Scalable E2E Framework for Heterogeneous (Wired-cum-wireless) Networks

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Summary
Next generation wireless networks aim to provide guaranteed Quality of Service (QoS) for multimedia applications. However, bandwidth is an extremely scarce resource in such networks that required an efficient and effective management mechanism to enhance the network performance and provide better services for mobile users. So, it would be desirable to investigate the integration of RSVP and a flow reservation scheme in wireless LANs, as an end-to-end solution for QoS guarantee in wired-cum-wireless networks. In this paper, we propose a lightweight RSVP-like flow reservation and priority based negotiable admission controlled SWRESV scheme for IEEE 802.11 wireless LAN. The proposed framework is designed for guaranteed flow reservation by taking advantage of the Adaptive resource Allocation algorithm with new calls in order to enhance the system utilization and blocking probability of new calls. SWRESV support the smooth roaming of mobile users among different basic service sets and also have an efficient handoff scheme, that considers both the flow rate demand and network resource availability for continuous QoS support. Omnetpp simulator is used for simulation work, simulation results show that the proposed scheme is promising in enriching the QoS support of multimedia applications in heterogeneous wired-cum-wireless networks. Results show that our framework outperforms the previous framework in terms of connection blocking probability, connection dropping probability, and bandwidth utilization.

Key words:
Quality of Service, End-to-end, Wired-cum-wireless networks, IEEE 802.11, RSVP, OmNetpp.

1. Introduction

The next generation wireless networks will combine high-speed mobile communications with the current Internet architecture to create novel ways to communicate access information, transact business, and provide entertainment. In many instances, wireless/mobile users need to access/exchange information stored in some servers located in wired/wireless networks. The goal is to reduce the distinction between wired and wireless networks, and provide any kind of service to any kind of user at any location. Unlike the bandwidth in a wired network, radio spectrum is a scarce resource. Supporting QoS across wired and wireless networks becomes important in these instances.

RSVP/SBM [7, 18] has been widely accepted as a reservation scheme for flow reservation in IEEE 802 style LANs to support Integrated Service (IntServ) [6]. Thus, a natural idea would be the integration of RSVP in wired infrastructure and a RSVP-like flow reservation protocol in wireless LAN. Although many optimization schemes have been proposed to improve QoS support by providing service differentiation in IEEE 802.11 wireless LANs [2, 3, 14, 17], they have three major disadvantages. First, most schemes do not provide explicit flow reservation and priority-based admission control. Without this, it is impossible to guarantee QoS of real-time flows when network traffic becomes heavy. Second most schemes only consider QoS support in WLANs and thus are not interoperable with QoS schemes in wired networks. These disadvantages make existing QoS schemes incomplete and ineffective in practice. So there is a need for a scheme that provides flow reservation, priority-based renegotiable admission control and seamless integration with wired, QoS schemes may become more popular. That scheme should renegotiate the resources of the lower priority requests.

In this paper, we propose scalable Wireless LAN Flow Reservation Protocol (SWRESV), a RSVP-like flow reservation, and priority-based negotiable admission control scheme for QoS guarantee in IEEE 802.11 WLANs with an adaptive service. Therefore, we provide the high priority to those requests that can not allow degradation and low priority to the request that can allow degradation of the resources in permissible limit under potential resource shortages. SWRESV takes a similar approach of signaling for flow reservation to facilitate the integration with RSVP. However, unlike RSVP, no soft-state is recorded at the mobile hosts (MHs) and no refresh message is required in SWRESV. Therefore, SWRESV does not suffer from the scalability issue. Furthermore, SWRESV uses channel busy time to estimate channel available bandwidth at the priority-based AP for accurate admission control decisions.

This paper is organized as follows. **Section 2** reviews the

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related works in QoS schemes in IEEE 802.11 wireless LANs and wired/wireless integration. **Section 3** describes the system architecture. **Section 4** introduces the proposed SWRESV protocol. **Section 5** discusses the details of the protocol integration of SWRESV and RSVP. **Section 6** discusses simulation results of the proposed framework and **Section 7** concludes this paper.

