RSVP Extended QoS Support for Heterogeneous Two-Tier Personal Communication Systems[1]

Long-Sheng Li sheng@mail.ncyu.edu.tw
Department of Computer Science and
Information Engineering
National Chiayi University
300 Syuefu RD., Chiayi City, 60004, Taiwan, R.O.C.

Gwo-Chuan Lee gclee@nuu.edu.tw
Department of Computer Science and
Information Engineering
National United University
1 Lien Da, Kung Ching Li, Miaoli,360, Taiwan, R.O.C.

Wei-Yu Chien tuna@csie.ncyu.edu.tw
Department of Computer Science and
Information Engineering
National Chiayi University
300 Syuefu RD., Chiayi City, 60004, Taiwan, R.O.C.

Abstract

The popularity of UMTS and WLAN networks is often combined into two-tier heterogeneous networks. Therefore, it is important for mobile hosts to have an end-to-end QoS support for service continuity in the UMTS/WLAN interworking systems. To maintain mobility in the QoS control of multimedia services when integrating UMTS and WLAN networks, an efficient resource management mechanism for the two-tier network is necessary. This paper proposes a heterogeneous RSVP extension mechanism, denoted as HeMRSVP (Heterogeneous Mobile RSVP), which allows mobile hosts to reach the required QoS service continuity while roaming across UMTS and WLAN networks. A performance comparison of HeMRSVP and conceivable two-tier resource management schemes is presented. Besides, two approaches were studied, namely hierarchical reservations as well as repacking on demand, for the performance enhancement of HeMRSVP. Numerical results show that the HeMRSVP significantly outperforms other two-tier resource management schemes and the enhanced mechanisms perform well in UMTS/WLAN combination networks.

Keywords: Heterogeneous Networks, Mobility, QoS, RSVP, UMTS, WLAN.

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1. INTRODUCTION

With the rapid development of Wireless Local Area Networks (WLAN) technology, WLAN has become the most popular wireless access system. However, due to the small coverage area of an 802.11 WLAN base station and the low capacity of the Universal Mobile Telecommunications System (UMTS), the integration of cellular systems and WLAN has been studied in recent years. Some two-tier architectures for integrating UMTS and WLAN networks have been proposed to compensate for the defects of the two systems. Much of the research discusses mobility management and interworking for the two-tier integration of UMTS and WLAN networks [15], [16]. Providing mobile hosts with QoS-guaranteed handoffs in the heterogeneous wireless networks has not been thoroughly studied yet [1].

For traditional wireless Internet environments, some schemes have been proposed to achieve the mobility independence of QoS-guaranteed services [2]. Mobile RSVP (MRSVP) resolves the mobility impacts on RSVP by making advance resource reservations in all neighboring subnets [3], [4]. Hierarchical Mobile RSVP (HMRSVP) [5] uses Mobile IP regional registration and thus makes fewer advance resource reservations that would diminish bandwidth consumption. The effective QoS-supported architecture for resolving Mobile IP triangular routing problems in all-IP wireless networks is also proposed [6]. However, these approaches do not clearly describe how an end-to-end QoS-guaranteed mechanism can be deployed in heterogeneous wireless networks. Recently, the issue of integrating cellular and WLAN-based systems has stimulated a lot of interest amongst researchers; all trying to improve technologies. A UMTS-WLAN dual-mode user can retrieve high data rate services through WLAN networks, while using UMTS to continue working on the Internet where WLAN does not support it. In the discussion of heterogeneous wireless networks, the Third Generation Partnership Project (3GPP) TS 23.207 has developed the combination of RSVP with integrated UMTS and WLAN networks [7]. In fact, many proposals for mobility management on roaming across UMTS and WLAN have been made [8], [9], [10]. How to provide mobile hosts with QoS-guaranteed continuity services in the integration of UMTS and WLAN networks has not been studied much, and thus the study of an efficient resource reservation mechanism in two-tier networks is necessary, especially for multimedia services.

The remainder of this paper is organized as follows. In Section 2, the integration of UMTS and WLAN networks is described and a heterogeneous RSVP extension is proposed for an end-to-end QoS support. Section 3 presents six schemes for two-tier resource management in UMTS/WLAN interworking networks, a two-tier simulation model, two enhanced HeMRSVP approaches, and the evaluation results of these schemes. Finally, some conclusions are drawn in Section 4.

2. HETEROGENEOUS END-TO-END QOS-GUARANTEED MECHANISMS

DiffServ and IntServ are the main strategies for resolving QoS-guaranteed services in the Internet. Much research claims that DiffServ can provide better performance than IntServ do. However, because DiffServ does not provide enough resources to maintain an end-to-end QoS support for service continuity in mobile environments, some research has been done on integrating the benefits of DiffServ and InteServ to compensate for the insufficiency of DiffServ [11]. This approach for RSVP extension uses DiffServ control in the core networks of the Internet and exercises IntServ on the edge router of the core networks. Thus the RSVP extension approach could provide an end-to-end QoS support for real-time multimedia services in mobile environments. The study on end-to-end QoS-guaranteed mechanisms for heterogeneous wireless networks in this paper is based on the above RSVP extension approach. This paper focuses on the study of resource management of the RSVP extension to supply end-to-end QoS-guaranteed services in UMTS/WLAN interworking networks.

In 3GPP TR 23.207, the approach of RSVP/IntServ has been deployed in the architecture of UMTS to achieve end-to-end QoS-guaranteed services [7]. It combines the Proxy-Call Session Control Function (P-CSCF) with a Gateway GPRS Support Node (GGSN) to support the policy decision functions of an admission control and thus to comply with service-based local policies. However, this approach of RSVP extension will have a great impact on the mobility of all-IP wireless networks. In the following subsections, a modified RSVP extension of QoS-guaranteed mechanisms is proposed, which can be deployed in UMTS/WLAN interworking systems to resolve the mobility impact on heterogeneous networks.

