RSVP State Reestablishment in WLAN-based Access Networks

Ha Duong, Arek Dadej and Steven Gordon
Institute for Telecommunications Research, University of South Australia, Australia
Ha.Duong@postgrads.unisa.edu.au, {Arek.Dadej, Steven.Gordon}@unisa.edu.au

Abstract- **Resource ReserVation Protocol (RSVP) is a QoS signalling protocol developed by IETF for fixed networks. However, in mobile networks where mobile nodes are freely moving, the standard RSVP is inadequate. There is substantial number of published works aiming to support RSVP mobility. Our contribution in this paper is to explore further the proactive context transfer scheme [6] in the context of RSVP state reestablishment. As shown in the paper, the proactive scheme is well suited to RSVP state reestablishment. We also suggest the concept of deferred reestablishment to increase the probability of resource availability during the proactive reestablishment process. Finally, we analyse the cost and benefits of state reestablishment in terms of wasted resources (we express the resources as a product of bandwidth and time and call it bandwidth-time in the paper) to confirm the effectiveness of our scheme.**

Keywords: **RSVP, Context Transfer, QoS, Mobile IP, WLAN.**

I. INTRODUCTION

Guaranteed Quality of Service (QoS) in delivery of real-time applications has become a key factor to the success of the future Internet. The IETF has developed two models to provide QoS in the Internet: Integrated Services (IntServ) and Different Services (DiffServ). The InterServ model uses explicit set-up mechanisms and signalling protocols to reserve the required resources along the data path. ReSource reserVation Protocol (RSVP) [13], a well known resource set-up mechanism and signalling protocol, has been developed and promoted to standard track of RFC. However, RSVP is not suited to mobile networks as it is an end-to-end signalling protocol, and handovers of users between access routers (AR) force a reestablishment of state at the new AR, often expensive in terms of time and signalling overhead.

There have been many attempts to extend RSVP to work efficiently in mobile networks. A summary of such works can be found in [2] and [14]. Many researchers [1],[8] favour the idea of localising RSVP state changes i.e. RSVP state reestablishment is carried out only on the new portion of the data path. There are two main arguments behind this idea. Firstly, Mobile Nodes (MNs) encounter local handovers more frequently than global handovers, and local handovers result in local changes in the data paths. Secondly, many works on the QoS [11], [17] seem to agree on a hybrid QoS model featuring DiffServ in the core network and InterServ with RSVP as the signalling protocol in the access network. Therefore when the MN moves from one access network to another, RSVP state reestablishment is limited to the new access network, and can be seen as local reestablishment.

Currently, the IETF Seamoby Group [16] is working on Context Transfer Protocol (CTP) [9], an alternative to rebuilding service states when MN encounters a handover. RSVP has been seen as a potential candidate to be included in the set of services within the scope of CTP. CTP describes a simple way to transfer state or context information from old Access Router (AR) to new AR so that the services could be re-established faster after the handover. This can lead to savings in time and bandwidth, and consequently improve handover performance. However, CTP only specifies the transfer procedure between two ARs; therefore, for an end-to-end QoS mechanism such as RSVP, such transfer is insufficient to completely re-establish the IntServ QoS state. Another problem is that reestablishment of the new RSVP path may be time consuming; consequently, the MN may suffer unsatisfactory QoS from the moment of handover until reestablishment of RSVP state. It is desirable, to save time, that the RSVP state for the new path is set up in advance; however this advanced or proactive reestablishment may lead to a waste of network resources. To minimise the waste of network resources, the proactive reestablishment should start as close as possible to the moment of handover, but still allow sufficient time to be completed before the MN resumes the communication with the new AR. The reserved resource in the previous RSVP path should also be released as soon as the MN connects to the new AR because, as we show in section IV, the amount of reserved resources can be significant.

In the previous work [6], we have proposed a proactive scheme that estimates the best moment for RSVP state reestablishment and carries out the context transfer by means of CTP. The proactive scheme makes use of Candidate Access Router Discovery (CARD) protocol to find out the next AR for context transfer and handover. In the proactive scheme, we have suggested a new concept, the forced handover that can ensure the shortest waiting time for the newly re-established context.

There is also a problem of resource availability in the proactive reestablishment. The problem can be seen as part of resource management in mobile environment, and has been extensively studied. Solutions to the problem mainly focus on how to allocate resources among MNs, particularly MNs performing handover and MNs attempting to join the network. In this paper, we suggest deferred RSVP reestablishment, a simple way to increase the probability of resource availability during RSVP state reestablishment.

In this paper, we will explore further the proactive scheme for the RSVP state reestablishment process. Our contribution is to fit this process into the framework of proactive scheme. Moreover, we will focus on the analysis of the wasted resources (measured by a product of bandwidth and time and denoted by a short expression "bandwidth-time").