2. Review of works:

Several admission control schemes have been proposed in order to guarantee QoS in wireless LANs [19]. Valaee and Li [17] suggest a measurement based admission procedure using a sequence of probe packet for ad hoc networks. Instead of using probe packets, Shah and Chen [14] propose a measurement based admission control scheme using data packets to measure the network load. Banchs and P´erez [2] propose ARME, an extension of DCF, that uses a token bucket based algorithm to detect whether the network is in an overloaded condition, and thus improve the performance of system by adjusting contention window appropriately. All these schemes only consider the QoS guarantee within wireless LANs and no attempt has been made for the more challenging problem of supporting QoS over wired-cum-wireless networks.

In recent years, cross-layer interaction [8, 14] has gained more attention for protocol design in wireless network because of its efficiency. Usually, cross-layer interaction is implemented for different layers to share same useful information such as flow characteristics, node location, and network topology so that they can cooperate closely to meet application's QoS requirements. Integrating Differentiated Service (DiffServ) [5] with IEEE 802.11 WLAN has been studied. Park and Kim [13] propose a QoS architecture between DiffServ and IEEE 802.11e [4] by mapping priorities with IEEE 802.1D/Q. In order to support QoS and Mobility for wireless Internet, Garc´ıa-Mac´ıas, and Rousseau [9] present a hierarchical QoS architecture to extend DiffServ to WLANs with flexible mobility management. Ming Li, Hua Zhu proposed a frame-work for heterogeneous wired cum wireless networks [1], but there is no application of renegotiation mechanism at the time of admission of request and at the priority based AP, there is no degradation scheme applied. In this paper, we focus on a different approach of integrating RSVP with priority-based QoS schemes in IEEE 802.11 wireless LANs.

Talukdar and Badrinath [16] design MRSVP to enhance RSVP with advance resource reservations in order to provide integrated service to networks with mobile hosts. Then, Moon and Aghvami [12] propose a QoS mechanism in all-IP wireless access networks. In their scheme, re-routing of RSVP branch path toward the crossover router at every handoff event is made to reduce resource reservation delay and signaling overhead. Also, advance reservation is made via a new BS for ongoing flows to maintain QoS. Shankar and Choi [15] propose a MAC-level QoS signaling for IEEE 802.11e WLAN and address its interaction with RSVP and SBM. However, no effort is made to handle the specific issue of admission control in wireless LANs. Also, mobility issue is not addressed.

From the above review, we can see that existing works in the literature focus on QoS support in wireless LAN or protocol extension of RSVP without taking advantage of special characteristics of IEEE 802.11. We feel that it is of high importance that in order to support seamless QoS support spanning wired/wireless networks as well as different BSSs in wireless LANs, issues such as admission control in wireless LAN, protocol integration, support need to be addressed in combination to provide an end-to-end QoS solution.

3. System architecture:

The architecture of wireless Internet is depicted in Fig. 1 (revised from MIRAI architecture [10], Ming Li architecture [1]). Multiple basic service sets (BSSs) are inter-connected by a distribution system (DS) and form an extended service set (ESS). An ESS is connected to the Internet via a gateway router. In each BSS, all mobile hosts (MHs) are within the broadcast region of their associated priority based AP and can only access the infrastructure through the AP. All MHs can roam among different BSSs of the same or different ESSs.

In a wired-cum-wireless network, mobile/wireless users usually access/exchange information stored somewhere on the Internet via their associated APs and the gateway router. For multimedia applications such as audio/video streaming, end-to-end QoS guarantee is highly desirable in order to ensure user satisfaction. Therefore, we propose a priority based framework where RSVP is integrated with SWRESV, a wireless LAN flow reservation protocol, designed to be integrated with RSVP for end-to-end QoS support. In addition, due to the node mobility, if a MH moves towards another cell, its bandwidth should be allocated in the new cell and released from the old cell. To address this issue, SWRESV provides a seamless handoff scheme for support of user mobility.

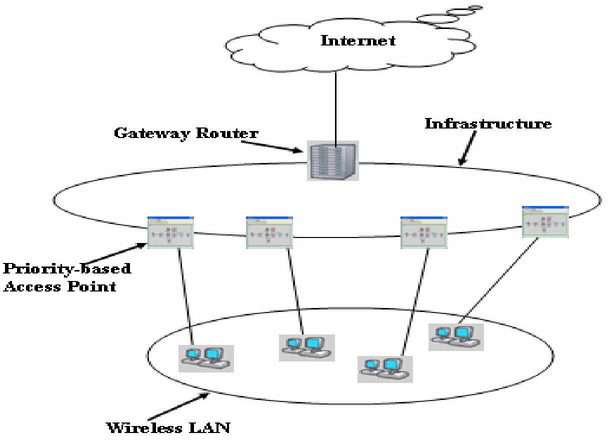


Fig. 1 Architecture of wireless internet

The major objectives of the proposed RSVP-SWRESV framework are:

(1) End-to-end QoS guarantee at the min and max level of request is provided through wired/ wireless signaling and accurate wireless LAN priority-based admission control. It can also renegotiate QoS agreement and degrade the level of low priority user in permissible limit under shortage of resources to admit new request.

