RSVP Extensions for Seamless Handoff with QoS Aware in Heterogeneous WLAN/WiMAX Networks

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***Abstract*—In this paper, we propose an RSVP extension scheme for seamless handoff in heterogeneous WLAN/WiMAX networks. This scheme is based on QoS aware mobility architecture to guarantee a certain QoS. The network selection is initiated by the mobility of the MS and pre-handoff is performed based on signal strength. On the other hand, if the selection is triggered by congestion, the handoff is based on congestion controlling delay according to the QoS parameters. Simulation results show that the proposed scheme outperforms previous schemes.**

***Index Terms*—Handoff, heterogeneous wireless networks, quality of service, WiMAX, WLAN..**

I. Introduction

In the recent evolution of wireless mobile networks, which are characterized by great heterogeneity, quality of service (QoS) is most important and cannot be ignored. QoS is specified usually as a set of parameters at the user level. These QoS parameters are then mapped or translated into resource requirements for the architectural layers (e.g. CPU, memory, etc. for the operating system and bandwidth, buffers, etc. for the network). When the resource requirements have been determined, a negotiation process takes place between the network and the called user application to set up a contract detailing the level of resources committed by each party. The level of committed resources might or might not be the same as the original level of requirements, depending on the capabilities of the components involved and the availability of resources. If the level of resources committed by the various parties is acceptable to the calling user application, a contract is set up and the application is admitted to the system, otherwise it is not. Once a contract is agreed on, the application can be started and a policing mechanism ensures that the various parties abide by the contract. Non-conformance by the parties involved might lead to the termination of the application.

The IEEE 802.11 WLAN (Wireless Local Area Network) is rapidly becoming established. It is cheap and easy to install. WLAN provides a higher speed data rate but covers only small areas and allows limited mobility. It is normally deployed using a hotspot approach. In comparison, WiMAX (Worldwide Interoperability for Microwave Access) has a large coverage range per cell and guarantees the quality of service. There are a variety of enterprise network architectures that can be implemented using 802.16e. This technology could connect campuses or could work directly with end-user laptops and desktop systems, replacing all or part of the wired backbone. While there will certainly be some overlap, the two standards have some important differences. WLAN has already been widely deployed and WiMAX with its wide coverage is developing dramatically. It is a basis for the next generation technology because of its IP architecture and QoS support guarantee.

However, when 802.16 WiMAX and 802.11 WLAN networks are combined, the situation becomes more complicated. The mutual inferences of devices or terminals from different subnets cause systems to become even more problematical. The completions between users in the same collision area trying to access a channel gets 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.

Providing a seamless handoff for QoS connections in heterogeneous WLAN/WiMAX environments becomes important. However, in the wireless networks used today, many mobile users still cannot obtain the network resources they need when employing real-time services like voice, video conferences, video IP phone, and so forth while handoff occurs, and it causes a serious delay or even the break of the link.

There are many researches focused on improving RSVP solution in heterogeneous networks [6, 10]. RSVP can provide the necessary QoS because of its bandwidth guaranteed capacity. However, RSVP cannot provide a resource reservation mechanism that is sufficiently flexible and suitable. In this paper, a RSVP extension scheme is proposed for seamless handoff in heterogeneous WLAN/WiMAX networks. The proposed scheme is based on QoS aware mobility architecture to guarantee a certain QoS.

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

II. Related Work

This section presents the RSVP overview and the related researches.

A. RSVP Overview

Resource Reservation Protocol (RSVP) provides real-time and reliable service through the use of virtual circuits. It is a resource reservation setup protocol designed for the Integrated Services (IntServ) [2, 11] model and has a number of attributes that have led to it being 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. This means that when an application uses RSVP to request a specific link QoS for a data stream, RSVP selects a data path relying on underlying routing protocols, and then reserves resources along the path according the QoS. As long as RSVP is receiver-oriented, each receiver is responsible for reserving resources to guarantee QoS. Thus, the receiver sends an RESV message to reserve resources along all the nodes on the delivery path to the sender.

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

B. Related Researches

With the increase of pervasive mobile wireless services, research in wireless network has been increasing. In [7] and [8], Huang and Kuo et al. propose an adaptive reservation mechanism for the next generation mobile communication systems. However, they do not apply it for heterogeneous networks. Following this research, more QoS mechanisms for heterogeneous wireless networks have been proposed [1, 5, 9]. Furthermore, Dai et al. propose a new user-centric algorithm for vertical handoff in heterogeneous wireless networks [4]. This scheme combines one trigger to maintain the connection and another one to maximize the user throughput. However, reserving resources for mobile stations necessary for handoff between BS and AP was not considered.

