RSVP Extensions for Seamless Handoff in Heterogeneous WLAN/WiMAX Networks

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ABSTRACT
Providing a seamless handoff for QoS connections in heterogeneous wireless local networks (WLANs) and worldwide interoperability for microwave access (WiMAX) networks is crucial. The handoff delay is one of the troublesome issues that users are facing in the heterogeneous WLAN/WiMAX networks. Many mobile users still cannot obtain the network resources they need when employing real-time services such as voices, video conferences, video IP phones, and so forth while a handoff occurs, which usually causes a serious delay or even a break of the link. Resource ReSerVation Protocol (RSVP) can provide the necessary QoS because of its bandwidth guaranteed capacity. In this paper, an RSVP extension scheme is proposed for seamless handoffs in the heterogeneous WLAN/WiMAX networks. The proposed scheme is based on QoS aware mobility architecture to guarantee a certain degree of QoS. The network selection is initiated by the mobility of the mobile station (MS) and a pre-handoff is performed based on received signal strength (RSS). Simulation results show that the proposed scheme outperforms the other two schemes.

Keywords: Handoff, heterogeneous wireless networks, QoS, WiMAX, WLAN.

1. Introduction

The IEEE 802.11 wireless local area network (WLAN) is rapidly becoming established because of its low cost and easy installment. Although a WLAN provides a higher speed data rate, it has only a small coverage area with limited mobility. It is generally deployed using a hotspot approach [1, 2]. Contrarily, the IEEE 802.16 WiMAX (Worldwide Interoperability for Microwave Access) network comparatively has a large coverage range per cell and guarantees the quality of service (QoS). It can connect sites to each other or work directly with end-user laptops and desktop systems, probably replacing all or part of the wired backbone [3, 4]. Though there is some overlap, the both standards have some important differences. The WLAN has already been widely deployed and the WiMAX network with its wide coverage is developing significantly.

However, when 802.11 WLAN and 802.16 WiMAX networks are combined, the situation becomes more complicated. The mutual interferences of devices or terminals from different subnets cause systems to become even more difficult. The completions between users in the same collision area trying to access a channel get quite fierce. Consequently, the wireless channel gets more unreliable because its performance deteriorates, even if the duration is short. Furthermore, the differences in delays and hardware resources of the different users make the handoff and roaming even more challenging.

New mobile devices such as PDAs, tablets, netbooks, and smartphones allow users to perform vertical handoffs among different wireless networks [5]. Providing a seamless handoff for QoS connections in heterogeneous WLAN/WiMAX networks is an important issue. However, in the wireless networks, many mobile users still cannot obtain the network resources they need when employing real-time services such as voices, video conferences, video IP phones, and so forth while handoff occurs, which usually causes a serious delay or even a break of the link. Resource ReSerVation Protocol (RSVP) can provide the necessary QoS because of its bandwidth guaranteed capacity. In this paper, an RSVP extension scheme is proposed for seamless handoffs in heterogeneous WLAN/WiMAX networks. The proposed innovative scheme is based on QoS aware mobility architecture to guarantee a certain degree of QoS.

The rest of this paper is organized as follows. In Section 2, related work is discussed. Our proposed scheme is developed in Section 3. Simulation results are given in Section 4. Finally, Section 5 draws the conclusions.

2. Related work

In this section, we first present the concept of RSVP and then give some related researches of this paper.

2.1 RSVP Overview

RSVP provides real-time and reliable services through the use of virtual circuits. It is a resource reservation setup protocol designed for the Integrated Services model [6, 7] and has a number of attributes that have led it to be adopted as an Internet standard approved by Internet Engineering Task Force (IETF). RSVP is not a routing protocol but a control protocol, which allows Internet real-time and reliable applications to reserve resources before they start transmitting data. When an application uses RSVP to request a specific QoS link for a data stream, RSVP selects a data path relying on the underlying routing protocols, and then reserves resources along the path according to the QoS. Since RSVP is receiver-oriented, each receiver is responsible for reserving resources to guarantee the QoS. Thus, the receiver sends an RESV message to reserve resources on all the nodes along the delivery path to the sender.