The rest of the paper is structured as follows. In the next section, we provide background information on handovers in 802.11 WLAN, RSVP reestablishment in local mobility scenarios, and two protocols, namely Context Transfer Protocol and CARD protocol. Then, in section III we discuss RSVP state reestablishment in the context of the proactive scheme. An analysis of the waste of network resources is shown in the section IV. Finally, we give some concluding remarks and comment on intended future work.

II. HANDOVERS AND CONTEXT TRANSFER IN 802.11 WIRELESS LAN

In this section, we give an overview of signal strength based handover algorithm in 802.11 WLAN, RSVP state reestablishment and two protocols developed by the IETF Seamoby WG, namely the Context Transfer Protocol (CTP) and Candidate Access Router Discovery (CARD) Protocol. These two protocols are expected to work closely with Mobile IP [3] to facilitate seamless handover. To simplify the discussion, we assume that a handover between Access Points (AP) results in a handover between ARs.

A. *Handovers between WLAN Access Points.*

In an 802.11 WLAN, a MN leaving an AP is required to find the next AP and re-associate. A fundamental question is: when does the MN need to switch from one AP to another? In most implementations, for example in [10], quality of the communication link is used to make the handover decision, however more advanced decisions can be made by also taking into account the AP load, e.g. as in [4]. Fig. 1 shows how the typical parameter of communication quality, signal-to-noise ratio (SNR), changes as a MN moves from AP1 to the adjacent AP2. As soon as SNR from AP, SNR_1, drops below the so-called Cell Search Threshold SNR_{CST} (point 1 in Fig. 1), the MN enters the "cell-search" state where it scans to find the better APs. In the scanning process, for every channel, the MN broadcasts Probe Request and waits for Probe Response from AP. The scanning process is repeated every Scanning Interval (T_{SI}) until one of scanned APs provide SNR at least Δ greater than the current SNR (point 4 in Fig. 1). Now, the MN can switch to the channel used by the selected AP, and start the reassociation process. In summary, the condition for the inter-AP handover is as follows

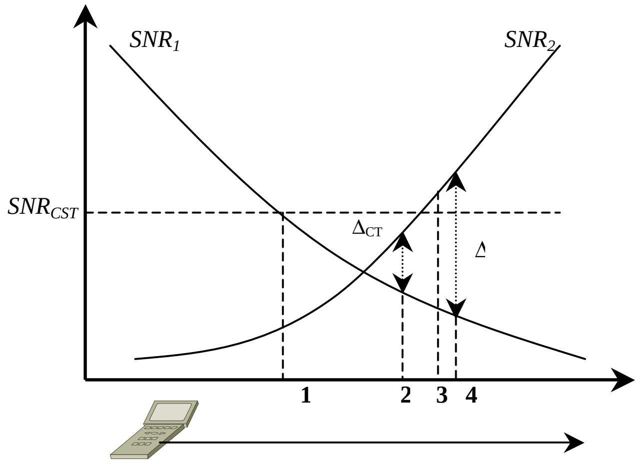


Fig. 1 SNR change between AP1 and AP2

$$\begin{cases} SNR_1 < SNR_{CRT} \\ SNR_2 > SNR_1 + \Delta \end{cases} \quad (1)$$

The above handover algorithm reveals the main difference in handover procedures between WLAN and 3G cellular networks: in a 3G network, the MN can communicate simultaneously with two Base Stations (or Node Bs), and therefore a soft handover is possible, while in WLAN, MN has to perform hard handover which can only happen after a scanning cycle takes place. Our approach to handover, as described later in section III, will be to identify the scanning cycle closest to the actual handover, and to transfer context information immediately after this scanning cycle is finished.

B. *RSVP State Reestablishment in Local Mobility*

RSVP is an end-to-end Quality of Service (QoS) signalling protocol operating in a hop-by-hop manner. This means that RSVP messages are transmitted from one RSVP-enabled router to another along the data path. Fig. 2 illustrates a