(2) Seamless roaming is supported when users move among different BSSs. Partially consider in this paper detail is left for future work.

4. SWRESV–wireless LAN flow reservation protocol

RSVP is designed to provide integrated service for packet-switched network such as IEEE 802.3. We extend RSVP to wireless LANs with several modifications by fully considering the characteristics of IEEE 802.11 wireless LANs. First, since all packets are relayed through AP, AP acts as the junction for resource management (i.e. application of priority based mechanism on these packets or requests) for admission control and flow reservation, defined as wireless bandwidth manager (WBM). Second, by introducing signaling messages for handoff process, seamless handoff is also well supported. Finally, the broadcast nature of the wireless medium can be utilized in multicast sessions so that wireless LAN bandwidth usage becomes more efficient. In our protocol, WBM monitors the wireless channel continuously and estimates the channel available bandwidth to ensure accurate admission control decisions. Before data transmission of a real-time flow, the source station sends a request with its QoS requirement to AP, which will accept/reject the flow according to the estimated available bandwidth in wireless LAN.

The basic objective is to design a this framework that will maintain existing user dropping probability and new user dropping probability to a sufficiently low value while providing better QoS. The proposed algorithm will take advantage of adaptive nature of multimedia applications for achieving this objective. Other objective is to create user classes on the basis of QoS requirements of individual users and providing service quality in accordance to that.

In this paper we consider three kinds of user with different priority; the higher priority user will have lower probability of being degraded in case of bandwidth adaptation is performed to incorporate a new user. Users with strict QoS requirements are belong to the highest priority class and will be paying more for the similar class of service availed by lower priority user classes. Medium and lowest priority users with adaptive QoS requirements can degrade bandwidth up to lowest level not less than $B_{i,requested}$. Our scheme admits these requests and schedule flow based on two main procedures: degradation and expansion. The degradation procedure is activated when an accepted arriving request (new user) arrives to an overloaded cell. On the other hand, the expansion procedure is activated when there is an outgoing request or a call completion in the given cell.

For convenience, we call the proposed priority based renegotiable flow reservation scheme “Scalable Wireless LAN Flow Reservation Protocol” (SWRESV). In the following subsections, we will discuss channel available bandwidth estimation and the flow reservation procedure in details.

4.1. Channel available bandwidth estimation:

To extend reservation based protocols such as RSVP to wireless LAN, the success of the flow reservation largely relies on the accuracy and efficiency of the admission control decisions, which in turn depend on accurate and dynamic online estimation of available bandwidth. We calculate available bandwidth based on two important metrics: node saturation throughput and c*hannel busy time*.

To fully consider the shared medium CSMA/CA MAC in IEEE 802.11, we define saturation throughput of a node i , $b_{sat,i}$ as *the maximum aggregate throughput that can be received by* i *under the current network condition*. Similar to [11] and [14], saturation throughput is calculated as

$$b_{sat,i} = \frac{S}{t_{ack} - t_{enqueue}} \qquad \text{………..} (1)$$

Where *S* is the MAC layer payload (upper layer packet) length in the current measurement period, $t_{enqueue}$ and t_{ack} is the time when a packet arrives at MAC layer of

node i and when node i receives a MAC ACK about the same packet, respectively. The duration Δt of $t_{ack} - t_{enqueue}$ actually includes the time a node waiting for channel access. Based on $b_{sat,i}$ we can get channel available bandwidth, $b_{ava,i}$ by considering channel busy time. In other words, $b_{ava,i}$ should be the remaining *allocable* bandwidth for a node. Let α_i be the percentage in time that the node i is in "busy" state. Note that a node is not in "busy" state unless all the following conditions are: no packet is waiting in the MAC queue, the node is not in NAV state, the node does not sense a busy channel at the MAC layer satisfied simultaneously:
α is important for the accuracy of available bandwidth estimation. If α is very low (e.g., 0.1), then almost the whole saturation throughput is allocable to new flows. On the other hand, If α is very high (e.g., 0.8), it is highly possible that the channel is busy transmitting existing flows and not much free bandwidth can be used for new data transmissions. Therefore, α well reflects the dynamics of wireless channel resource availability.
With channel busy time estimated, we have that

$$b_{ava,i} = (1-\alpha_i).b_{sat,i} \quad \ldots\ldots\ldots\ldots (2)$$

Then, combine Eqs. (1) and (2), we obtain the following expression for channel available bandwidth estimation.

