PAPER

QoS NSIS Signaling Layer Protocol for Mobility Support with a Cross-Layer Approach

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SUMMARY Providing seamless QoS guarantees for multimedia services is one of the most critical requirements in the mobile Internet. However, the effects of host mobility make it difficult to provide such services. The next steps in signaling (NSIS) was proposed by the IETF as a new signaling protocol, but it fails to address some mobility issues. This paper proposes a new QoS NSIS signaling layer protocol (QoS NSLP) using a cross-layer design that supports mobility. Our approach is based on the advance discovery of a crossover node (CRN) located at the crossing point between a current and a new signaling path. The CRN then proactively reserves network resources along the new path that will be used after handoff. This proactive reservation significantly reduces the session reestablishment delay and resolves the related mobility issues in NSIS. Only a few amendments to the current NSIS protocol are needed to realize our approach. The experimental results and simulation study demonstrate that our approach considerably enhances the current NSIS in terms of QoS performance factors and network resource usage.

key words: *quality of service (QoS), mobile Internet, NSIS, handoff, cross-layer approach*

1. Introduction

As mobile devices become popular and have more computing power, the demands for real-time multimedia services are rapidly increasing. However, in mobile Internet, there are some obstacles against providing such services. For instance, the host mobility causes considerable service disruption and a traffic redirection overhead. The mobility-induced variation of available network resources is another potential barrier. Achieving seamless QoS guarantees is one of the crucial challenges for such services. Mobility tends to disrupt services mainly due to the delays in the link/network layers, and the QoS signaling. This paper focuses on reducing the QoS signaling delay.

The resource reservation protocol (RSVP) [1] was developed for QoS signaling within integrated service, but it cannot be applied directly to mobile Internet because it was originally designed for wired Internet. Although a number of studies [2]–[5] have extended the RSVP to address the mobility issues, they did not provide appropriate signaling mechanisms for resolving the quality degradation due to the mobility. In addition, the RSVP is known to have the constraints including flexibility, scalability and security problems [6], [7]. Accordingly, the Internet Engineering Task Force (IETF) proposed a general IP signaling protocol suite called the next steps in signaling (NSIS) [7].

There are some mobility issues in NSIS [8], [9] and the basic NSIS operation for those problems in [9]. A crossover node (CRN), which is a merging-diverging point of multiple signaling paths, is discovered after handoff in the basic operation. This incurs relatively long latency for the CRN discovery and the session reestablishment. In addition, research projects such as DAIDALOS [10] and WEIRD [11] have proposed the NSIS-based QoS architecture in mobile environments, but the detailed signaling mechanisms and the performances were not presented. As a consequence, the efficiency of the NSIS protocol that supports mobility has not been adequately verified.

This paper proposes a scheme for seamless QoS guarantees based on a make-before-break model, which refers to the advance reservation with a cross-layer design. In our approach, a CRN can be discovered before handoff. Thus, the nodes on a new signaling path can prepare the QoS session setup in advance so that they immediately use the network resources after handoff. Our approach has several advantages over existing schemes. First, a new signaling path is optimized as a direct routing path simultaneously with the session reestablishment. Second, no extra signaling is needed over an IP tunnel. Third, our approach can be easily adapted to other mobility support protocols such as session initiation protocol (SIP), mobile stream control transmission protocol (mSCTP) as well as Mobile IP (MIP) because our cross-layer design is based on the interaction between the QoS signaling and the link layer. Finally, our approach requires only a few amendments to the current NSIS and no other components are needed to the network entities. Note that the preliminary version of this paper appeared in [12].

The performance of our approach is simulated and an implementation is tested. The measured results from the implementation confirm that our approach incurs no additional delays except the handoff latency and guarantees continuous QoS even when an MN moves to congested networks. In addition, the simulation results demonstrate that our approach outperforms the conventional NSIS [9] in terms of the signaling performance parameters. The performance gain of our approach appears more significant as the offered load in

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the network is increased.