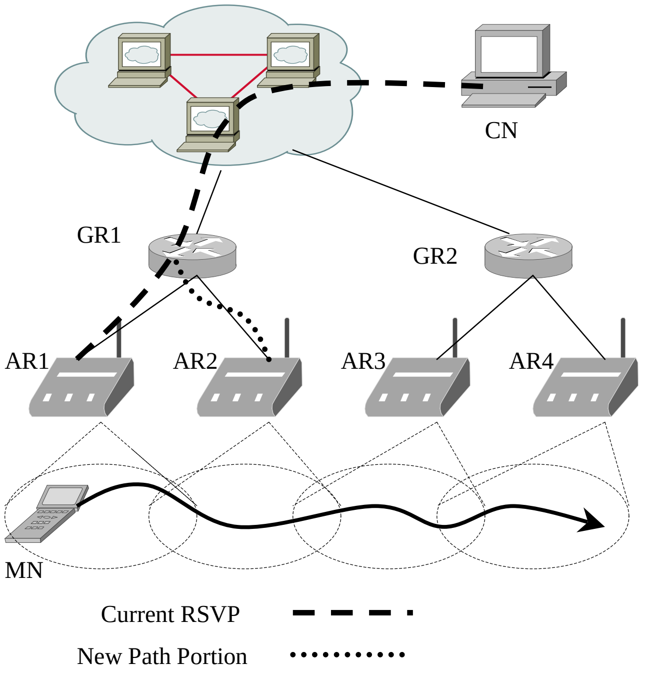
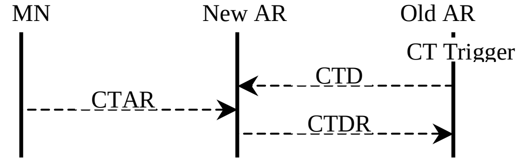


Fig. 2 RSVP state reestablishment in local mobility

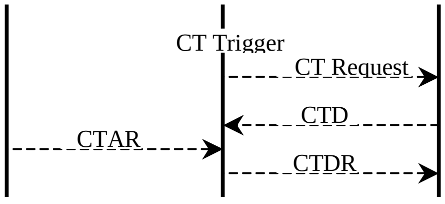
scenario where MN sets up an RSVP state for the flow from itself to a Corresponding Node (CN) at AR1 and the Gateway Router 1 (GR1). The MN moves towards AR2, and eventually performs handover to AR2. As both AR1 and AR2 belong to the same domain served by GR1, the handover can be seen as local and the MN just needs to re-establish the RSVP state along the new portion of the path (AR2 – GR1). In this scenario, the GR1 becomes a crossover router (CR), where the old path portion (AR1 – GR1) and the new path portion meet. In the subsection III.D, we will discuss how to identify the CR.

C. Overview of Context Transfer Protocol and Candidate Access Router Discovery Protocol

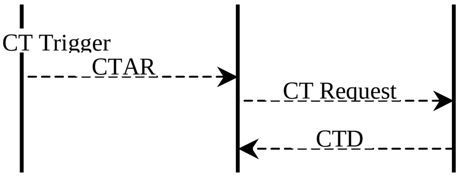
The Context Transfer Protocol (CTP) [9] enables nodes to be informed when context can be transferred due to handover (using a Context Transfer trigger), and provides mechanisms for performing the transfer (using CT requests and responses). The protocol operation is illustrated in Fig. 3. The protocol can be initialised by either MN or AR depending on the CT trigger. The CT trigger is still an open issue as it depends on specific link layer technology. As shown later in the subsection III.C, our proactive scheme will use the condition from equation (3) as a CT trigger. In network-initiated scenarios, if the CT trigger is detected at the old AR, this AR will send the CT Data (CTD) to the new AR; otherwise the new AR will request the old AR to transfer context (CT Request). Upon receiving CTD, the new AR optionally may reply back to the old AR (CTDR – CT Data Reply). In both cases, the MN will send the CT Activation Request (CTAR). In mobile-initiated scenarios, the MN will send the CTAR upon receiving a CT trigger, usually from the link layer. Then, the new AR can request context transfer from the old AR.



a) Network controlled, initiated by Old AR



b) Network controlled, initiated by New AR



c) Mobile controlled, predictive new L2 up / old L2 down

Fig. 3 The IETF Context Transfer Protocol Operation

There are several issues that arise when applying the CTP to specific services. For example, the CTP does not specify how dynamic context data such as Header Compression context can be transferred, as pointed out in [7]. More seriously, the CTP is insufficient in case of services involving network entities other than ARs. Intuitively, reestablishment of these services will require more time; hence reactive reestablishment may not be well suited to real-time applications. We will consider a proactive approach to context transfer in the next section.

The Candidate Access Router Discovery (CARD) [12] is another draft resulting from the work of the IETF Seamoby WG. The objective of CARD is to identify (discover) the IP addresses of candidate ARs (CARs) for handover, and to discover their capabilities. Our proactive scheme will make use of the first CARD function mentioned above which, by CARD recommendations, can be implemented in centralised or decentralised schemes. Reader should refer to [12] for more details of each option. The result of address mapping is included in the CARD Reply message that is sent back to the current AR.

