in the session reestablishment delay, compared to the standard use of the RESV_ACK message.

Several directions can be taken from the results presented in this work. One would be to develop a mechanism to decrease the number of reservation refresh messages sent by the mobile node in order to save the mobile node battery power. One solution for this problem would be putting a fixed node (for instance the actual mobile node base station) responsible for forwarding the states renovation messages.

7 References

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