2.1 The Integrating of UMTS and WLAN Networks

As **FIGURE 1** shows, 3GPP TR 22.934 introduces an interworking architecture for UMTS and WLAN [10], [12]. In this architecture, the WLAN-based GPRS Support Node (WGSN) combines UMTS with WLAN to support the first stage deployment for commercial operations of cellular/WLAN combinations. When a Mobile Host (MH) is equipped with both a WLAN card and a GPRS/UMTS module, it is allowed to roam between UMTS and WLAN. WGSN can communicate with the Home Location Register (HLR) to support roaming operations following the standard GPRS/UMTS mobility management mechanism. In this scenario, the WGSN node allows the MH to access mobile Packet Switched (PS) services via the WLAN. Besides, the WGSN acts as a router to interact with the MH by using the standard IP protocol. That is, the WGSN can monitor and control all the data flows for the MH. In our approach, the Mobility Agent (MA) used in Mobile IP is integrated into the WGSN node to facilitate the IP mobility of UMTS/WLAN interworking. This approach is similar to the integration of MA and GGSN proposed in 3GPP TR 23.923 [9].

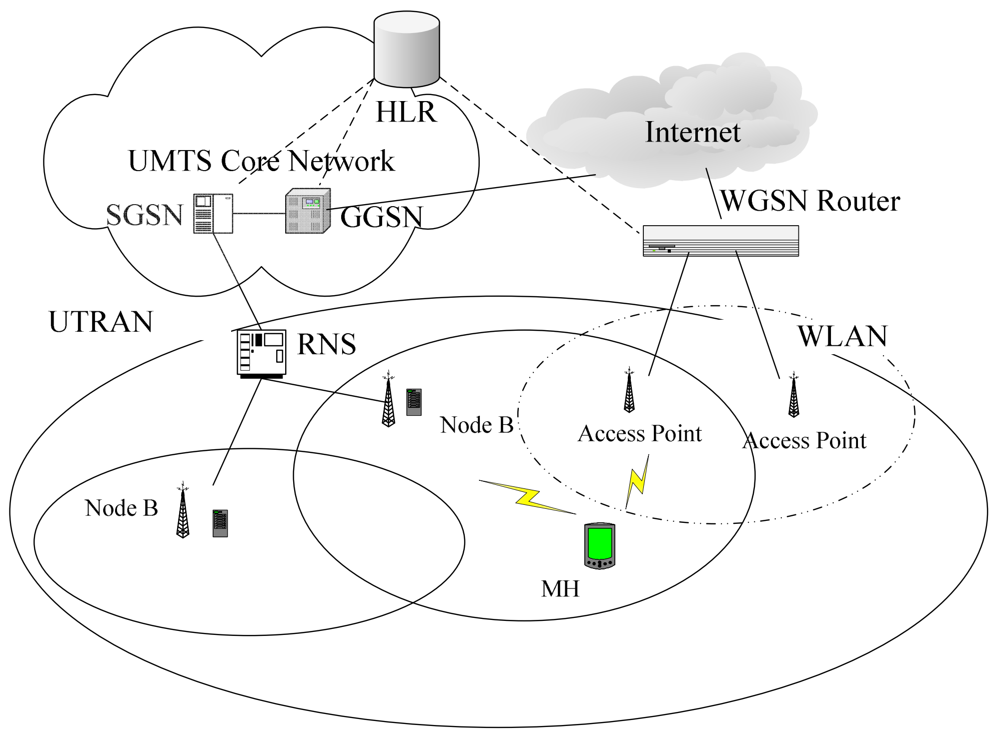

FIGURE 1: Integrating of UMTS and WLAN by Deploying WGSN.

2.2 RSVP Extension in Heterogeneous Wireless Networks

In this subsection, a mechanism for resource management in the heterogeneous wireless networks is proposed. The mechanism provides end-to-end QoS-guaranteed services in the integrated architecture of UMTS and WLAN by using an MRSVP (Mobile RSVP) extension, denoted as HeMRSVP (Heterogeneous Mobile RSVP). There are five inter-handoff scenarios of the HeMRSVP that need to be studied in UMTS/WLAN interworking systems. These handoff scenarios are described as follows:

- Scenario A : Inter-RNS handoff

The inter-RNS (Radio Network Subsystem) handoff occurs when an MH moves between two RNSs of a GGSN node. If the Mobile IP is used to provide IP mobility for the GGSN, the inter-RNS handoff can be seen as an intra-handoff in the same MA (Mobility Agent)/Proxy Agent of Mobile IP/MRSVP protocols. In this scenario, it is necessary to carry out a RA (Routing Area) update and a PDP context update. However, no Mobile IP registration update or HeMRSVP session update is required.

- Scenario B： Handoff from UMTS to WLAN

This vertical handoff occurs when an MH moves from UMTS to WLAN. In this scenario, it is necessary to carry out the update operations of the PDP context, Mobile IP registration and HeMRSVP sessions. These updates are similar to those of scenario D described below.

- Scenario C： Inter-WLAN-Intra-RNS handoff

This horizontal handoff occurs when an MH moves between two Router/MAs in a WGSN/RNS. The handoff operations in this scenario are the same as the original mobility management for the Mobile IP and MRSVP in wireless Internet. The update of the HeMRSVP session is the same as that of the MRSVP session. Note that it is not required to update the PDP context.

- Scenario D: Handoff from WLAN to UMTS

This vertical handoff occurs when an MH moves from WLAN to UMTS. In this scenario, it is required to carry out the update operations of the PDP context, Mobile IP registration and HeMRSVP sessions. These handoff operations are described below.

- Scenario E: Inter-GGSN handoff

This horizontal handoff occurs when an MH moves between two GGSNs of the UMTS network. In this scenario, it is necessary to do an RA update, PDP context update, Mobile IP registration update, and HeMRSVP session update. The operations for an RA update and PDP context update are the same as those for 3GPP TR 23.207. The updates for the Mobile IP registration and HeMRSVP session are also similar to those for scenarios B and D.