The rest of the paper is organized as follows: Sect. 2 briefly introduces the NSIS and the related mobility issues. Section 3 describes how our approach operates in detail. Section 4 illustrates the testbed environment and performance evaluation results. In Sect. 5, we present our simulation study. Finally, in Sect. 6, we conclude this paper and suggest future works.

2. Related Work

2.1 NSIS Overview

NSIS separates the functions of the signaling into two layers: NSIS transport layer protocol (NTLP) and NSIS signaling layer protocol (NSLP). The NTLP is responsible for delivering signaling messages of different signaling applications. The main part of the NTLP is the general Internet signaling transport (GIST) [13], which discovers NSIS nodes on a signaling path and delivers signaling messages in a hop-by-hop fashion. An NSLP for QoS, the so-called QoS NSLP [14] is responsible for the resource reservation. Similarly to the RSVP, the QoS NSLP establishes and maintains a QoS state at each node along the data path. It uses the following four types of messages for QoS signaling:

- RESERVE: establishes and handles a reservation state.
- QUERY: requests data path information, receiver-initiated reservations, or support of certain QoS models.
- RESPONSE: provides information about the result of a previous QoS NSLP message.
- NOTIFY: delivers information to a QoS NSLP node without preliminary request.

The QoS NSLP nodes are categorized by their role in signaling. QoS NSLP initiator (QNI) initiates QoS signaling. QoS NSLP entities (QNEs) forward the signaling messages along the signaling path, and QoS NSLP receiver (QNR) is the terminating point of signaling. The QoS NSLP provides both sender- and receiver-initiated operations. In the former case, the QNI first sends the RESERVE message with the QoS requirement for a data flow. The QNEs forward the RESERVE message toward the QNR and, the QNR sends the RESPONSE message to the QNI. The data flow starts after this signaling operation. The receiver-initiated operation is the same as the sender-initiated one except that the QUERY message is sent by the QNR before the QNI sends the RESERVE message.

A QoS NSLP message contains a common header including the message routing information (MRI). It conveys the direction of signaling (namely, an upstream or downstream) and the addresses of the QNI and the QNR. Thus, the MRI is used as a flow identifier (FID). Additionally, a session identifier (SID) manages the signaling states. Although it is mapped to a specific FID, the SID is independent of a data flow so that the changed FID can be remapped to the SID without affecting the reservation state.

2.2 NSIS Mobility Issues

Here, we discuss four known mobility issues that may significantly affect the NSIS operation in [9].

- Double state problem: Because the resources reserved along the old path are no longer valid after handoff, the double resources for one session should be reserved temporarily to support the continuous QoS. This temporary reservation incurs an additional overhead and wastes of the network resources.
- End-to-end signaling problem: Because the FID may change due to mobility, the signaling state should be updated along the entire path. However, installing signaling states along the entire path incurs a considerable processing overhead as well as service disruption.
- Invalid NSIS receiver (NR) problem: If the MN is an NR (i.e., a QNR in a QoS NSLP), QoS NSLP messages cannot be forwarded to the MN after handoff. Accordingly, an error message may be triggered to inform the QNI that the QNR fails or is truncated. Thus, the QNI mistakenly remove the state on the old path.
- IP tunneling problem: If the MIP is used, the IP-in-IP encapsulation makes the signaling messages invisible to the intermediate nodes within IP tunnels. Thus, extra signaling is required to resolve the invisibility problem.

The basic NSIS opreation provides a mechanism for CRN discovery and for updating a QoS state locally after handoff. Therefore, the session reestablishment delay may be significantly long for multimedia services. Moreover, the required network resources cannot be reserved in a congested network due to insufficient available resources. This approach also requires additional signaling incurred by the IP tunneling problem. In addition, a routing path for signaling and data flow, including an MIP tunnel, is not optimized when an MN resides in a foreign network.

Bless and Rohricht [15] addressed those NSIS mobility issues. In this approach, the flow information service element should be equipped on every node for the interaction between NSIS and MIPv6. This element provides an interface to QoS NSLP or GIST for the request of mobility information to MIPv6. However, this approach basically reestablishes the signaling session after handoff, thus the session reestablishment latency cannot be reduced sufficiently for real-time multimedia services.