RSVP provides receiver-oriented setups of resource reservations for multicast or unicast data flows and adapts dynamically to changing group membership and routes. RSVP reserves resources for simplex flows, that is, it requests resources in only one direction. Two types of messages, PATH and RESV, are used in RSVP to set up resource reservation states on the nodes along the path between a sender and a receiver. Each PATH message sent by the source is associated with a specific data flow. When a PATH message traverse the path to the destination, it is intercepted by RSVP-enable IP routers on the path. The routers set up soft path states for the data flow. The path state includes the previous and next hops of the flow and its traffic characteristics. As the PATH message reaches the intended receiver, the receiver replies with an RESV message if it wants to make a reservation for the specific flow. The RESV message traverses the path back to the sender. If the required resources are available, a soft-state reservation is established in the router. Otherwise, an RESVErr message will be replied to the receiver.

2.2 Related Researches

With the growth of prevalent mobile wireless services, researches in wireless network have been increasing. Wang and Kuo [8] proposed an adaptive reservation mechanism for the next generation mobile communication systems. However, they do not apply it for heterogeneous wireless networks. Following this research, more QoS mechanisms for heterogeneous wireless networks have been proposed. Shenoy and Montalvo [9] proposed a global mobility management framework to support seamless roaming across heterogeneous wireless networks. Hasib and Fapojuwo [10] analyzed a radio resource management scheme for end-to-end QoS support in multi-service heterogeneous wireless networks. Al-Karaki and Kamal [11] proposed a virtual grid architecture protocol (VGAP) for heterogeneous mobile ad hoc networks. Although heterogeneity in QoS schemes had been investigated, RSVP was not taken into consideration.

Many researches have addressed the resource reservation in a mobile IP environment. Huang and Chen [12] proposed the RSVP extensions for Hierarchical Mobile IPv6 (HMIPv6) using multicast and new reservation mechanisms. When a mobile node enters the cell, the mobile proxy will inform the adjacent mobile proxies to join the multicast group. The mobile proxy where the mobile node may access in the future will receive PATH messages and make predictive reservations. Kuo and Ko [13] proposed the dynamic RSVP (DRSVP) with dynamically adjusted bandwidth resources in networks. In the scheme, the resource utilization can be improved by

DRSVP because it provides different video resolutions to different receiver nodes with different needed reserved resources. Huang et al. [14] proposed a DRSVP-based handoff scheme (DBHS) to support soft handoffs. In the proposed DBHS, the DRSVP tunnel is established as soon as possible to reduce handoff latency. Then, an optimal DRSVP tunnel may be established after a handoff to shorten the transmission delay.

Moreover, some researches have focused RSVP issue in heterogeneous wireless networks. Lee et al. [15] proposed a heterogeneous RSVP extension mechanism which allows mobile hosts to reach the required QoS service continuity while roaming across UMTS and WLAN networks. The RSVP mobility extension could acquire the required end-to-end QoS grades to maintain the service continuity of a mobile host. Chen et al. [16] proposed a seamless handoff for QoS connections in an 802.16/WLAN environment. The proposed dynamic bandwidth management scheme is to treat the layer 2 connection of 802.16 as a pipe that aggregates multiple layer 3 RSVP connections with the same class of service. The proposed scheme demonstrated a quite good performance in managing resources for RSVP connections in the 802.16/WLAN environment. However, this scheme had not investigated the selection of optimal routing path in the networks. Benoubira et al. [17] proposed the mobility and QoS management in heterogeneous wireless networks. With a HMIPv6 based architecture, the UMTS users can have a seamless roaming between networks without registration to GGSN/HA. In order to guarantee the QoS in a heterogeneous environment, Benoubira et al. also implemented MRSVP to make a resource pre-reservation before a handover from the WiMAX to UMTS.

3. Our proposed scheme

In this section, an RSVP extension scheme for seamless handoffs in heterogeneous WLAN/WiMAX networks is proposed. This scheme provides resource pre-reservations for real-time services.