For WLANs, QoS management has been defined by IEEE 802.11. The QoS mechanism for 802.11 cannot be directly applied in the 802.16e environment. Several studies have addressed resource reservation in 802.16e or 802.11 [6, 7, 10]. However, few have addressed the QoS in the heterogeneous WLAN/WiMAX environment [3].

III. Proposed RSVP Extension Scheme In Heterogeneous WLAN/WiMAX Networks

In this section, a RSVP extensions scheme for seamless handoff in heterogeneous WLAN/WiMAX networks is proposed. This scheme provides pre-reservation for real-time services.

A. System Model

In heterogeneous WLAN/WiMAX networks, when an MS move away from a BS the signal level degrades and the MS needs to switch to another BS or AP. The access point (AP) of WLAN is attached to the subscriber station (SS) of WiMAX. The MS is equipped with multiple wireless interfaces, including any combination of WiMAX and WLAN interface. When a user wants to access a given service or application, there may be various connectivity alternatives to select from, 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 [4].

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

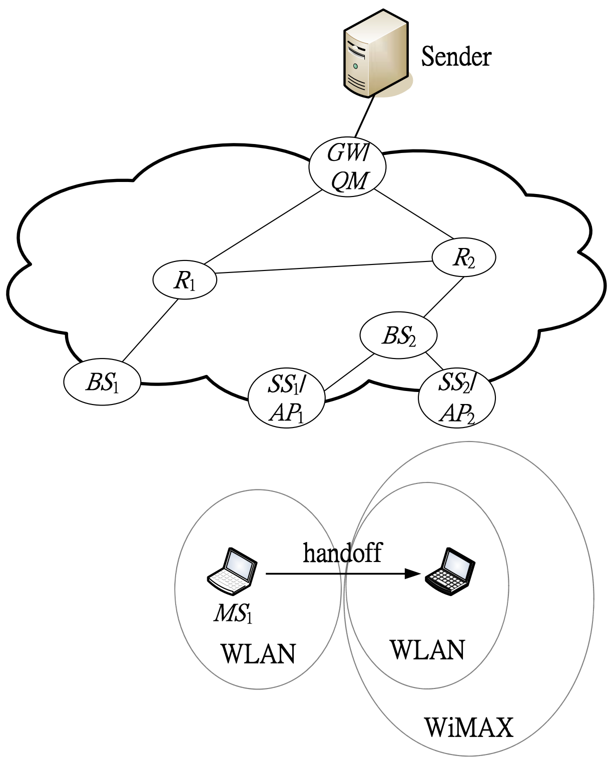

Fig. 1. Handoff scenario for a heterogeneous WLAN/WiMAX network.

In Fig. 1, MS_1 moves from the scope of SS_1/AP_1 to the scope of SS_2/AP_2, the related access points and gateways need to cooperate with MS_1 to select a network for sustaining service. In the system model, a reserve status report mechanism and a QoS manager (QM) have been added. There are QMs in the gateway of a site which intercept 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. Through this mechanism, BS_i or

SS_i/AP_i periodical broadcast the Reserve Requirement Vector (RSRV) message. The RSRV message, including multi-parameters vectors BS_i or SS_i/AP_i exchanges and collects all the related information.

Before starting, some QoS parameters which will influence the determining policies are obtained by interacting with MS_1. Other information needed includes: neighboring SS_i/AP_i or BS_i, characteristic parameters of link states such as residual bandwidth, round trip time etc., and resource reserving requirement vectors. Once there is a new call, MS_1 sends the requirements through call admission. Because it is assumed that there is no priority in the network situations and no exact measurements as guideline, some statistic parameters are included in the algorithm.

B. Proposed Scheme

The proposed scheme includes a handoff decision, and network selection which is also called pre-handoff, and then the actual handoff. Furthermore, it also needs a data structure, the reserve requirement vector RSRV. The RSRV is a multi-parameters vector defined as follows:

RSRV={**S**, **Ch**, **LPR**}, where

- **S** is the information about the signal (*Receive Signal Strength, RSS*) of MS_1 for BS_i or SS_i/AP_i received. **S** is the received signal *strength* of the MS_1. Through the value of **S**, the distance between them can be estimated leading to a resource reserving decision.
- **Ch**=(BW, DT) is the QoS resource parameter of every relay node still residual, where BW is the residual bandwidth for a relay node and DT is the delay time from it to the neighboring nodes. Through the periodical RSRV broadcasting of BS_i or SS_i/AP_i, they exchange and collect all the related information. Accordingly, they update the routing tables. Actually, **Ch** is determined by choosing the maximum residual bandwidth path with the minimum delay for each route. Utilizing this metric, all information about each node becomes available and this metric can be taken as the measurement when establishing the resource reservation path.
- **LPR** is the lost packet rate (LPR). There is a predefined threshold value for LPR, LPR_{th}. The handoff will happen when $LPR_i > LPR_{th}$. MS_1 knows the status of the neighboring SS_i/AP_i or BS_i via the RSRV. MS_1 then chooses either BS_i or SS_i/AP_i; the one which satisfies the requirements and then sends the notification information to require the set up of the resource reservation path.