Another proposal of Benmammar and Krief [16] basically operates with hierarchical MIPv6 (HMIPv6) and is based on a make-before-break model. It makes advance reservations from a mobility anchor point to all candidate ARs. Thus, it suffers from excessive advance reservations, and requires considerable modification on the current Internet due to the use of the HMIPv6. In addition, it predicts the future location by the mobility profile that should be handled by the mobile device in spite of its limited computing power. In summary, the efficiency of NSIS in mobile environments has not been sufficiently verified.

3. Proposed Approach

3.1 Overview

In our approach, the advance CRN discovery is based on the movement prediction from link-layer information. Because the CRN is discovered before handoff, it can initiate a resource reservation in advance along a new data path. After handoff, the reservation on the new path is immediately activated without the session reestablishment on the entire path. As a result, the session reestablishment latency can be significantly reduced. In addition, the signaling path between CRN and MN can be directly routed without the bidirectional tunnel. This signaling path optimization is performed simultaneously with the above session reestablishment. Our approach can achieve those effects with simple amendments to the current NSIS protocol. Just three message flags to the QoS NSLP messages and two mobility control modules need to be added to the current QoS NSLP.

Figure 1 depicts the overall message exchange procedure among NSIS nodes in our approach. With the movement prediction, the MN informs the QoS NSLP of its future location for triggering the advance reservation process. Thereafter, the QoS NSLP in the MN informs its handoff initiation with a Handoff_Init message along the (old) current path (Step 1). After that, each QNE in the current path determines whether it is the CRN for the MN (Step 2). If a QNE is not selected as the CRN, it forwards the Handoff_Init message to the next QNE. Otherwise, the CRN immediately establishes an advance reservation to the new AR (Step 3). This advance reservation does not trigger the QoS state installation in the QNEs along the new path until the handoff completion. When the MN completes its handoff, it sends a Handoff_Done message along the new path (Step 4). Subsequently, the new AR forwards the Handoff_Done message toward the CRN and each QNE on the new path activates the previously stored advance reservation (Step 5). Upon receiving the Handoff_Done message, the CRN immediately requests the state update along the common path (Step 6(a)). At the same time, the CRN sends a teardown message toward the old path in order to avoid the double state and the invalid NR problems (Step 6(b)). For simplicity, we assume that Steps 2 and 3 are completed before Step 4 in general. Even though Step 3 might not be completed before Step 4, the QNEs along the new path just install a new QoS state for the corresponding session with that in the advance reservation message received later.

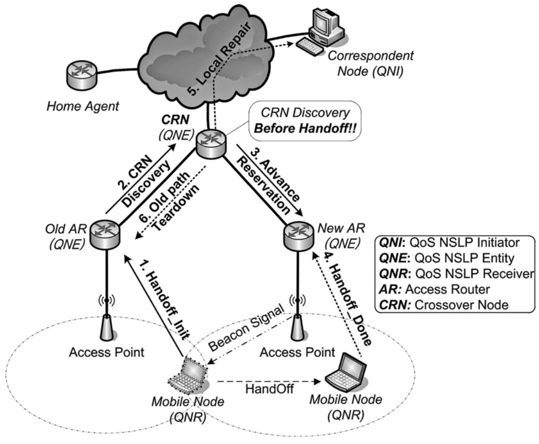


Fig. 1 Overall message exchange procedure.

Figure 2 shows the modified NSIS protocol stack. As shown in Fig. 2, our approach predicts the MN's movement with a link-layer API. This prediction information is delivered to the advance CRN discovery module in the QoS NSLP via a GIST API. We modified the parts of the GIST API for handling the movement prediction and defined the movement information for communicating with the link layer. Advance CRN discovery and local state update modules are added for mobility control in the QoS NSLP.