$$b_{ava,i} = (1-\alpha_i).\frac{S}{t_{ack} - t_{enqueue}} \quad \ldots\ldots\ldots (3)$$

This measurement can effectively calculate the available channel bandwidth experienced by a node during a very short period of time. In a wireless LAN where stations are within the broadcast region of each other, AP can measure the available bandwidth of the channel and enforce admission control accordingly.
In our implementation, available bandwidth estimation is updated every second to ensure the accuracy. To show the effectiveness and accuracy of the proposed available bandwidth estimation scheme, we run a simple simulation. As shown in Fig. 2, available bandwidth decreases as the increase of number of flows in the BSS.

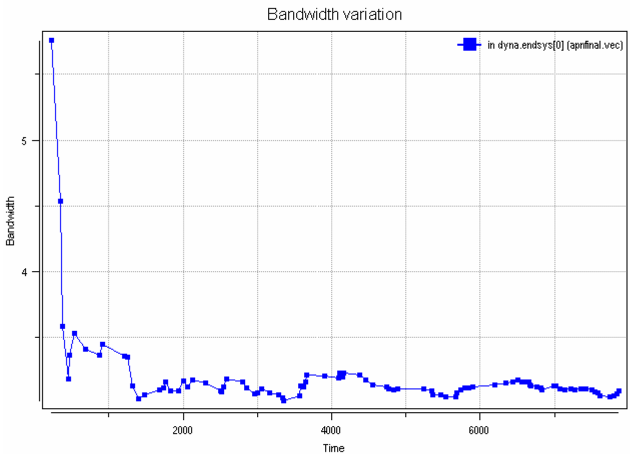


Fig. 2 Estimation of available bandwidth

Thus the available bandwidth becomes very small and does not decrease significantly as new flows arrive. Therefore, the proposed scheme does capture the bandwidth availability change dynamically with reasonable accuracy.

4.2. Flow reservation procedure:

We adopt explicit signaling for request/response reservation messages for efficient admission control. REQUEST is defined as the message sent from wireless sender to AP which specifies the traffic characteristics of the source, and RESPONSE is defined as the message sent from AP to the wireless sender which indicates whether the flow can be supported or not. If flow not supported than sent message RENEGOTIATION from AP to ongoing lowest or medium priority senders to reduce the rate of flow to minimum level to admit new request and it will also use the RENEGOTITION message to increase the rate of flow for outgoing request or at call completion in the given cell and than RESPONSE message sent from AP to wireless sender to support their flow. It can make the decision locally without the necessity of forwarding REQUEST to the wireless receiver.
The contents of signaling messages are fully compatible with RSVP specification [7]. As shown in Fig. 3, Here Mean/Maximum Data Rate corresponds to Token Bucket Rate and Peak Data Rate specified in RSVP. A *Result* field is also included in RESPONSE message to indicate the success/failure of flow reservation after renegotiation. These messages are sent as the payload of IEEE 802.11 MAC frames. Since only one pair of request/response messages are sent per flow, the signaling overhead is $O(n)$, n be the number of real-time flows in the network.

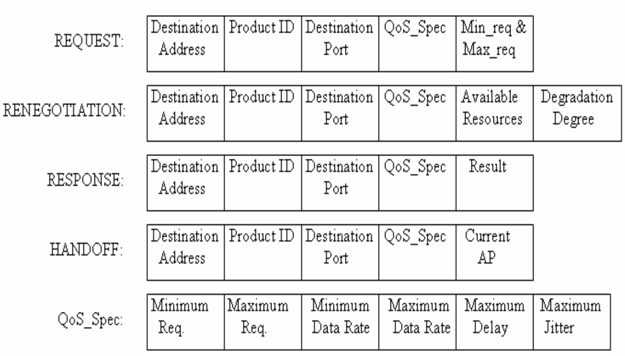


Fig. 3 Contents of SWRESV message.