C. Reserving Management

The resources reservation for MS_1 is decided according to the signal strength (RSS) by MS_1 from BS_i or SS_i/AP_i. As shown in Fig. 2, the RSS is divided into two phases threshold values which are used to decide how to tackle the situation. In Fig. 2, the tracks of the MS_1 are consistent with the changing RSS and network status.

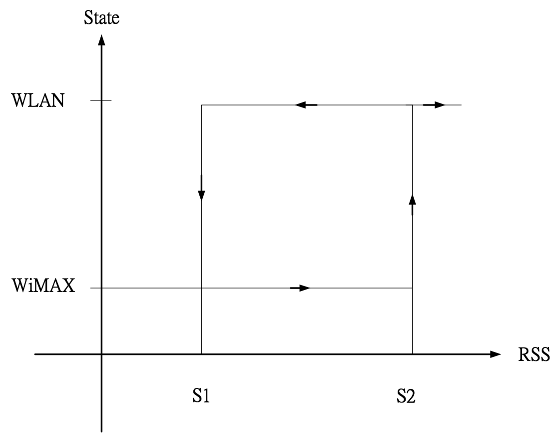

Fig. 2. Changing of network status with different RSS thresholds.

Assume that MS_1 moves from WLAN network coverage area to WiMAX network coverage area, if MS_1 receives no other RSS from the WLANs and the RSS by MS_1 from WLAN is less than threshold S_2, as shown in Fig. 3, QM will make a pre-reservation for MS_1. To allocate resources for the WiMAX network, QM notifies the corresponding active BS_i to make a pre-reservation for MS_1. If the received signal 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.

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

D. Handoff Decision and Network Selection

In the case of any one of the following situations, SS_i/AP_i or BS_i need to decide if a call admission for MS_1 needs to perform handoff:

1. The signal received by MS_1 from BS_i or SS_i/AP_i is so weak it is lower than $signal_{th}$.
2. **Ch** is the QoS resource parameter that considers bandwidth and delay time as QoS metrics, for feasible path computation. For example, as shown in Fig. 3, this process in detail as follows:

(1) In the initial state, MS_1 is in SS_1/AP_1, and moves to SS_2/AP_2.

(2) When MS_1 moves to SS_2/AP_2, there are four paths to choose from. MS_1 tries to find the optimal route to sender, which is 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}. P_1= {(3, 3), (5, 2), (2, 4)}, the maximum bandwidth of the reserved path is 2 Mbps, delay time is 9 seconds. P_2={(3, 3), (5, 2), (4, 2), (3, 1)}, the maximum bandwidth of the reserved path is 3 Mbps, delay time is 8 seconds. P_3={(5, 2), (2, 4)}, the maximum bandwidth of the reserved path is 2 Mbps, delay time is 6 seconds. P_4={(5, 2), (4, 2), (3, 1)}, the maximum bandwidth of the reserved path is 3 Mbps, delay time is 5 seconds. As a result, MS_1 chooses the path with maximum residual bandwidth, P4. If the conditions are the same, then MS_1 selects the minimum delay time path.

(3) The optimal route is based on signal strength. In this case, MS_1 chooses P_2 to establish a RSVP path.

(4) A notification message is sent from MS_1 to SS_1/AP_1. This message is used by MS_1 to notify GW/QM of the visiting location and mobile profile.

(5) When receiving the notification message, SS_1/AP_1 forwards it to BS_2.

(6) BS_2 receives the notification message, it forwards it to GW/QM along P_2.

(7) GW/QM receives the notification message, it terminates the message.

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

(9) When receiving the DSA-REQ message, SS_2/AP_2 forwards the PATH message to MS_1. At the same time, SS_2/AP_2 forwards the DSA-RSP message to GW/QM along P_2.

(10) Then, a RESV message is sent from MS_1 to SS_2/AP_2.

(11) Now, the newly established path is SS_2/AP_2-BS_2-R_2-R_1-GW/QM. So, the RSVP tunnel from sender to MS_1 is {GW/QM, R_1, R_2, BS_2, SS_2/AP_2}.

3. SS_i/AP_i or BS_i is too busy to satisfy current connection service, in this situation which can be measured in terms of LPR. Therefore, the handoff decision mainly takes the responsibility to check these two conditions periodically. Once any of them occurs, the handoff control algorithm has to choose a network for the call admission.