3.2 Advance CRN Discovery

A CRN can be discovered before handoff when an MN determines the access point (AP) to which it will be associated later. There are some approaches [17]–[20] that use layer 2 (L2) information for reducing the handoff latency. Similarly to those approaches, our approach utilizes the L2 information to predict the movement of the MN. We assume that an MN can simultaneously detect L2 signals from multiple APs, and there is always an overlapped area between two adjacent wireless cells. The MN continuously compares the signal strength of the neighboring APs by active or passive scanning [21]. One of the reachable APs that emits the strongest signal during the movement prediction time is selected as a future location before handoff. If the movement prediction is inaccurate, the QoS NSLP operates in a conventional way (that is, it discovers the CRN after handoff).

Figure 3 shows the advance CRN discovery procedure. After determining the future location, the MN sends the NOTIFY message, which contains the MAC address of the new AP, toward the upstream path. The NOTIFY message contains the HO_INIT flag, which refers to the handoff initiation. Upon receiving the message, the old AR resolves the IP address of the new AR by using the neighbor AR mapping table, which contains the binding information between the MAC addresses of neighboring APs and the IP addresses of the corresponding ARs. Note that the mapping table is assumed to be created with the deployment of ARs and the

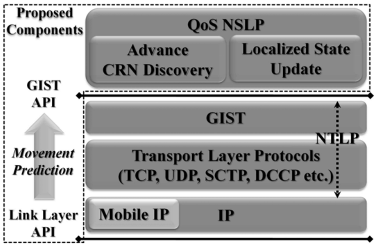


Fig. 2 Proposed QoS NSLP in the NSIS protocol stack.

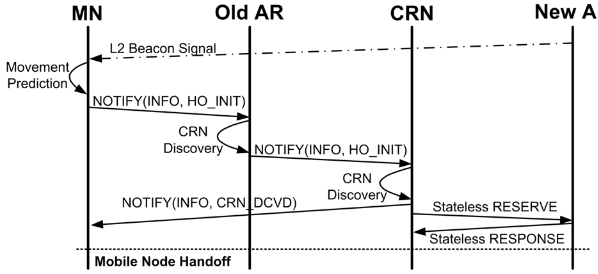


Fig. 3 Advance CRN discovery procedure.

spatial overhead incurred by the mapping table is just a few bytes of memory.

For the advance CRN discovery, each QNE can find a route to the new AR by simply referring to its routing table. In most cases, each entry, *r* in a routing table, *RT* has a next hop field, which indicates the IP address of the next hop router to which the packet is to be sent on the way to its destination. The NSIS-aware routers store the reservation direction in SID (i.e., *SID.direction*) and the IP addresses of its upstream and downstream peers in GIST. Note that non-NSIS-aware routers forward the NSIS messages according to the routing algorithm. A QNE follows Algorithm 1 to determine whether it is the CRN. If the change of destination in the MRI is detected in the received NOTIFY message, the QNE first looks up *RT* to know the next hop router toward the new AR (i.e., *r.nexthop(new_AR)*) and compares its address with the current upstream or downstream peer's address. At the same time, the QNE examines whether its outgoing interfaces for the next hop router and the peer are different or not. If the two addresses are equal, the QNE is not selected as a CRN. If the two addresses and outgoing interfaces are not equivalent, the QNE recognizes that there is a different route to the new AR. Thus, that QNE decides to be a CRN.

As shown in Fig. 3, the selected CRN immediately sends the NOTIFY message by setting the CRN_DCVD flag to inform the MN that CRN is discovered. At the same time, a stateless RESERVE message with the new MRI is sent to the new AR. Then, the QNEs on the new path store the new MRI, but does not immediately install the reservation state to avoid a waste of resources. Therefore, this advance reservation enables the network resources on the new path to be used for other flows while it is inactivated.