The flow reservation procedure of SWRESV works as follows. Before data transmission, the sender of a real-time flow sends its traffic information (embedded in REQUEST message) to AP, which obtains the traffic information and checks whether or not the rate demand can be met according to the bandwidth availability. Once admitted, the new flow is added to a reserved flow list maintained at AP. Then, AP sets the result in the response message and sends it back to the sender. If the available bandwidth $B_{i,available} \geq B_{i,requested}$ the arrival request will be assigned a bandwidth between $B_{i,requested}$ and B_i, K_i and set the result 1, then the flow is accepted and allowed for transmission immediately. If the request is not 1, find degradation degree according to the minimum requirement of the request.

Then, Bandwidth Allocation Algorithm (BAA) used in our framework sorts the computed adaptability ratios in an increasing order. Calls that belong to the lower priority class which has the smallest adaptability ratio will be degraded first. If the saved bandwidth is enough to accommodate the arriving new call then the algorithm stops.

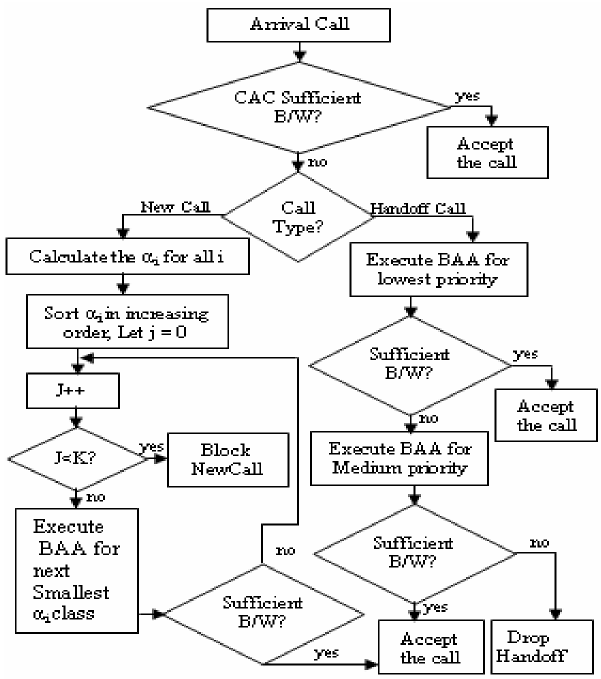


Figure 4: Bandwidth adoption algorithm

Otherwise, the algorithm degrades the calls which belong to the class with the second smallest adaptability ratio and so on. This process is illustrated in Figure 4. It should be noted that when a flow finishes, it is not necessary for the sender to notify AP. The reason is that a released flow does not consume channel time and bandwidth, the new estimated channel available bandwidth will be increased. Thus, when a new flow request arrives, AP is aware of the channel status change and will make decision on direct admission/renegotiate admission/rejection of the new flow according to the new available bandwidth estimation.

5. RSVP-SWRESV integration

With the proposed admission control strategy and signaling scheme, SWRESV itself can work alone for QoS support in single-hop wireless LANs. In this section, we focus on integration of RSVP-SWRESV integration so that QoS guarantees spanning wired and wireless networks can be provided. As shown in Fig. 5, to establish end-to-end flow reservation, signaling messages need to be sent between wireless users and wired servers through wireless AP, gateway router, and intermediate IP routers. As QoS signaling schemes for the Internet and wireless LAN, RSVP and SWRESV should be integrated to realize end-to-end flow reservation. Since SWRESV follows the same procedure of request/response as RSVP does, mapping of signaling messages can be made between the reservation messages of Path/Resv of RSVP, and REQUEST/RESPONSE of SWRESV, respectively. To facilitate information sharing and message mapping, cross-layer interaction between MAC and upper layers at AP is implemented.