As mentioned earlier, three protocols, Mobile IP, CTP and CARD are expected to work to together to facilitate seamless handover. In our previous work [6], we have proposed one of possible ways to combine these three protocols into a proactive handover and context transfer scheme. To ensure smooth operation of the proactive scheme, we also suggest the concept of forced handover. In the next section, we will describe in detail how to fit the RSVP state reestablishment into the framework of proactive scheme.

III. RSVP STATE REESTABLISHMENT USING CONTEXT TRANSFER AND FORCED HANDOVER

This section is entirely devoted to a description of the RSVP state reestablishment process. Firstly, we describe the concept of forced handover. Secondly, we suggest how to estimate the trigger for RSVP state reestablishment process. Finally, we show one of possible ways to combine those concepts and protocols (CTP and CARD) to facilitate the seamless handover, and discuss the problem of crossover router and deferred reestablishment.

A. Motivation for the Forced Handover

Typically, proactive RSVP reestablishment is based on handover prediction. If handover prediction fails, the proactively reserved resource will be wasted. There have been a number of works on handover prediction models. In mobile networks, typically the handover occurs when its condition is satisfied. Handover prediction techniques try to guess when the handover condition will be satisfied i.e. estimate the handover moment. Here, our approach is different. We still use simple techniques to monitor the MN’ mobility. When there is an indication that the handover condition is about to be satisfied, **we force the handover to happen at a certain moment of time**. The forced handover, once triggered, always occurs regardless of whether the handover condition is satisfied at the moment of handover or not. The main advantage of forced handover is that the MN knows exactly when the handover will occur, and therefore can be well prepared for such event, including reestablishment of RSVP context at the new path portion. The shortcoming of forced handovers is that in some cases, the handover is forced when the handover condition is not yet satisfied; therefore, the number of unnecessary handovers may increase.

B. Estimation of Trigger Moment for RSVP State Reestablishment

As mentioned in II.A, the best moment for starting RSVP state reestablishment is the time immediately following the second last scanning cycle before the re-association process has to be triggered. The procedure to identify the second last scanning cycle is described as follows. When in the cell-search state, after every scanning cycle, the MN estimates the time until handover as follows

$$T_{until\_handover} = \frac{\Delta - \left(SNR_2 - SNR_1\right)}{R_{SNR2} - R_{SNR1}} \qquad (2)$$

where R_{SNR1} and R_{SNR2} are rates of SNR change for signals from the current AP and the scanned AP respectively. These rate values are obtained and updated on the basis of SNR measurements performed as part of the current and previous scanning cycles.

If the $T_{until\_handover}$ is less or equal than the T_{SI} (point 3 in Fig. 1), the current scanning cycle is likely to be the second last (now called **scanning-to-CT**), and in the next scanning cycle (now called **scanning-to-handover**), the handover condition is likely to be satisfied. In short, the MN identifies the scanning-to-CT by

$$T_{until\_handover} \le T_{SI} \qquad (3)$$

To reduce computation, the MN may start to estimate the $T_{until\_handover}$ when the following condition is satisfied

$$\begin{cases} SNR_1 < SNR_{CRT} \\ SNR_2 > SNR_1 + \Delta_{CT} \end{cases} \qquad (4)$$

where Δ_{CT} is less than Δ.

Δ_{CT} (point 2 in Fig. 1) should be selected such that there is at least one scanning cycle before scanning-to-handover; therefore it can be defined from the following formula

$$\frac{\Delta - \Delta_{CT}}{R_{SNR2\max} - R_{SNR1\max}} = T_{SI} \qquad (5)$$

where $R_{SNR1max}$ and $R_{SNR2max}$ are maximum rates of SNR change from the current AP and the scanned AP. The rate values of interest can be estimated from previous measurements, or pre-set.

C. Description of the Proactive Process

Now we will describe the proactive scheme for RSVP reestablishment. Assume that MN is moving into an area where the SNR from the current AP drops below the SNR_{CST}, as illustrated in Fig. 4.

(i) The MN starts a scanning cycle every T_{SI} seconds until the condition (4) is satisfied.

(ii) The MN starts estimation of the $T_{until\_handover}$ and continues scanning cycles until at least one of the scanned APs satisfies $T_{until\_handover} \le T_{SI}$.

(iii) The MN collects L2 addresses of scanned APs satisfying the condition (3) (now we call them target APs), and sends them to the current AR via a CARD Request message.

(iv) Upon reception of the CARD Request message, the current AR resolves address mapping as described in the previous subsection (the CARD protocol), selects the best AR (now we call it the new AR) from candidate ARs (if more than candidate ARs), and sends the CT Data message to this target AR. Recall that we only consider an inter-AR handover i.e. the handover between APs results in the handover between ARs.