Algorithm 1: CRN discovery algorithm on a QNE

```
if SID == NOTIFY.SID AND NOTIFY.HO_INIT == TRUE then
    if SID.direction == upstream then
        new_AR = NOTIFY.MRI.destAddr;
        next_peer = upstream_peer;
    endif
    else
        new_AR = NOTIFY.MRI.srcAddr;
        next_peer = downstream_peer;
    endif
    while each r ∈ RT != NULL do
        if r.nexthop(new_AR) != next_peer AND
        outgoing_interface(r.nexthop(new_AR)) !=
        outgoing_interface(next_peer) then
            isCRN = TRUE;
            exit;
        endif
        else
            continue;
        endif
    endw
    isCRN = FALSE;
    Forward the received NOTIFY message to the next_peer;
endif
```

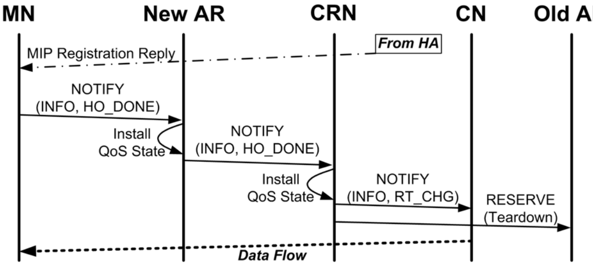


Fig. 4 Local state update procedure.

3.3 Local State Update

After handoff, two signaling procedures are performed for reservation session adjustment: activation of the advance reservation on the new path; and a local state update on the common path (that is, the path between the CN and the CRN). Figure 4 depicts the message exchange procedure.

Each step in Fig. 4 is described in detail as follows:

- Handoff notification: After receiving an MIP registration reply or a binding update from its home agent, the MN immediately sends a NOTIFY message toward the CRN with the HO_DONE flag set.
- Activation of advance reservation: Upon receiving the NOTIFY message, each QNE on the new path installs the QoS NSLP state for the given session and flow as long as the network resources are sufficient to be reserved. Thus, the flow can be given high priority over other traffic (e.g., the best-effort traffic). This message is forwarded until it reaches the CRN.
- Reservation state update: When the HO_DONE NOTIFY message has arrived, the CRN immediately sends a NOTIFY message with an RT_CHG flag set to the CN. On receiving this message, each QNE updates its state of the corresponding session.
- Old path teardown: At the same time as it sends a state update message to the CN, the CRN also sends a RESERVE message toward the old AR with a T-flag set in order to release the previously reserved resources so that we can avoid the double state problem and the invalid NR problem.

The local state update can significantly reduce the session reestablishment latency because only the reservation states on the common path are updated, not on the entire path. After the local state update, the QoS NSLP notifies the changed destination address to the corresponding multimedia application so that the CN replaces the destination address of the data flow with the MN's care-of-address to transmit packets along the new path.

4. Testbed Implementation

4.1 Testbed Construction

We implemented an experimental testbed for evaluating the operability of our approach. As shown in Fig. 5, the testbed contains four routers including ARs, an MN, and a CN. In spite of its simplicity, the testbed configuration is sufficient for comparing and characterizing the performance of our scheme and conventional NSIS.

A proposed NSIS is installed on every node except the traffic generator. The ARs are equipped with an MIP module. For wireless access, the APs and the MN are equipped with IEEE 802.11 [21] interfaces providing 11 Mbps data rate. The APs connected to the ARs reside in different subnet and have different ESSID. A hierarchical token bucket [22] and a stochastic fairness queuing [23] are used for QoS differentiation. Dynamics MIP software [24] is deployed on the ARs and MN to support mobility. For video transmission, a VideoLAN client [25] is used, and a multi-generator tool [26] is used to generate the background traffic.