3.1. System model

In heterogeneous WLAN/WiMAX networks, when a mobile station (MS) move away from a base station (BS) the signal level degrades and the MS needs to switch to another BS or access point (AP). The AP of the WLAN is attached to the subscriber station (SS) of the WiMAX. The MS is equipped with multiple wireless interfaces, including any combination of WLAN and WiMAX interfaces. When a user wants to access a given service or application, there may be various connectivity alternatives to select, and hence the main question is how to detect availability of multiple alternatives and select the most suitable one for a given type of service [18].

In order to manage the mobility of MSs and make the resource reservations for users, we propose an RSVP extension scheme for seamless handoffs. Figure 1 illustrates a handoff scenario for a heterogeneous WLAN/WiMAX network. In the system model, a gateway/QoS manager (GW/QM) mechanism is needed. GW/QM forwards the packets transmitted by the sender to an MS via a conventional reservation link. The arrow from the MS shows the direction it is moving in. SS/AP is the subscriber station of the WiMAX and the AP of the WLAN, respectively. No matter what the network is, all access the IP network through this gateway.

In Figure 1, MS_1 moves from the scope of SS_1/AP_1 to the scope of SS_2/AP_2, the related APs and gateways need to cooperate with MS_1 to select a network for sustaining services. In the system model, a reserve status report mechanism and a QM have been added. There are QMs in the gateway of a site which intercepts all incoming packets and changes route from regional care-of-address (RCoA) to local care-of-address (LCoA) of MSs according to the mapping table. Then, the intermediate routers forward the packets to MSs via LCoA. By means of this mechanism, BS_i or SS_i/AP_i periodically broadcast the Reserve Requirement Vector (RSRV) messages to change and collect all the related information.

Before starting, some QoS parameters which will influence the determination policies are obtained by interacting with MS_1. Other information needed includes: neighboring BS_i or SS_i/AP_i, characteristic parameters of link states such as residual bandwidth, round trip time, and resource RSRVs.

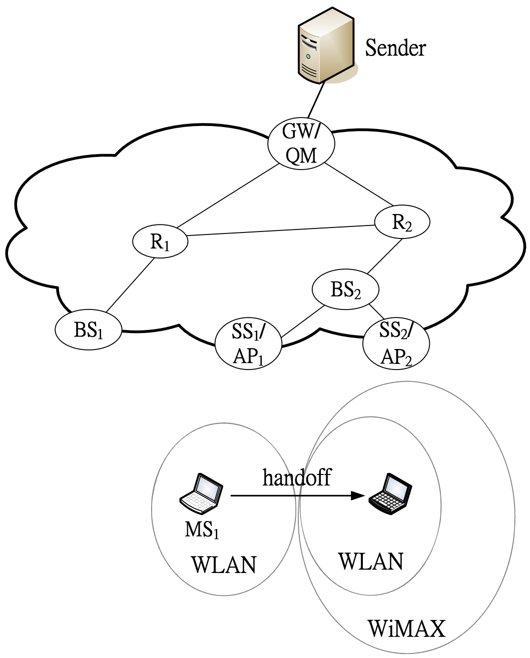

Figure 1. A handoff scenario for a heterogeneous WLAN/WiMAX network.

3.2. RSRV

The proposed scheme includes a handoff decision process and a network selection process. The network selection is also called a pre-handoff. Besides, it needs a data structure RSRV, which is a multi-parameter vector defined as follows:
RSRV={S, Ch, LPR}, where

- S is the information about the *received signal strength (RSS)* of MS_1 from BS_i or SS_i/AP_i. According to the value of S, the distance between them can be estimated to make a resource reservation decision.

- Ch=(RB, DT) is the QoS resource parameter of a relay node to its neighboring nodes, where RB is the residual bandwidth and DT is the delay time from it to its neighboring nodes. By periodically broadcasting RSRV messages, BS_i or SS_i/AP_i exchange and collect all the related information to update their routing tables accordingly. CH can be taken as the measurement when establishing the resource reservation path.

- LPR is the lost packet rate. A handoff will happen when $LPR_i > LPR_{th}$, where LPR_{th} is a predefined threshold value for LPR. MS_1 knows the status of the neighboring SS_i/AP_i and BS_i via the RSRV. MS_1 then chooses either BS_i or SS_i/AP_i, the one which satisfies the requirements, and sends the notification information to set up the resource reservation path.