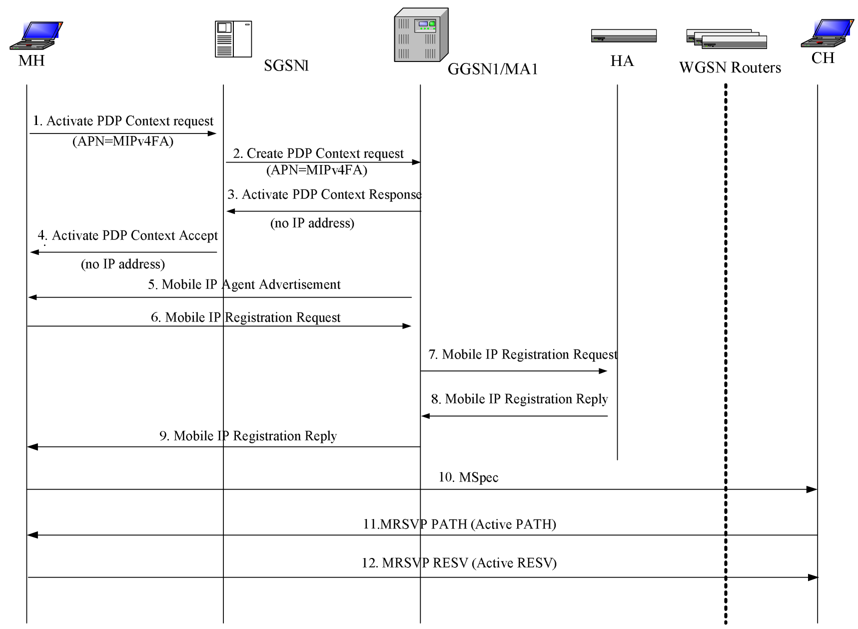

FIGURE 2: The Message Flows of HeMRSVP Occur When MH Handoffs from WLAN to UMTS (Scenario D).

FIGURE 2 shows the handoff operations in scenario D. In this scenario, Mobile IP can be used to provide IP mobility for WLAN-UMTS handoffs. This approach is similar to the IP mobility for inter-UMTS networks, which is based on 3GPP TR 23.923. Steps 1-4 establish the session of a PDP context between an MH, SGSN1 and GGSN1/MA1. In Step1, the MH issues an Activate PDP context request to SGSN1. The APN (Access Point Name) “MIPv4FA” is included in the request message of the Activate PDP context. On receiving the request message of the PDP context, the SGSN1 uses the APN to select a suitable GGSN, i.e., GGSN1/MA1, which has Mobility Agent capability. Note that the GGSN1/MA1 does not assign an IP address when sending the response of the Activate PDP context (Steps 3-4). In Step 5, the GGSN1/MA1 broadcasts the Mobile IP Agent advertisement. When the MH receives the advertisement, Mobile IP registration operations can be easily accomplished (Steps 6-9). In addition, the MH uses a proxy agent discovery protocol to detect Mobility Agents in its neighborhood and then sends a Receiver_MSPEC (Mobility Specification) message to the corresponding host CH (Step 10). The Receiver_MSPEC “MA1” in **FIGURE 4** informs the CH that the MH is visiting a subnet within the service area of RNS2. The CH then issues an Active PATH message to GGSN1/MA1 to initiate the reservation of RSVP tunnel CH-GGSN1/MA1 (Steps 11-12). **FIGURE 3** shows the HeMRSVP messages occurring when the MH is roaming in the WLAN service area of Router/MA3. The MH issues a Receiver_MSPEC {MA1, MA2, MA3} message to inform the CH that both the service areas of MA1 and MA2 are their respective neighboring service areas. In this situation, two passive reservation paths CH-GGSN/MA1 and CH-Router/MA2, and the active reservation path CH-Router/MA3 will be established by exchanging two pairs of the Passive PATH/RESV and Active PATH/RESV messages. **FIGURE 4** shows the HeMRSVP messages occurring at the time after the MH handoffs to UMTS. In this scenario, the passive reservation path CH-GGSN/MA1 will be changed to active, whereas the original active reservation path CH-Router/MA3 will be changed to passive. If the MH moves continuously toward the boundary area of RNS3, the MH will detect the new Mobility Agent MA4 in the boundary area but will not be able to detect the MA2. The MH then issues a revised Receiver_MSPEC {MA1, MA3, MA4} message to inform the CH that the service area of the MA4 is its neighboring service area. Thus, the new passive reservation path CH-GGSN/MA4 will be established and the original passive reservation path CH-Router/MA2 will be torn down.

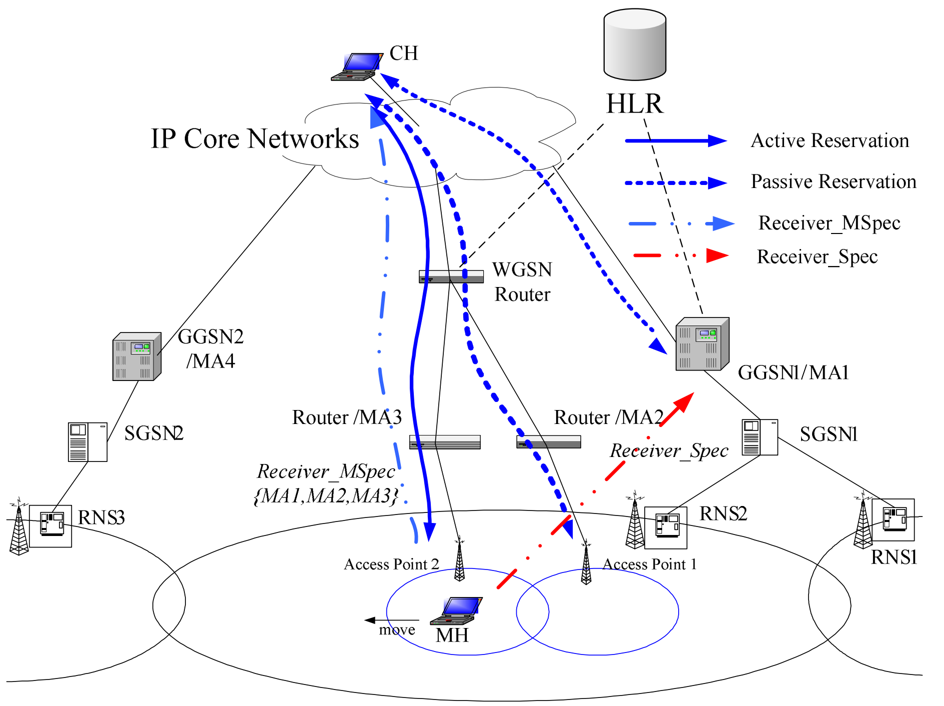

FIGURE 3: HeMRSVP Messages Occur at The Time before MH Handoffs to UMTS.