(v) Upon reception of the CT Data message, the new AR starts to re-establish RSVP state along the new path portion. Then, the new AR sends the CT Data Reply to the current AR to inform the result of state reestablishment process, and, in its turn, the current AR notify the MN by the CARD Reply message.

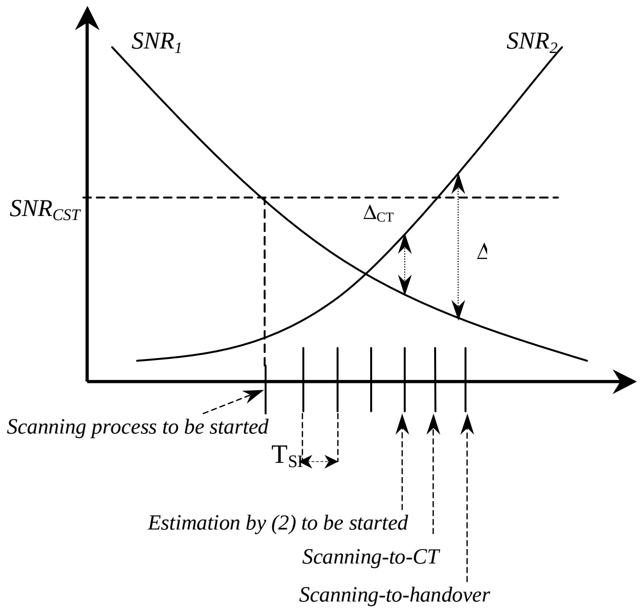


Fig. 4 Time diagram of the proactive CT scheme

(vi) In the next scanning cycle, the MN performs forced handover to the AR specified in the CARD Reply message.

(vii) When the MN gets connected to the new AR, it sends the CTAR to activate the transferred context at the new AR.

(viii) Upon receiving the CTAR, the new AR can notify the current AR (now the old AR) about the completion of the whole context reestablishment and handover process so that the old AR can take appropriate action to delete RSVP state in the old path portion.

In RSVP state reestablishment process (step (v)) with local mobility scenarios, there is a question of identifying the crossover router, where the old path portion and new path portion meet. The next subsection will briefly review the existing solutions. We also suggest deferred reestablishment, an enhancement of RSVP.

D. Crossover Router Identification and Deferred Reestablishment

There are two cases of CR identification, depending on data path direction, the data path from MN to Corresponding Node (CN) (flow (MN→CN)) or the data path from CN to MN (flow (CN→MN)). For the flow (MN→CN), the new AR sends Path message [13], which will travel until it reaches the CR. The CR can be identified by checking existence of RSVP state with Previous HOP attribute [13] different from one in the Path message. The CR can send back the Resv message [13] on behalf of CN. The case of flow (CN→MN) is more complicated as one of routers needs to know that it is the CR for the current flow. Then, it can send the Path message on behalf of CN. There are a few ways to identify CR in such cases, for example, by using localised RSVP [8], or by using regional Foreign Agent (FA) in Regional Mobile IP [5]. In the latter, a router with regional FA functionality will know that it is the CR when receiving Registration Request.

The idea of deferred reestablishment is directly derived from the concept of Deferred REServation (DRES) suggested by S. Norden and J. Turner in [15]. The key idea of DRES is that an RSVP-capable router can defer the reservation until either the required resource is available or the deferring period (T_D) expires. Recall that the standard RSVP uses all-or-nothing principle when making reservation i.e. if one of RSVP-capable routers along the data path cannot provide the requested resource; it immediately sends the Tear message back to the source to tear down the reservation at previous RSVP-capable routers. The DRES concept is similar to the "call-in-waiting queue" in the telephone service that allows new calls to be held until one of operators (telephone lines) is available. The deferring period T_D is the key parameter in DRES that can be defined from either user or network perspective. In our proposed scheme of RSVP reestablishment, T_D depends on how long the MN can tolerate the deferral of handover moment.

Based on estimation of time from the scanning-to-CT (when the RSVP state reestablishment is to be started) until the SNR reaches the minimum threshold (when the MN can not communicate properly with the current AP), we define the deferring period T_D as follow.

$$T_D = \frac{SNR_{CT} - SNR_{\min}}{R_{SNR1}} \quad (6)$$

where SNR_{CT} is SNR at the scanning-to-CT cycle, SNR_{min} is the minimum level of SNR where the MN can still communicate with the current AP, R_{SNR1} is the current rate of SNR change from the current AP.

When applying the DRES concept to the RSVP state reestablishment, the proactive process in subsection C requires some modifications as follows.

In step (iii), the MN estimates the deferring period T_D and includes it in the CARD Request message sent to the current AR.

In the step (v), the new AR considers the presence of T_D as an indication that the MN is willing to defer the reservation for the period of time T_D.