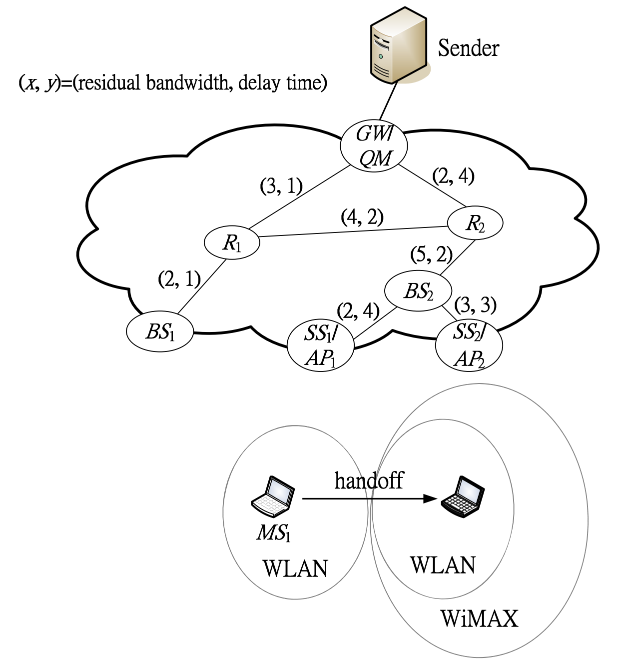

Fig. 3. Handoff for an MS move from the WLAN to WLAN/WiMAX area.

IV. PERFORMANC EVALUATION

In order to evaluate the performance of the proposed scheme by the different metrics in the whole network, a simulation was designed and conducted, simulations were carried out on the OPNET 11.5 platform. In the system model, we assumed that an MS which moves in a random direction at the speed of 0-5 m/s. Two kinds of BS or SS/AP, linked together through gateways, follow the MS's tracks and are responsible for exchanging the packets and maintaining the QoS paths. It was assumed that the WLAN network had a 2 Mbps bandwidth and the WiMAX network a bandwidth of 4 Mbps for downlinking and 2 Mbps for uplinking. The radius of the WLAN was 100 m, 1 Km for WiMAX BS, and their distribution was random.

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

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

In Fig. 4, the handoff blocking probabilities were compared for different mobility speed for NRHS, RSVP, and the proposed schemes. The BS or SS/AP was reserved for all the MS in the neighboring area. Accordingly, most of the handoff requests were rejected when the MS moved faster than 1 m/s because there was no reservation. In the proposed scheme, most of the handoff requests were satisfied when they moved in the BS or SS/AP coverage of others. That was because the mobility of MS could predict and the resources were reserved accordingly. However, the handoff blocking probability was still high when the cost was too high for reserving in the RSVP scheme. The failed handoff would immediately result in another request.

Fig. 5 shows 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 and its lost packet probability was lower than 3.5%.

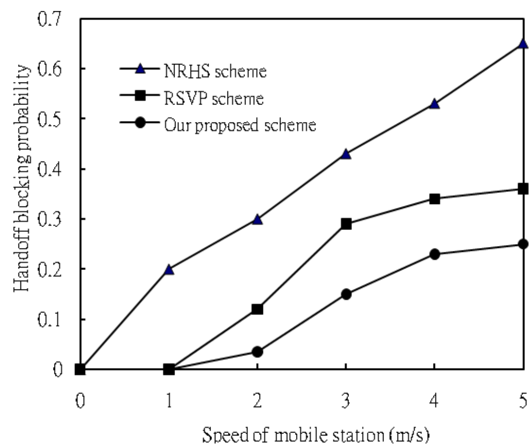

Fig. 4. Handoff blocking probability vs. speed of mobile station.

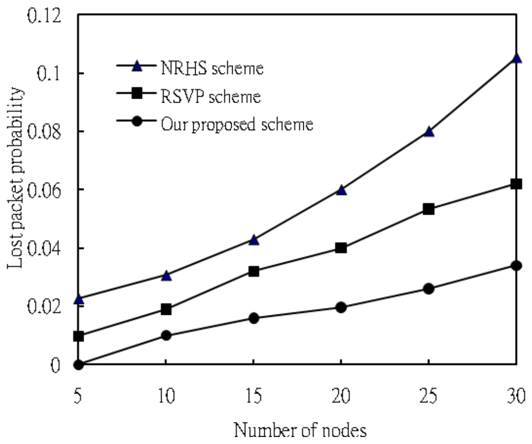

Fig. 5. Lost packet probability vs. number of nodes.

V. CONCLUSIONS

In this paper, a RSVP extension scheme for seamless handoff 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, by resource reservation and precise pre-handoff decisions, the concept of pre-handoff which allowed the BS or SS/AP to reserve some resources and do re-routing beforehand was adopted. Simulation results show that the proposed scheme outperforms previous schemes.

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