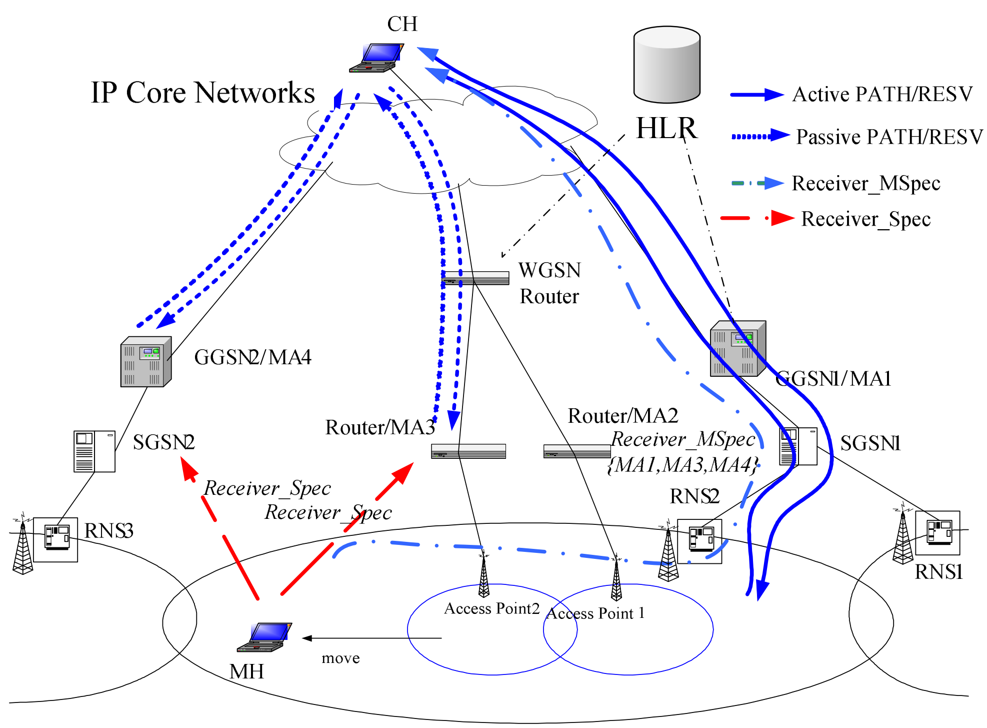

FIGURE 4: HeMRSVP Messages Occur at The Time after MH Handoffs to UMTS.

3. PERFORMANCE EVALUATION

3.1 Six Two-tier Resource Management Schemes

The proposed HeMRSVP has been studied on the two-tier architecture of a UMTS/WLAN interworking system. In this section, five two-tier resource management policies are compared with the HeMRSVP approach to evaluate the performance of HeMRSVP. **TABLE 1** shows six conceivable means of two-tier resource management schemes. The descriptions of these schemes are also listed in this table. Excluding the first strategy, the other two-tier schemes are based on RSVP extensions for an end-to-end QoS support. These two-tier resource management schemes in the UMTS/WLAN interworking systems were evaluated by using a two-tier simulation model.

Resource Reservation Schemes	Description
No QoS	Not using any QoS policy in 3G/UMTS or WLAN
RSVP(3G)	Using RSVP in 3G/UMTS
MRSVP(W)	Using MRSVP in WLAN
HeRSVP(3G+W)	Using RSVP in both 3G/UMTS and WLAN
HeMRSVP(3G+W)	Using MRSVP in both 3G/UMTS and WLAN
RSVP(3G)+MRSVP(W)	Using RSVP in 3G/UMTS and MRSVP in WLAN

TABLE 1: Six Two-Tier Resource Management Schemes.

3.2 A Two-tier Simulation Model

Simulations were conducted to measure the performance of the six resource management approaches. As **FIGURE 5** shows, an 8x8 wrapped-around mesh topology was used to simulate a UMTS/WLAN interworking system with an unbounded number of service areas. For simplicity, a hierarchical infrastructure of two-tier cell model was set up to simulate the heterogeneous networks. The two-tier model consists of 2x2 service areas of UMTS RNS. Each UMTS service area is partitioned into 4x4 cells. Only one quarter of these cells contains WLAN access points. Thus, there are 16 WLAN cells in this two-tier model. Six two-tier resource management schemes and five handoff scenarios in HeMRSVP could be fully verified by using this model.

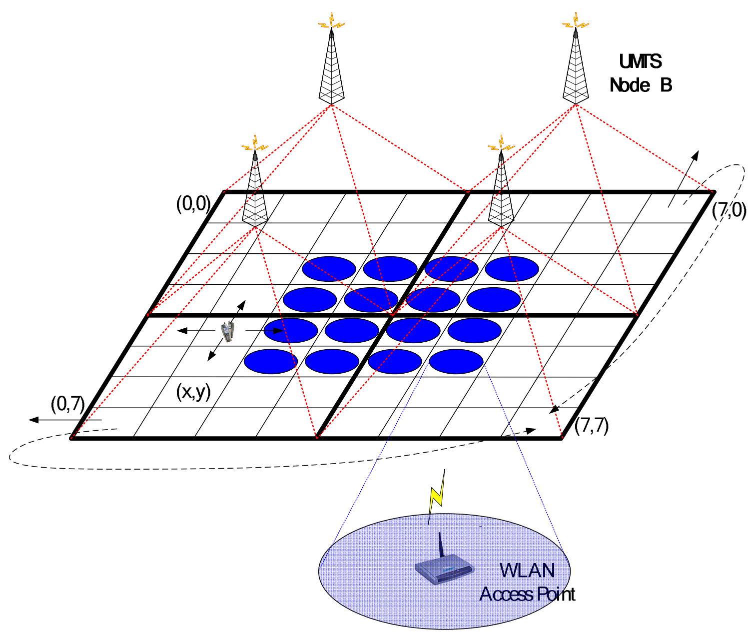

FIGURE 5: 8 x 8 Mesh of a Two–Tier Simulation Model.

To measure the performance of the two-tier resource management schemes, the following performance metrics were evaluated in the simulation.

- *New session blocking probability* (P_b) represents the probability of a failure occurring when an MH wishes to create a new service of an end-to-end QoS-guaranteed session.

- *Handoff session failure rate* (P_{fh}) represents the probability of an ongoing end-to-end QoS-guaranteed session being forced to terminate when an MH handoff occurs in the UMTS/WLAN interworking systems.
- *Session completion rate* (P_{sc}) represents the probability of an MH making an end-to-end QoS-guaranteed session and completing the session successfully regardless of the number of cell-handoffs during the service connection time.
- *Session Incompletion rate* (P_{ns}) represents the probability of an MH making an end-to-end QoS-guaranteed session and without successfully completing the session during the service connection time.