3.3. Reservation management

The resource reservation for MS_1 is decided according to the RSS of MS_1 from BS_i or SS_i/AP_i. As shown in Figure 2, the RSS is divided into two threshold values applied to decide how to tackle the situation. In Figure 2, the tracks of the MS_1 are consistent with the changing RSS and network status.

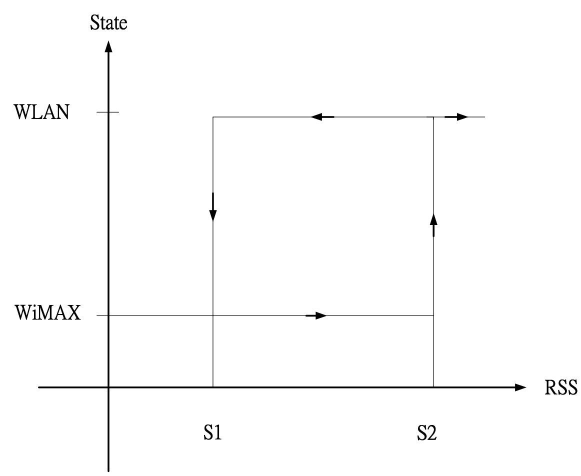

Figure 2. Changing of network status with different RSS thresholds.

Assume that MS_1 moves from the WLAN to WiMAX network coverage area. If the RSS of MS_1 from the WLAN is less than threshold S_2, QM will make a pre-reservation for MS_1. To allocate resources of the WiMAX, QM notifies the corresponding active BS_i to make a pre-reservation for MS_1. If the RSS drops below threshold S_1, QM switches the data flow to an active reservation path for MS_1. On the other hand, if the RSS from either the old SS_i/AP_i or the new one is less than threshold S_1, the corresponding link is released immediately.

Contrarily, assume that MS_1 moves from the WiMAX to WLAN network coverage area. If the RSS of MS_1 from the WLAN is higher than threshold S_1, MS_1 sends a notification message to QM to notify the corresponding active SS_i/AP_i to make a pre-reservation for MS_1. If the RSS is higher than threshold S_2, QM switches the old reservation path to the new one by performing a seamless handoff and sends a message to request deleting the BS_i reservation path. In a horizontal handoff, MS_1 sends a notification message to QM to notify target BS_i or SS_i/AP_i to make a pre-reservation when it receives the RSS higher than threshold S_1. On the other hand, if MS_1 receives the RSS higher than threshold S_2, QM switches the data flow to the active reservation path.

3.4. Handoff decision and network selection

A handoff for an MS move from the WLAN to WLAN/WiMAX area, as shown in Figure 3, is described in detail as follows:

1. The RSS received by MS_1 from BS_i or SS_i/AP_i is so weak that it is lower than $signal_{th}$.

2. Ch = (RB, DT) is the QoS resource parameter, where RB and DT are employed as QoS metrics for feasible path computation. Initially, MS_1 is in SS_1/AP_1. When MS_1 moves to SS_2/AP_2, there are four paths to choose: P_1={SS_2/AP_2, BS_2, R_2, GW/QM}, P_2={SS_2/AP_2, BS_2, R_2, R_1, GW/QM}, P_3={BS_2, R_2, GW/QM}, and P_4={BS_2, R_2, R_1, GW/QM}. The QoS resource parameters of the four paths are shown as Table 1. In this scheme, the MS selects the path with maximum RB. If the conditions are the same, then MS selects the one with minimum DT. With the maximum RB and minimum DT, P_4 is selected consequently.

3. A notification message is sent from MS_1 to SS_1/AP_1 to notify GW/QM of the visiting location and mobile profile.

4. When receiving the notification message, SS_1/AP_1 forwards it to BS_2 and subsequently BS_2 forwards it to GW/QM along P_4.

5. After receiving the notification message, GW/QM terminates the message.

6. A DSA-REQ message is sent from GW/QM to SS_2/AP_2 along P_2.

7. When receiving the DSA-REQ message, SS_2/AP_2 forwards the PATH message to MS_1. Besides, SS_2/AP_2 forwards the DSA-RSP message to GW/QM along P_2 as well.