In the DRES mode, the MN forces handover to happen at the scanning cycle right after being notified about successful reestablishment via the CARD Reply message as shown in Fig. 5.

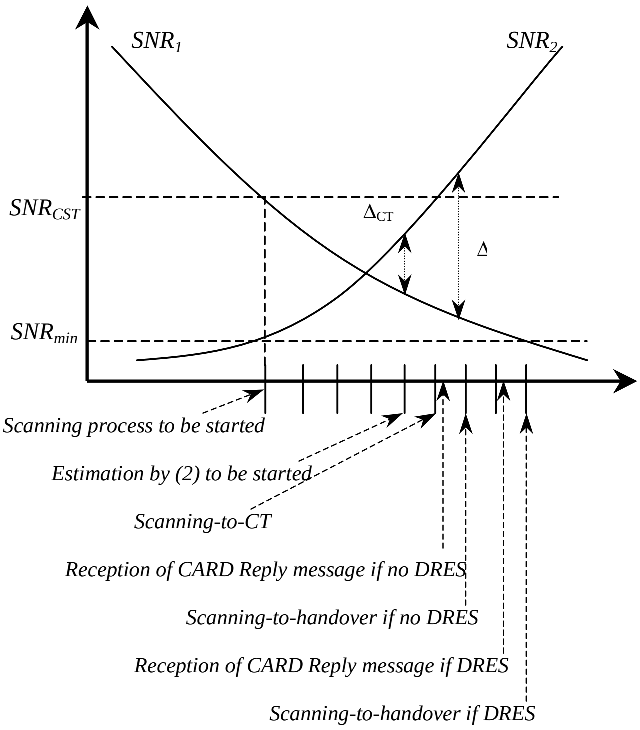


Fig. 5 Time diagram of the proactive scheme with DRES and without DRES

IV. ANALYSIS OF RESOURCE WASTE IN RSVP-BASED NETWORK

A. *Wasted Bandwidth-Time*

We will measure the resource wasted (e.g. due to unnecessary reservation) by a product of bandwidth and time, and call it **bandwidth-time** (the amount of bandwidth reserved or used during a period of time). In RSVP, the network resource (bandwidth *B*) is reserved at an RSVP-enabled router for a session for as long as the RSVP state at the router is valid. RSVP uses the concept of “soft state” to manage the RSVP state i.e. the RSVP state is created at the beginning of the session and refreshed periodically as a result of Refresh messages. The wasted bandwidth-time occurs because either the MN leaves the current AR without sending the Tear message to delete the RSVP state or the proactively reserved resource is held at the new AR for the MN. Intuitively, the wasted bandwidth-time has direct impact on the utilisation of network resources and probability of RSVP session (new and handed over) being blocked. In the next two subsections, we will investigate the wasted bandwidth-time at the old path portion and the new path portion.

B. *Wasted Bandwidth-Time at the Old Path Portion*

The RSVP standard [13] specifies that every RSVP-enabled router should send a Refresh message to the next hop router every *r* sec (*r* is randomly selected from the range [0.5*R*; 1.5*R*]). Upon receiving the Refresh message, the RSVP state lifetime ($T_{LIFETIME}$) is calculated as specified in [13]

$$T_{LIFETIME} = 1.5(K + 0.5)R \qquad (7)$$

It is easy to see that the RSVP state can tolerate loss of up to (*K*-1) successive Refresh messages without being deleted. Therefore, we are interested in the remaining lifetime of the RSVP state (T_{REM}) after handover i.e. from the moment of handover until the RSVP state lifetime expires. Fig.7 illustrates the time diagram of events such as reception of the Refresh message, handover, and expiry of the RSVP state lifetime.

We have run simulations to obtain the probability of various values of elapsed RSVP lifetime ($T_{ELAPSED}$). Recalling that the Refresh message is sent every *r* sec, randomly selected from the range [0.5*R*; 1.5*R*], we expect that $T_{ELAPSED}$ within the range [0; 0.5*R*] have equal probability, and this probability decreases linearly for the values of $T_{ELAPSED}$ within the range [0.5 *R*; 1.5*R*]. The graphs for R = 30,60,90 and 120 sec in Fig.6 confirm this expectation