In the following subsections, the simulation results in the two-tier model of UMTS/WLAN interworking networks are discussed. In the simulation, it was assumed that the cell resident time of MHs, the session service time, and the session inter-arrival time for QoS-guaranteed services were all exponential distributions with means $1/\eta$, $1/\mu$, and $1/\lambda$, respectively. The Erlang load (ρ), $\rho = \lambda/\mu$, represents the traffic load of all session requests in one cell. When a new session arrives, the simulator needs to decide which the cell type is. If an MH visits a two-tier cell, it should use the wireless resources of WLAN first except when the WLAN capacity is zero. Initially, the capacities of UMTS and WLAN were assumed to be 12 and 8, respectively.

3.3 Performance Analysis of Deploying Policies

First, the performance analysis of the policies for deploying WLAN cells into the two-tier UMTS/WLAN network is presented. **FIGURE 6** shows ten deploying architectures used in the two-tier simulation models. In this figure, models 1-7 represent the different deploying policies for WLAN cells, and models 8-10 show the different densities of WLAN cells deployed in UMTS service areas. The simulation results of models 1-7 are shown in **FIGURE 7**. These results illustrate that the session incompletion rate P_{nc} does not change significantly in the two schemes, No-QoS and HeMRSVP, regardless where the WLAN cells are deployed. **FIGURE 8** depicts the simulation results of models 8, 1, 9 and 10 for the WLAN to UMTS cell ratio of 6.25%, 25%, 56.25% and 100%, respectively. It shows that the increase of WLAN cells causes a significant decrease on the session incompletion rate P_{nc} regardless which resource management scheme is applied. It is an intuitive result that the greater the amount of WLAN cells added, the larger the total bandwidth of a two-tier cell. The increase of the average bandwidth makes the P_{nc} decrease more explicit. For simplicity and without loss of generality, Model 1 was applied for all the simulations in the following discussion.

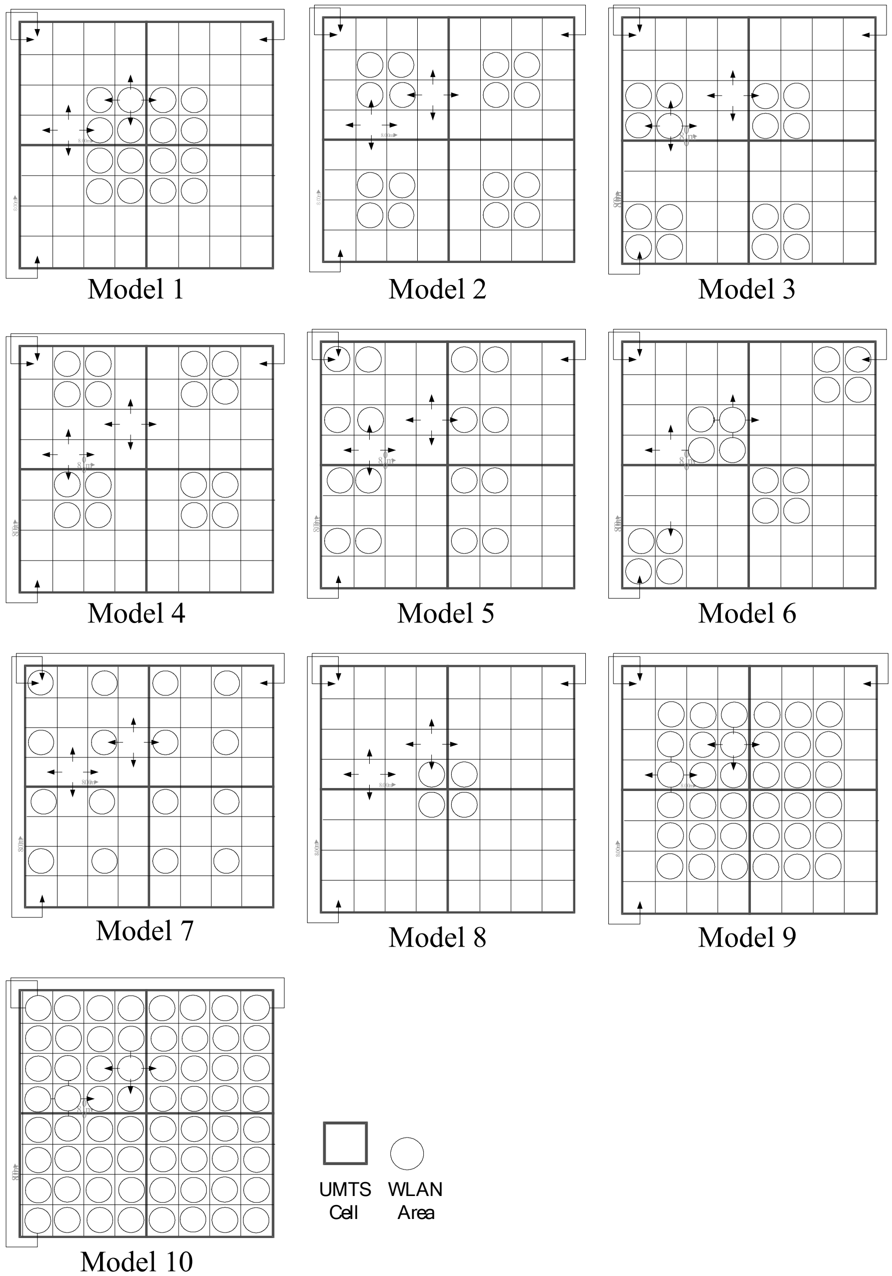

FIGURE 6: Deploying Architectures of Two-Tier Simulation Models.