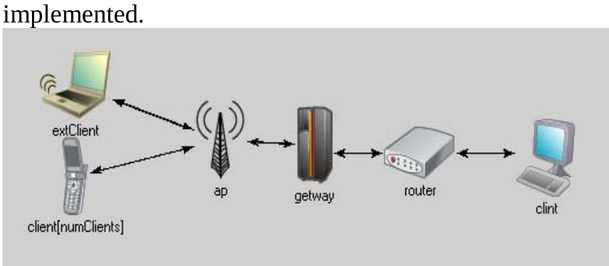


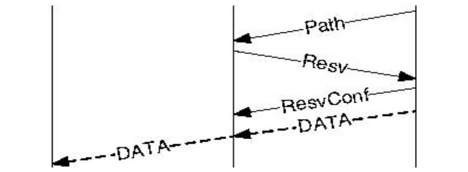
Fig. 5 Illustration of end-to-end reservation

5.1. End-to-end reservation

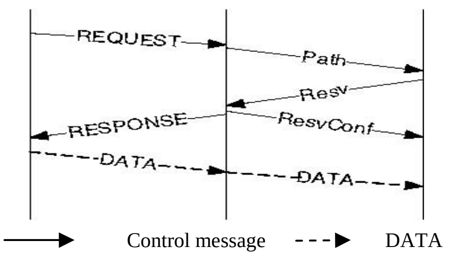
The end-to-end reservation setup procedures for downstream (wired-to-wireless) and upstream (wireless-to-wired) flows are depicted in Fig. 6(a) and Fig. 6(b), respectively.

5.1.1. Downstream reservation

When RSVP Path message from a sender arrives, AP needs to enforce admission controls for both WLAN and wired network. Based on the available bandwidth of wireless channel.



(a) Downstream reservation



(b) Upstream reservation

Fig. 6 Procedures of successful end-to-end reservation setup

WBM admits the flow by allocating bandwidth for the flow, second way could be renegotiate by finding the degradation degree or reject the reservation because of the unavailability of the resources. If the flow can not be satisfied in WLAN, AP just gives up the reservation. Otherwise, AP checks whether the outgoing link supports the requested rate.

5.1.2. Upstream reservation

When SWRESV REQUEST message from the sender MH arrives at AP, AP obtains the session id and maps the QoS specific parameters. Then, the AP sends RSVP Path to wired receivers along the path selected by a specific routing protocol. Due to some possible errors, RSVP PathErr may be sent from receiver or an intermediate router to AP. In this case, no reservation request is received at the AP. After some time, AP times out and may send RSVP PathTear message to the receiver to remove all the path states. Note that the reservation messages outside of the wireless LAN is processed by RSVP/SBM agents located at intermediate routers. Thus, as far as AP is concerned, it receives two messages, RSVP Resv or RSVP ResvTear, indicating the success or failure of the corresponding flow reservation in the wired network, respectively.

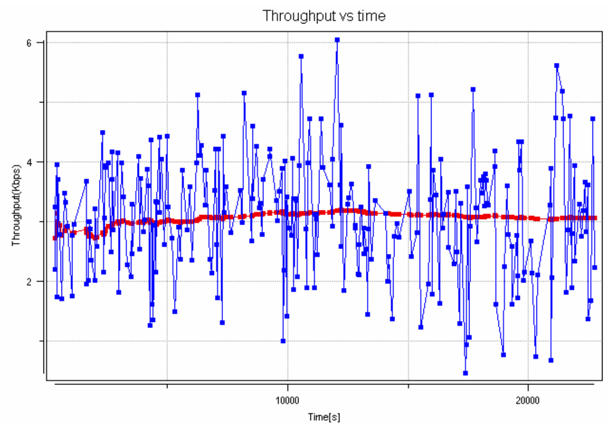
6. Simulation Results

OMNeTPP network simulator with mobility framework [20] is used to validate the proposed scheme with appropriate modifications. In our simulations, we evaluated the proposed RSVP-SWRESV integrated protocol maximized acceptance of requests. The following performance graphs measured throughput, packet delay, and overall delivery ratio.

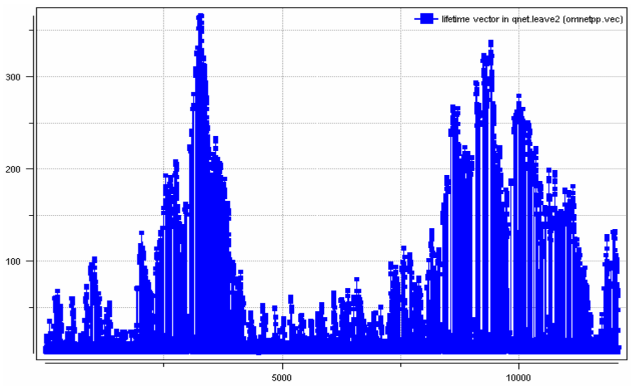
In this simulation, we compared the performance of the proposed RSVP-SWRESV scheme with the BASIC case of a wired-cum-wireless network without admission control enforced.