8. An RESV message is sent from MS_1 to SS_2/AP_2.

9. Finally, the newly established path is SS_2/AP_2–BS_2–R_2–R_1–GW/QM. Therefore, the RSVP tunnel from sender to MS_1 is {GW/QM, R_1, R_2, BS_2, SS_2/AP_2}.

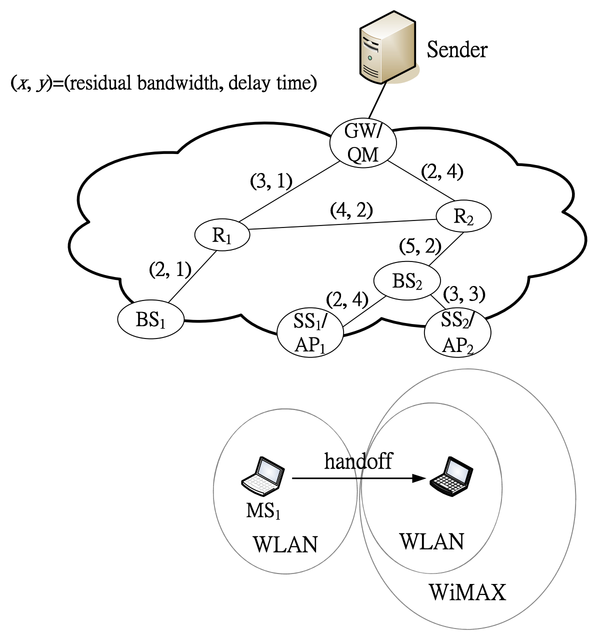

Figure 3. A handoff for an MS move from the WLAN to WLAN/WiMAX area.

Path	CH of each node	RB (Mps)	DT (second)
P_1	{(3, 3), (5, 2), (2, 4)}	2	9
P_2	{(3, 3), (5, 2), (4, 2), (3, 1)}	3	8
P_3	{(5, 2), (2, 4)}	2	6
P_4	{(5, 2), (4, 2), (3, 1)}	3	5

Table 1. The QoS resource parameters of the four paths.

The handoff decision process is illustrated as in Figure 4. The network selection is based on an RSRV message which denotes the reservation results and comes from neighboring SS_i/AP_i or BS_i. If a better network for the current MS_1 is not available, the network selection or handoff will be rejected. In this situation, a new call admission will be blocked and the mobile handoff call will be dropped.

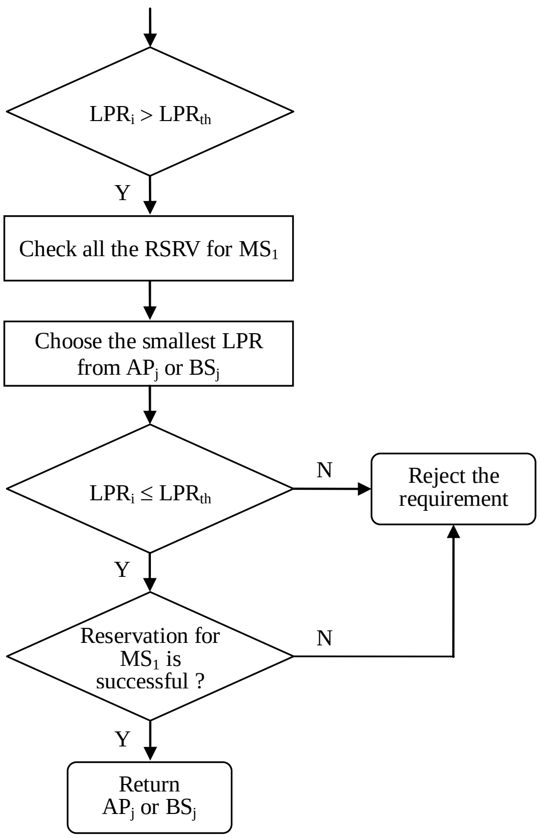

Figure 4. Handoff decision process.