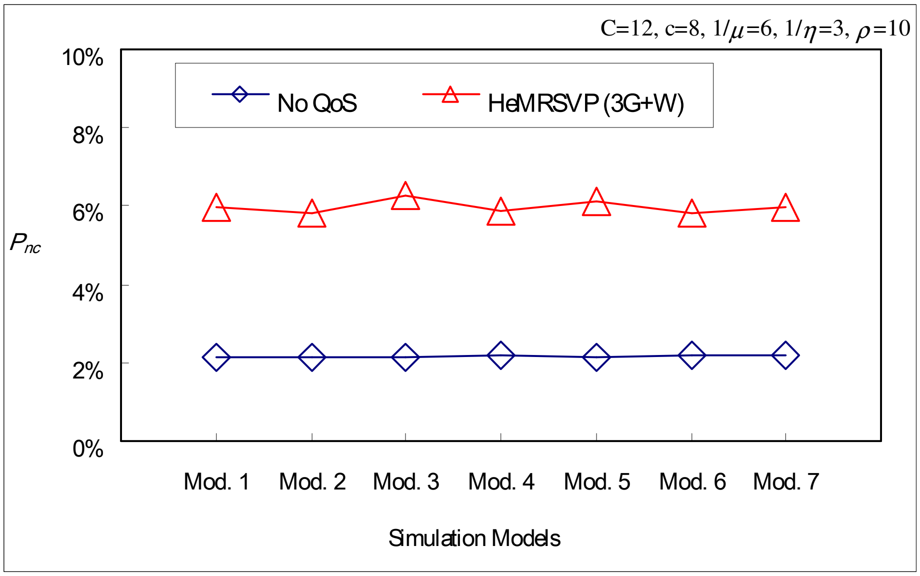

FIGURE 7: Effects of Deploying Policies for WLAN Cells.

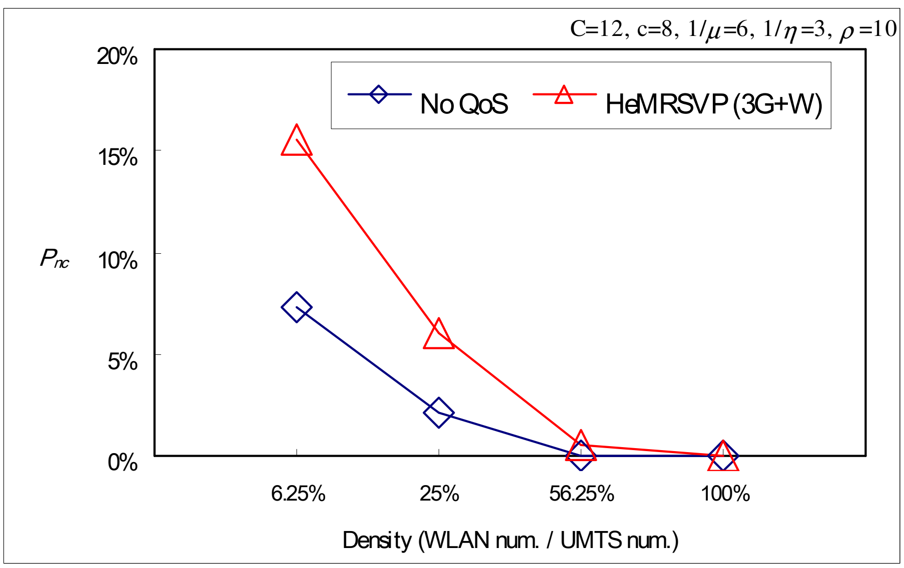

FIGURE 8: Effects of Densities of WLAN Cells.

3.4 Performance Analysis of Two-tier Resource Management Schemes

In this subsection, the simulation results of six two-tier resource management schemes are shown in Figures 9-11. **FIGURE 9** shows the new session blocking rates (P_b) of six schemes for the effects of traffic loads in a two-tier network. It can be found that the blocking rate P_b is the best in the No-QoS scheme and the worst in the HeRSVP(3G+W) scheme. This is because HeRSVP(3G+W) and HeMRSVP(3G+W) reserve much greater resources in both networks than other schemes. Since HeRSVP(3G+W) can't detect a mobile hosts' mobility, it might make resource reservations much longer than HeMRSVP(3G+W) does. In other words, HeMRSVP(3G+W) could quickly release all the occupied resources when an MH handoff occurs. Hence, the blocking rate P_b of HeMRSVP(3G+W) is small, almost the same as the smallest blocking rate in the No-QoS scheme.

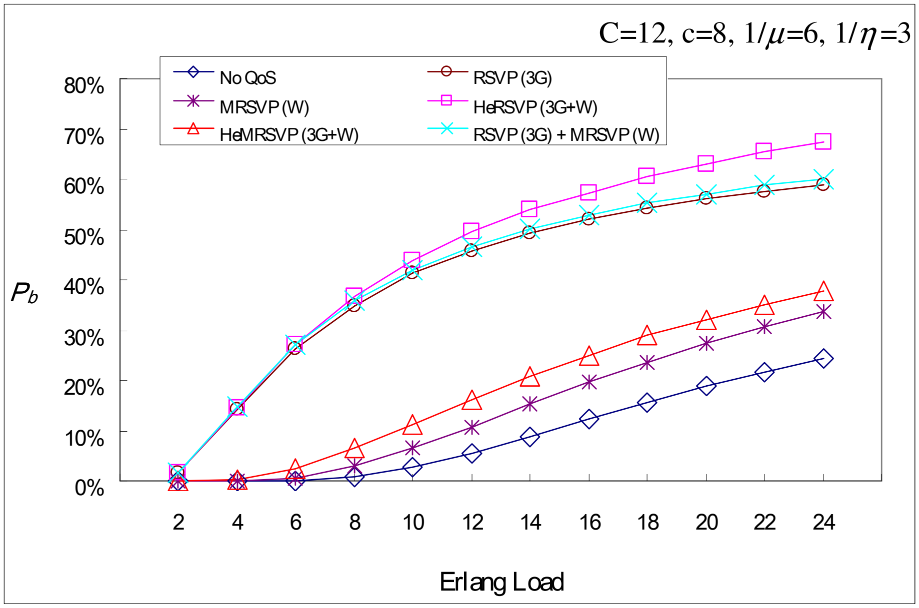

FIGURE 9: Effects of erlang (□) on P_b.

FIGURE 10 shows the handoff session failure rates (P_{fh}) of six schemes for the effects of traffic loads in the two-tier network. It is obvious that HeMRSVP(3G+W) has the smallest handoff failure rate P_{fh} in all schemes. The phenomenon can be explained with the fact that mobile hosts make much greater advance reservations in both UMTS and WLAN, and thus the P_{fh} in HeMRSVP(3G+W) is the smallest.