We first measured the overhead of signaling in our protocol for flow reservation and priority based admission control. In our simulation, the average reservation delay is very less as compared with the BASIC case of a wired-cum-wireless network without admission control, even when the channel is approaching saturation.

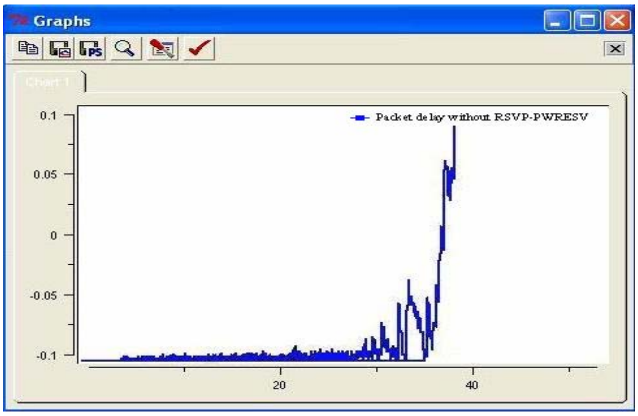
Therefore, per-flow overhead is acceptable. When network is saturated, first of all degradation process is carried out by degrading the request with the help of degradation degree and if at all resources are not available, all reservation requests from wireless senders are rejected at AP, and the error messages are returned immediately without going through the wired part. In this case, the signaling overhead is even smaller.



8 (a) Throughput



8(b) Packet delay with RSVP-SWRESV



8(c) Packet delay without RSVP-SWRESV

Fig. 8 Throughput and packet delay of an individual real-time flow

Note that this reservation delay includes the round-trip delay the source to the AP, then to the destination. The throughput and mean delay of the first real-time flow are depicted in Fig. (8). We can see that when the number of real-time flows increases, the network traffic keeps increasing without admission control. With the large traffic load, the BASIC scheme (plotted with red line) cannot effectively protect real-time flows. On the other hand, with the proposed RSVP-SWRESV scheme, real-time flows maintain satisfactory performance in terms of high throughput and low delay due to the rejection of new flows. With RSVP-RESV, the packet delay is always low, which is very desirable. In contrast, under the BASIC scheme, packet delays become more Fig.-8(c). We also calculated the overall delivery ratio of all real-time flows. We can see from Fig. 9 that after admitting few flows, the network is not able to support more real-time flows. However, without RSVP-SWRESV, all new flows are allowed to enter the wireless LAN. As a result, the delivery ratio decreases as the network is saturated.

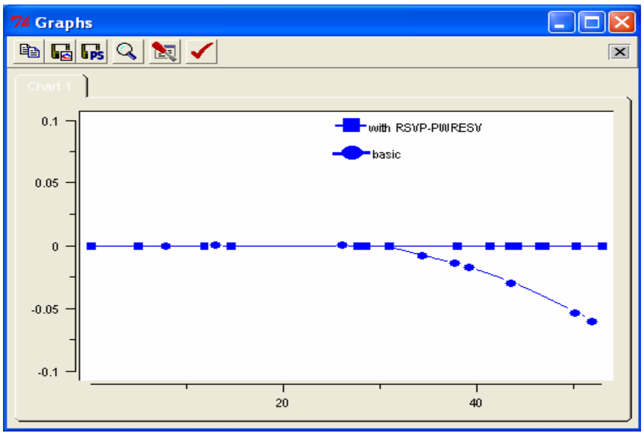


Fig. 9 Overall delivery ratio of real-time flows

7. Conclusion

Wireless users accessing Internet often require QoS guarantees from both the wireless and wired network. To address this issue, we proposed SWRESV, a general flow reservation, and admission control scheme for IEEE 802.11 wireless LANs, and investigated the integration of RSVP-SWRESV. The proposed priority based admission control scheme considers both features of RSVP thereafter before it moves out. Our results from figure 8a and 8b, 8c shows throughput and packet delay of an individual real-time flows have decreased to a great value showing better performance results of the network. Finally, we show the improvement of RSVP-SWRESV over BASIC on supporting seamless node mobility. Figure 9 shows that the overall mobility has also attained a constant value which was previously dropping after certain interval.
Extensive simulation results showed that the proposed framework can provide sufficient QoS support for real-time flows in heterogeneous wired/wireless networks.

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