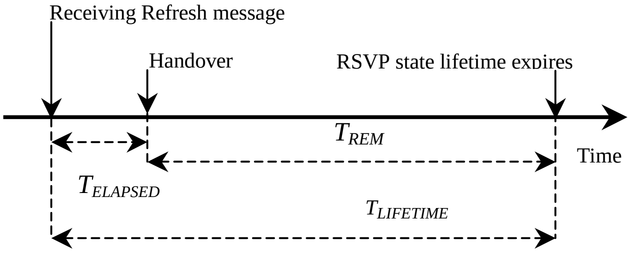


Fig.7 Time diagram of handover during state lifetime

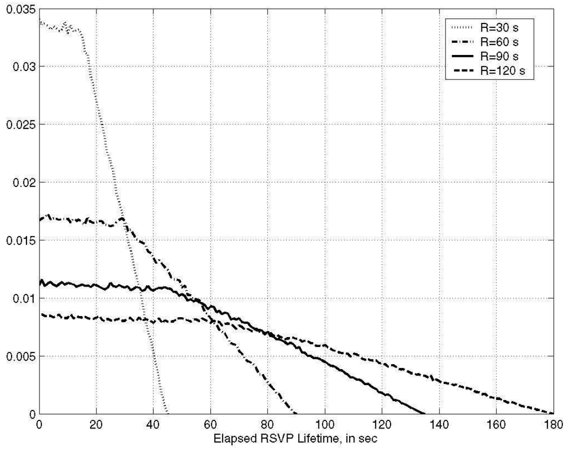


Fig.6 Probability of elapsed RSVP lifetime in different average refresh intervals R.

. From the simulation results, we derived an approximate calculation for the average value of the elapsed RSVP lifetime ($T_{ave\_ELAPSED}$) as follows

$$T_{ave\_ELAPSED} = 0.548R - 0.559 \qquad (8)$$

From there, we can easily calculate the average remaining lifetime (T_{ave_REM}) of the RSVP state by subtracting $T_{ave\_ELAPSED}$ from $T_{LIFETIME}$. Fig.8 depicts the graphs of $T_{ave\_ELAPSED}$ for the coefficient K from the range [2; 5].

Let us consider an example of default values from RSVP specification i.e. *K=3, R=30 sec* and a typical bandwidth for

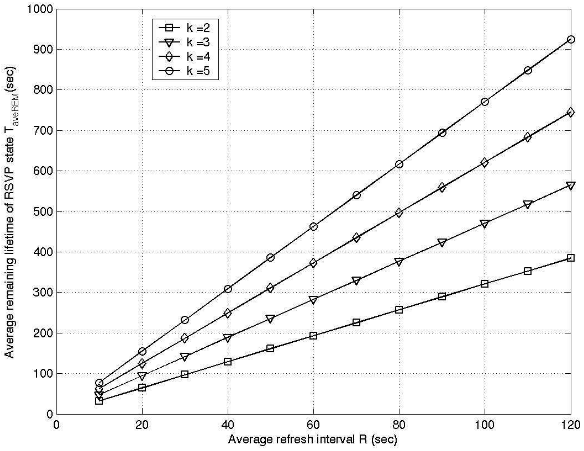


Fig.8: Average remaining RSVP lifetime vs. average refresh interval R in different coefficients K.

VoIP application B = 43.2 kbps. The wasted bandwidth-time in this scenario will be 150 sec x43.2 kbps = 6480 kb. This is quite significant amount of bandwidth-time, considering bandwidth limitations over a wireless link such as WLAN. Therefore, it is important that the reserved resource at the old access network is released as soon as the MN connects to the new access network. In our proposed proactive scheme, the reserved resource at the old path portion is released by notification from the new AR (see step (viii) at III.C). Another important point is that the above calculation of the wasted bandwidth-time is for one RSVP-capable router or one hop. The total wasted bandwidth-time of the old path portion is $\boldsymbol{N_{hop}}$ times of the wasted bandwidth-time at one hop, where $\boldsymbol{N_{hop}}$ is number of hops along the old path portion.

C. *Wasted Bandwidth-Time at the New Path Portion*

At the new path portion, the waste of bandwidth-time occurs because of the nature of the proactive reservation (reestablishment), and is proportional to the waiting time T_{WAIT} of the reserved resource. Intuitively, the waiting time is defined from the time the resource reservation is made (RSVP state is re-established) until the MN connects to the new AR.

In the scenarios where the resource at all hops along the new path portion can be reserved immediately upon request, the waiting time T_{WAIT} is approximately equal to the scanning interval T_{SI} (i.e. from scanning-to-CT and scanning-handover, and we ignore signalling delay of CARD protocol, CTP and Mobile IP protocol). However, there is difference in scenarios where the resource is not available at the moment of request, and we make use of DRES. Here, the waiting time at each hop may vary, and **the maximum total waiting time for all hops** is limited to the deferring period T_D.