4. Performance evaluation

We conducted a simulation on the OPNET 11.5 platform to evaluate the performance of the proposed scheme. In the system model, we assumed that an MS which moved in a random direction at the speed of 0-5 m/s. Two kinds of BS or SS/AP, linked together through gateways, followed the MS's tracks and were responsible for exchanging the packets and maintaining the QoS paths. The WLAN had a 2 Mbps bandwidth and the WiMAX had a bandwidth of 4 Mbps for downlinking and 2 Mbps for uplinking. The radiuses of the WLAN and WiMAX were 100 m and 1 km, respectively. Their distribution was random.

In the physical model, the channel power gain was 4 dB and the bit error rate was 10^{-3}. The lost packet probability was 0.008, while the data rate of the WLAN was 1 Mbps and that of the WiMAX was 384 Kbps. The transmission power of BS or SS/AP was 23 dBm and that of MS was 3 dBm.

A network handoff strategy called No Reservation Handoff Scheme (NRHS) was assumed for the necessity of comparison. In NRHS, none of the BS or SS/AP reserved any resource for MS. The negotiation was initiated whenever the MS became aware of being necessary between the MS and the target BS or SS/AP.

At first, Figure 5 shows the handoff blocking probabilities of NRHS, RSVP, and the proposed schemes in terms of different mobility speeds. In Figure 5, most of the handoff requests were rejected when the MS moved faster than 1 m/s. In the proposed scheme, the mobility of MS could predict and the resources were reserved accordingly, so most of the handoff requests were satisfied when they moved in the BS or SS/AP coverage of others. However, the handoff blocking probability was still high owing to the cost was too high for reserving resources in the RSVP scheme. The failed handoff will immediately lead to another request.

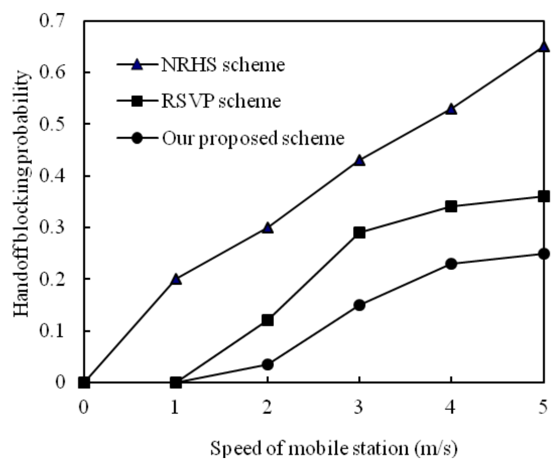

Figure 5. Handoff blocking probability vs. speed of mobile station.

Figure 6 illustrates the performance of the lost packet probability with a different number of nodes. It can be observed that the proposed scheme performed better than the other two schemes with lost packet probability lower than 3.5%.

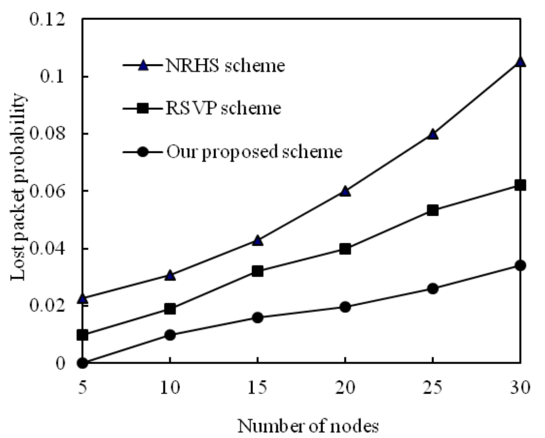

Figure 6. Lost packet probability vs. number of nodes.

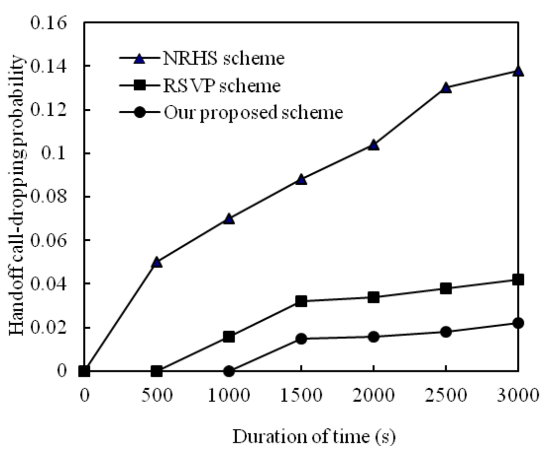

Figure 7. Handoff call dropping probability vs. duration of time.