With the testbed, we analyzed the delay factors of the handoff that affects the service disruption as shown in Fig. 6. The time taken to pass through the overlapped area, T_{OA}, varies with the configuration. The measured time for the advance reservation (T_{AR}) in our testbed averages about 18 ms. Actually, T_{OA} is longer than T_{AR}. For example, T_{OA} is 2 s when the width of the overlapped area is 30 m and the velocity is 15 m/s. Thus, the advance reservation is guaranteed to be completed in our testbed before the connection is lost. The handoff latency, $T_{Handoff}$, consists of the delay of L2 roaming, T_R, MIP advertisement, T_{Ads}, and MIP binding update, T_{BU}. L2 roaming is performed by the reassociation with the new AP [21]. Because there are only two APs that should be scanned before handoff, T_R is less than a few milliseconds in our testbed. After the L2 roaming, the MN waits for an advertisement from a new foreign agent or solicits for new connection. In our testbed, the interval of the agent advertisement, T_{Ads} is configured to be 100 ms. If the MN receives the agent advertisement, it sends the MIP registration request to its home agent. The binding update time, T_{BU}, is the interval from when a registration request is sent to when the corresponding registration reply is received. In our testbed, T_{BU} is measured as 42 ms on average. In our approach, the total service disruption time, $T_{Disruption}$, is the sum of $T_{Handoff}$ and the delay of the reservation activation process, T_{Act}, which is measured as 9 ms on average. Thus, the portion of T_{Act} within $T_{Disruption}$ is about 9% so that it does not significantly affect the service disruption. On the other hand, the time for the QoS session reestablishment in the conventional NSIS, $T_{Re-establish}$, is about 1.5 s on average. Thus $T_{Re-establish}$ significantly increases $T_{Disruption}$.

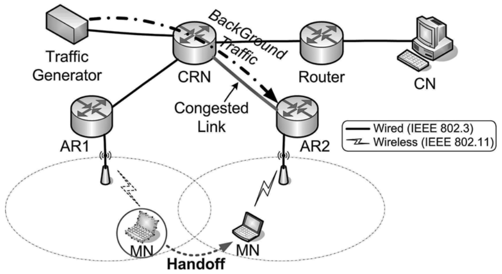


Fig. 5 Experimental testbed environment.

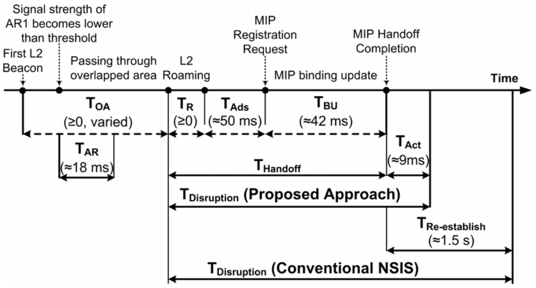


Fig. 6 Handoff delay factors in the service disruption.

4.2 MPEG Video Streaming

To perform video streaming experiments, MPEG video is streamed from CN to MN over UDP at a constant bit rate (CBR) of 1.75 Mbps. The maximum capacities of the wired and wireless links are about 94.1 Mbps and 4.9 Mbps. A bandwidth of 2 Mbps is reserved on intermediate routers for the video stream. We measured the average video streaming rate and the PSNR values of the video frames. The PSNR is one of the objective and widely-used quality metrics for video because it can be calculated simply in terms of the mean square error [27]. The maximum PSNR is 78.13 dB when the complete video frames are streamed. If the PSNR is less than 30 dB, we conclude that the frames are lost or damaged [28]. As depicted in Fig. 5, the MN is initially attached to AR1 and moves to the cell managed by AR2 while receiving and playing the video stream. The heavy background traffic of 93 Mbps is loaded between the CRN and AR2.

Figure 7 shows the variation of the video streaming rate. At around the 29 second, the handoff procedure is initiated and the data rate is rapidly decreased in both approaches. After the completion of handoff, the conventional NSIS suffers from significant video quality degradation due to heavy background traffic for about 7 s. Considering that the session reestablishment time in conventional NSIS is estimated to be 1.5 s, as shown in Fig. 7, the congestion of the new wireless cell managed by AR2 significantly impacts on the quality degradation of the streamed video. However, our approach quickly recovers the stable data rate after a short service disruption (of less than 1 s). This quick recovery is