We have run simulations to obtain values of this parameter as follows. The simulation area is covered by 61 APs distributed uniformly at a distance of 200m from each other. Transmission power of all APs is the same, and there are no obstructions to transmissions as the simulation area is assumed to be an open outdoor environment. Every AP, excluding the APs residing close to the edges, has 6 neighbour APs. In the simulation area, the MN is moving according to the random waypoint model as follows. After randomly selecting a destination, the MN moves towards the selected destination with a constant velocity v (the velocity v is randomly selected from a range of (0.5 m/s – 5 m/s)). After reaching the destination, the MN stops for the duration of pause time and then selects another destination and speed, and moves again. The MN is always associated with an AP, and keeps monitoring *SNR* with this associated AP. As soon as this SNR drops bellows the threshold SNR_{CST}, the MN starts to follow the procedure described in section III.C. Such scenario of the MN was repeated in a very large number of times to ensure that collected data are consistent.

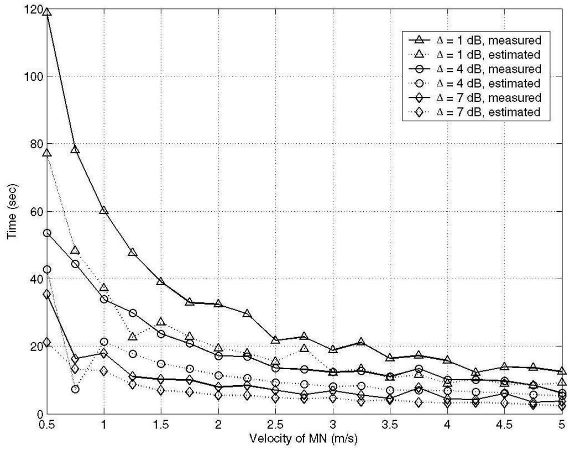


Fig. 9 Deferring period, estimated by (6) and measured in the simulation.

Fig. 9 show estimated and measured values of the deferring period with different hystereses Δ. There are a couple of important points in the graphs we want to mention. Firstly, measured values are always greater than the estimated ones because the estimations are calculated on the basis of linear formula (6), while the actual relationship is logarithmic. However, we still prefer the linear estimation because of its simplicity and more importantly, because it provides a "safe gap" between the estimated and actual moments of link break. Secondly, bigger values of Δ result in smaller T_D, since with bigger Δ the MN is closer to boundary of AP's coverage. Finally, the deferring period T_D is much longer when the MN is moving in walking pace (0.5 – 1 m/s), then dramatically drops when the MN is moving at the speed of slow vehicles (> 2m/s).

Once again, it is noted that the above value of T_D is the maximum total waiting time at the new path portion. The actual value of the total waiting time depends on the load offered to the network such as RSVP flow arrival rate, RSVP flow duration, given hop resource. Let us discuss further the deferring period in the example in Fig. 2. It is reasonable to assume that the wireless part is the bottleneck of the network, where the RSVP reestablishment process spends most of the time during the deferring period to wait for the resource availability. Therefore, the wasted bandwidth-time occurs mostly in the wire-line part of the network. For example, in the new path portion (AR2 – GR1), the RSVP reestablishment process is likely to spend more time to wait for resource released in the wireless interface, and during this waiting period, the reserved resource in the wire-line part interface between AR2 and GR1 will be wasted. This is an important point, as the wireless bandwidth is more "expensive", and we normally prefer to sacrifice the wire-line bandwidth rather than wireless bandwidth.

The above analysis of wasted bandwidth-time in the old path portion and the new path portion leads to the following preliminary conclusion. The wasted bandwidth-time is quite significant, and can affect greatly resource utilisation. Consequently, the waste can increase probability of blocking new and handed over sessions. Our proposed scheme has taken this into account by notifying the old AR and allowing it to explicitly send the Tear message [13] in order to release the resource in the old path portion. On the other hand, the proposed scheme increases the probability of the resource availability as well as minimises the waiting time of the reservation at the new path portion. As the wasted bandwidth-time more likely occurs in the wire-line part, it would not probably affect significantly the probability of session blocking.

V. CONCLUSION & FUTURE WORK

We have shown that the process of RSVP state reestablishment can fit well into the framework of proactive scheme for context reestablishment. Besides the forced handover of the proactive scheme, which can ensure that the proactive reestablishment is not wasted and the waiting time is shortest, we also proposed and described a new concept of deferred reestablishment to improve the probability of availability of the requested resource.

There are a number of ways the current research can be developed further. Firstly, we intend to verify the proactive scheme for other simulation scenarios, i.e. characterised by different AP distributions, mobility models and simulated environment (open, semi-open, office). Secondly, we would like to evaluate the impact of unnecessary handovers resulting from using forced handovers on the performance of the proposed scheme. Finally, we would like to obtain more results on deferred reestablishment, to evaluate its impact on the reestablishment blocking and resource utilisation.

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