Figure 7 demonstrates the handoff call-dropping probability of the three handoff schemes. As a result, the performance of the proposed scheme is also superior to that of NRHS and RSVP schemes. It's necessary for an MS to switch to another service network when there is no resource. A completely successful handoff cannot be guaranteed due to the absence of resources. Therefore, the situation starts deteriorating because the MS initiates another call once it fails. Although the proposed scheme reserves resources for the MS in the coverage of the neighboring BS or SS/AP, the dropping of some handoff calls cannot avoided when the resource unavailable to reserve for them in the target BS or SS/AP.

The cancellation probability due to false resource reservation for the three schemes is shown in Figure 8. It is obvious that the cancellation probability does not fluctuate until the number of WLANs exceeds 15. The proposed scheme also outperforms the other two schemes.

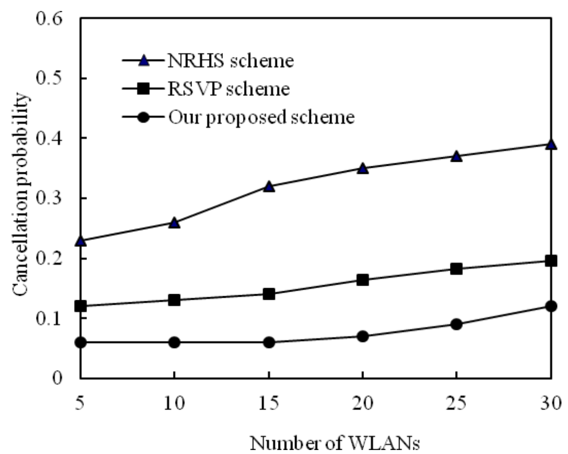

Figure 8. Cancellation probability vs. number of WLANs.

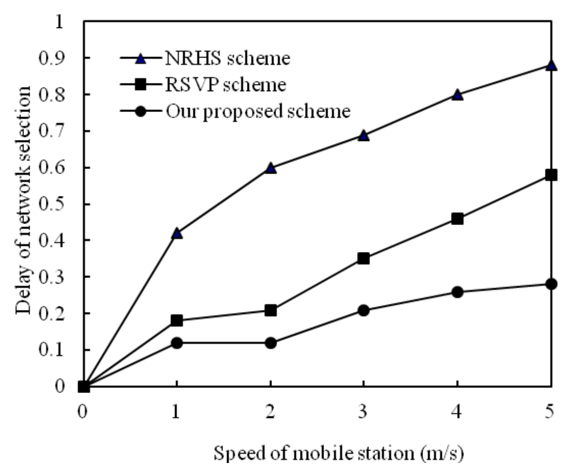

Figure 9. Delay of network selection vs. speeds of mobile station.

Figure 9 shows the delay of network selection under different mobility speed for the three handoff schemes. In the proposed scheme, the neighboring BS or SS/AP always reserves resources for MSs, hence network selection is timely. It is observed that the delay of network selection of NRHS scheme doubles that of the proposed scheme. The handoff delay of the proposed scheme is still stable.

5. Conclusions

With the development of real-time applications and wireless communications, there are growing demands for supporting different types of services such as QoS guarantees and seamless roaming across different types of wireless networks. To provide real-time access services, an enhanced handoff controlling architecture is required for a heterogeneous wireless network. In this paper, an RSVP extension scheme for seamless handoffs in heterogeneous WLAN/WiMAX networks is proposed. This scheme is based on QoS aware mobility architecture to guarantee a certain QoS.

In order to manage the mobility of mobile users, the proposed scheme adopts the concept of a pre-handoff which allowed the BS or SS/AP to reserve some resources and do re-routing beforehand. Simulation results show that the proposed scheme outperforms the other two schemes.

Acknowledgements

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