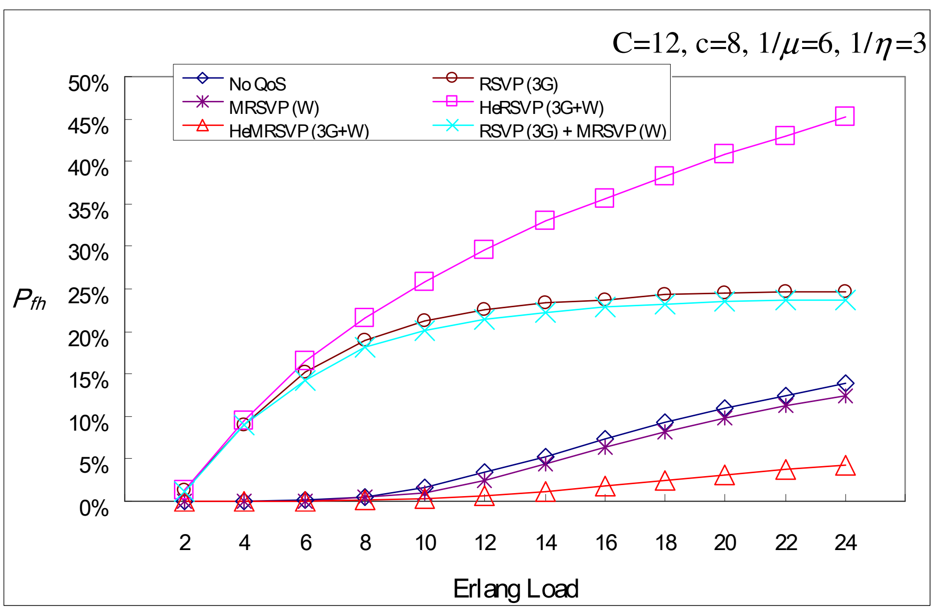

FIGURE 10: Effects of erlang (□) on P_{fh}.

In FIGURE 11, the session completion rates (P_{sc}) of six schemes are presented. It can be also found that HeMRSVP(3G+W) has the largest P_{sc} . It's because an MH, by deploying HeMRSVP(3G+W), has the smallest handoff session failure rate P_{fh}, and thus it obtains the greatest P_{sc} .

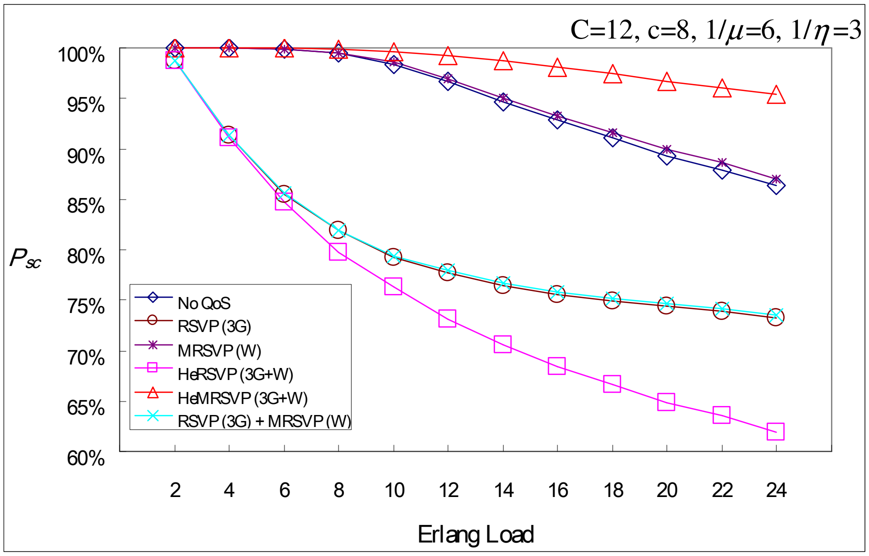

FIGURE 11: Effects of erlang (□) on P_{sc}.

3.5 Performance Analysis on Call-to-Mobility Ratio

Furthermore, to investigate the performance of HeMRSVP, a Call-to-Mobility Ratio (CMR) as one simulation parameter was used to study the mobility impact on HeMRSVP. The CMR denotes the session arrival rate λ divided by the handoff rate η. **FIGURE 12** depicts the session completion rate P_{sc} for six resource management schemes with various effects of CMR. From this figure, it can be seen that the P_{sc} in HeMRSVP is greater than that in other schemes. This is because that HeMRSVP makes advance resource reservations in all MH's neighboring cells. The HeMRSVP thus could achieve better performance than all other schemes regardless of the CMR value. Besides, it is very clear that the session completion rate P_{sc} is proportional to the CMR. This phenomenon is particularly obvious in the RSVP approaches of two-tier resource management schemes, HeRSVP(3G+W), RSVP(3G)+MRSVP(W), and RSVP(3G). However, in the MRSVP approaches of two-tier schemes, the circumstances are not explicit. It is clear that a lower CMR enlarges the mobility rate of an MH, and thus the benefit of advance reservations makes HeMRSVP and MRSVP perform significantly better.

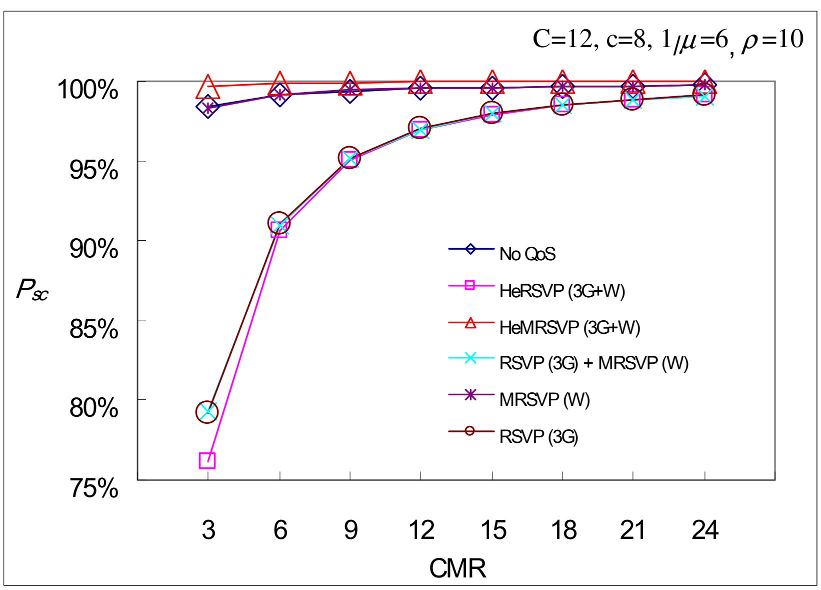

Figure 12: Effects of CMR on P_{sc}.