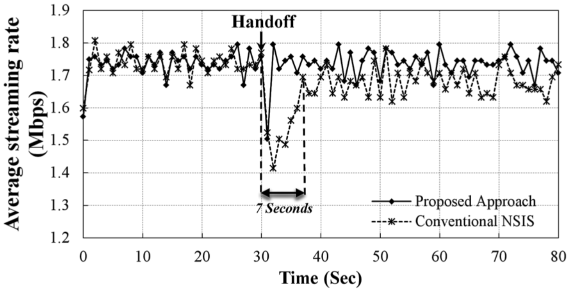
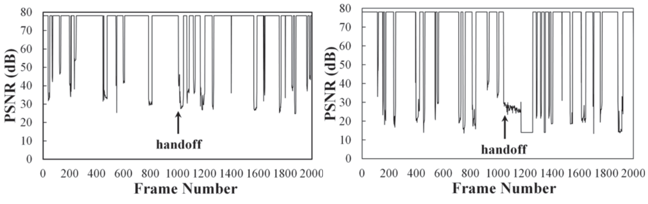


Fig. 7 Average video streaming rate.



(a)

(b)

Fig. 8 PSNR of an MPEG video stream with (a) the proposed approach and (b) conventional NSIS.

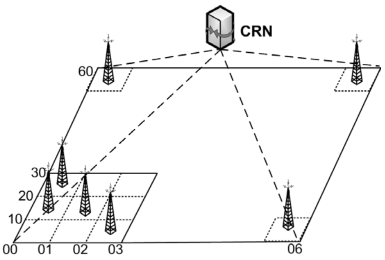


Fig. 9 Simulated network topology.

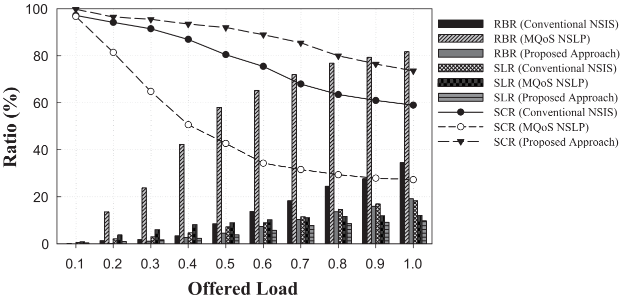


Fig. 10 QoS signaling performance factors.

possible because, with advance reservation, the variation of streaming rates is scarcely affected by severe service disruption, except for the handoff latency.

Figure 8 shows the PSNR values for the video frames delivered to an MN when our approach (a) and the conventional NSIS (b) are applied. As depicted in Fig. 8(b), the conventional NSIS suffer from about 216 damaged frames. In this case, the desired QoS level is not guaranteed because of heavy background traffic. However, our approach leads to only 31 frames being damaged after handoff as shown in Fig. 8(a). Note that most of the damaged frames are affected exclusively by the handoff latency caused by the link and network layer not by the QoS signaling latency. This outcome shows that our approach can avoid the video quality degradation by reducing the session reestablishment latency even in a congested network.

5. Simulation Study

In addition to the testbed implementation, we conducted a simulation with ns-2 [29] to illustrate how effectively our approach guarantees that a MN would complete its reservation session without failures. We compared the proposed approach to the conventional NSIS and MQoS NSLP [16]. Figure 9 shows the network topology where all 49 ARs are uniformly distributed in the simulation area. Each wireless cell has a coverage of 250 m, and the overlapped area between two cells is 150 m. For simplicity, the distance between the CRN and each AR is configured to be one hop. In our simulation, the MNs' movement pattern follows the random walk on the tours model [30], where the initial locations and the movement directions of the MNs are randomly chosen. When an MN reaches the border of the simulated area, the movement direction of the MN is randomly changed. The speed of the MN's movement varies from 1.5 m/s to 25 m/s.

The QoS evaluation factors are the same as those in [3]. They are useful for showing the overall performance of the QoS signaling protocols. The reservation blocking ratio (RBR) is the probability of a reservation request for a wireless cell being blocked due to a lack of network resources. The session loss ratio (SLR) indicates the probability of an MN losing its active reservation path after handoff due to a lack of network resources. The session completion ratio (SCR) represents the probability of an MN successfully completing the reservation session without suffering any reservation blocking or session loss. Hence, this ratio reflects the combined effect of the first two factors.