3.6 Performance Enhancement of HeMRSVP

As mentioned previously, the proposed HeMRSVP could achieve much greater performance for QoS-guaranteed services in terms of P_b, P_{fh}, and P_{sc}. To enhance the performance of HeMRSVP, a hierarchical reservation scheme, denoted as HeHMRSVP (Heterogeneous Hierarchical MRSVP), was first applied to reduce the reservation overhead of HeMRSVP. Since the two-tier WLAN/UMTS cells have a larger capacity than the one-tier UMTS cells, the excessive reservations in the two-tier cells are not necessary. The excessive reservation cost can be reduced by making advance reservations only in the boundary cells of two-tier and one-tier service areas, but not in the two-tier WLAN/UMTS cell.

The underlying principles behind the hierarchical reservation strategy of HeHMRSVP are illustrated as follows.

- WLAN-to-WLAN handoffs: When an MH handoffs from a two-tier WLAN/UMTS cell to another two-tier WLAN/UMTS cell, the MH would not make advance reservations in the neighboring two-tier WLAN/UMTS cells.
- UMTS-to-WLAN handoffs: When an MH handoffs from a one-tier UMTS cell to a two-tier WLAN/UMTS cell, the MH would not make advance reservations in the neighboring two-tier WLAN/UMTS cells.
- WLAN-to-UMTS handoffs: When an MH handoffs from a two-tier WLAN/UMTS cell to a one-tier UMTS cell, the MH would make advance reservations in the neighboring UMTS cells.
- UMTS-to-UMTS handoffs: When an MH handoffs from a one-tier UMTS cell to another one-tier UMTS cell, the MH would make advance reservations in the neighboring UMTS cells.

Further, a repacking mechanism, denoted as HeHMRSVP+Repacking, was applied to enhance the performance of HeHMRSVP. In the original HeMRSVP strategy, when a new service request arrives, the wireless bandwidth of WLAN in a two-tier WLAN/UMTS cell is allocated first. If there are no bandwidth resources in WLAN, the wireless bandwidth of UMTS in the two-tier cell is allocated to the new service request. However, in the repacking mechanism, this request service, which is allocated to the wireless resources of UMTS, should be repacked to be allocated to the wireless resources of WLAN, if any wireless resources are released from WLAN in the same two-tier cell. Some alternative strategies for a repacking mechanism have been evaluated in cellular networks. In this paper, Repacking-on-Demand (RoD) was chosen for HeHMRSVP+Repacking to enhance the performance of HeHMRSVP [13], [14]. Performance evaluations of HeMRSVP, HeHMRSVP, and HeHMRSVP+Repacking are illustrated in **FIGURE 13**. It can be seen that the HeHMRSVP+Repacking could achieve a greater session completion rate P_{sc} than the other two schemes. The simulation result shows that both hierarchical reservations and bandwidth repacking could enhance the performance of HeMRSVP significantly.

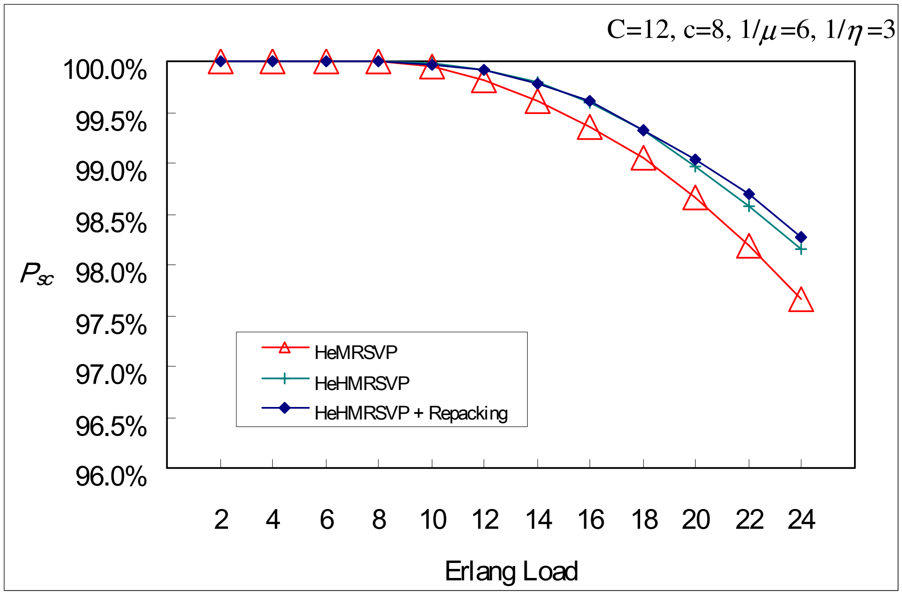

FIGURE 13: Effects of Erlang load on P_{sc} (Model 9).

4. CONSLUSIONS

The issue of integrating heterogeneous wireless networks is important as a field of study because all-IP wireless networks are getting more complicated than before. The end-to-end QoS-guaranteed mechanisms in all-IP two-tier networks still need to be studied. A heterogeneous RSVP extension, HeMRSVP, was developed to resolve the mobility impact when RSVP is deployed in UMTS/WLAN combination systems. This RSVP mobility extension could acquire the required end-to-end QoS grades to maintain the service continuity of an MH. Simulation shows that HeMRSVP could have a smaller handoff session failure rate and a greater session completion rate. It is clear that HeMRSVP achieves excellent performance in the resource management of heterogeneous networks. Furthermore, to enhance the HeMRSVP performance, hierarchical reservations and repacking on demand were applied. With the hierarchical reservation scheme, the bandwidth consumption of advance reservations can be minimized significantly. By applying repacking techniques, the capacity of two-tier UMTS/WLAN networks can be increased, and thus the enhanced HeMRSVP achieves a greater session completion rate.

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