To measure those QoS factors, we increased the offered load (ρ), which is the total number of active reservation requests (i.e., RESERVE messages) from MNs in the simulated area. If we assume that the inter-arrival time of reservation requests and the reservation duration follow exponential distributions with a mean $1/\lambda$ and $1/\mu$, respectively, the offered load is equal to $N\lambda/C\mu$, where N is the average number of MNs per AR and C is the average total number of available reservation sessions supported by an AR. In our simulation, λ and μ are configured as 1/180. We can change the offered load so that it ranges from 0.1 to 1.0 by increasing N which varied from 5 to 50.

Figure 10 shows the RBRs, SLRs, and SCRs for the conventional NSIS, MQoS NSLP and the proposed approach. As the offered load increases, the RBR increases in all cases because the lack of the available resources. Especially, RBR of MQoS NSLP steeply increases because it unnecessarily reserves the resources of all candidate ARs before handoff. When the offered load is greater than 0.4, the

RBR of the conventional NSIS increases more rapidly than that of our approach. This is because the reservation state of the current session is not prepared in the routers on the new path. In addition, the extra signaling for the IP tunnel requires additional network resources between the CRN and the home agent. That is, the distance of the new signaling path is increased and the network resources of the IP tunnel should also satisfy the QoS requirements. As a ressult, the reservation request for a new session cannot be accepted by the routers on the new path. On the other hand, the proposed approach prepares the reservation along the new path before handoff. Moreover, the distance of the new path is shorter because our approach does not require extra signaling over the IP tunnel. Thus the reservation requests of a new session can be accepted more easily.

Clearly, the greater the number of advance reservations, the lower the SLR. The conventional NSIS does not make any advance reservations. Thus the SLR increases more sharply as the offered load increases. In contrast, MQoS NSLP and our approach make advance reservations so that the reservation session is not easily lost. In the proposed approach, the advance reservation is performed for at least one of ARs to which an MN is most likely to move into whereas the advance reservation in MQoS NSLP is performed for all the neighboring ARs. Therefore, more resources are available in our approach compared to MQoS NSLP. The SCR decreases in all approaches as the offered load increases. However, the slopes of both the conventional NSIS and MQoS NSLP are steeper than that of the proposed approach. This outcome indicates that our approach can achieve SCR of 73.6% even when the offered load is 1.0 while the corresponding SCR of the conventional NSIS and MQoS NSLP are 59.1% and 28.0%, respectively because of greater RBR and SLR.

6. Conclusion

In this paper, we proposed an enhanced QoS NSLP that supports mobility with a cross-layer approach. Our approach uses movement prediction based on link layer information to reduce the number of unnecessary advance reservations. In our approach, the CRN is discovered before handoff, and the network resources along the new path are proactively reserved. Moreover, Our approach requires only a few modifications to the current NSIS and does not need additional software on the network entities (such as the CN, CRN, ARs, and MN) except for the modified NSIS itself. The experimental results show that our approach can recover the reservation state for a QoS guaranteed flow within a few milliseconds after handoff. Thus, the service disruption due to handoff is significantly reduced. The performance comparison with several QoS factors in the simulation study shows that the current NSIS and MQoS NSLP can be considerably enhanced by the proposed approaches, especially with respect to RBR, SLR, and SCR. This capability indicates that our approach can guarantee a seamless multimedia QoS in mobile Internet by reducing the latency of signaling session adjustment. In addition, the proposed approach resolves the mobility issues that arise in the current NSIS protocol.

We have shown that our approach is an efficient way to provide QoS guarantees when the network is congested. In future works, we plan to improve our mechanism by making it compliant with other mobility management protocols such as SIP and mSCTP. For a seamless mobile multimedia service, the total handoff delay incurred by L2 roaming and the routing path switching in the network layer must be drastically reduced.

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