Guard Channel based Call Admission Control Schemes in Hierarchical Mobile IPv6 Networks

Shun-Fang Yang and Jung-Shyr Wu

1Department of Communication Engineering, National Central University, No.300, Jung-da Rd., Jung-li City, Taoyuan, 32054 Taiwan
945403004@cc.ncu.edu.tw

Abstract: Call Admission Control (CAC) strategies are required to guarantee all service types meet their quality of service (QoS) requirements in wireless broadband mobile networks. Although much research focuses on modified Mobile IP to get better efficient performance, there are few papers to discuss admission control when considering handover and mobility management. CAC should be introduced to Mobile IP-based network to guarantee the QoS for users. In this paper, we extend Hierarchical Mobile IPv6 (HMIPv6) Binding Update message to support CAC schemes. According to the simulation results, it was evident that these CAC schemes can reduce the probability of the handoff dropping and the cell overload and limit the probability of the new call blocking. The method can provide QoS in Mobile IPv6 networks with few modifications on MAP functionality and slight change in binding update (BU) message formats. In future work, we will enhance the threshold adjustment procedure so that our CAC schemes can accommodate themselves to the drastic changes of mobility patterns in mobile networks.

Keywords: Call Admission Control, Hierarchical Mobile IPv6, Guard Channel, Wireless Internet.

1. Introduction

Recent research has intensively focused on the next generation wireless networks that will meet the increasing demand for services with higher data rate and for enhanced multimedia applications, such as video phones and video streaming. Instead of developing an all new network, the next generation wireless networks strive to seamlessly integrate existing multiple heterogeneous networks and make modification of protocol and signaling schemes as few as possible. But there are a number of challenges that must be addressed to enable compressive Quality of Service (QoS) and mobility support. Networks should be able to support seamless handover to maintain a high quality of enhanced multimedia applications. Otherwise, packet losses occurring during handover will degrade QoS. [1] Thus mobility management is a key requirement for the next generation wireless networks.

Since the next generation networks will be unified networks based on IP architecture, the design of IP-based mobility management schemes becomes necessary. The IETF Mobile IPv6(MIPv6) [3] and its extension were proposed for efficient mobility management. Hierarchical Mobile IPv6 (HMIPv6) [4] manages the mobility of a Mobile Node (MN) using both a router located in the MN’s home domain (Home Agent, HA), and a router located in a domain visited by the MN (Mobility Anchor Point, MAP). Local movements of the MN are hidden from the outside of the visited domain. The HMIPv6 can reduce the amount of signaling and improve the performance of handover latency. Although much research [5,6,7] focus on modified Mobile IP to get better efficient performance, there are few research papers to discuss admission control scheme when considering handover and mobility management.[2]. The HMIPv6 is to reduce the number of messages sent by a mobile node (MN) over a wireless link while maintaining an optimal route to the mobile node. The HMIPv6 mobile nodes send one binding message to a Mobility Anchor Point (MAP) located in the visited network. MAP is essentially a local Home Agent (HA) for the MN and the MN will maintain two IP addresses -- one is the on-link CoA (LCoA) and the other is the regional CoA (RCoA). Whenever the MN enters into a domain, it first registers with MAP after receiving a router advertisement that includes a MAP option. In the process of binding update, the MN acquires a RCoA on that MAP’s link. After that, the MN uses this address to register with its HA and all the Correspondent Nodes (CNs). As long as the MN moves only inside that MAP’s domain, the movement remains transparent to the nodes (including its HA) outside the domain. Only the LCoA changes which the MN informs only to the MAP entity. The IPv6 packets, sent from CN to the MN, reach the MAP first and consequently, the MAP tunnels the packet to the MN’s LCoA. The MN’s outgoing traffic is tunneled to the MAP in a manner identical to the tunneling of outgoing packets to the HA.

CAC in wireless networks has been receiving a great deal of attention during the last two decades and the central role that CAC plays in QoS provisioning in terms of the signal quality, call blocking and dropping probabilities, packet delay and loss rate, and transmission rate. In the first and second generation of wireless systems, the CAC schemes have been developed for a single service environment. In the third generation (3G) wireless systems, multimedia services such as voice, video, data, and audio are offered with various QoS profiles. It is anticipated that different access technologies will coexist in future wireless networks. Henceforth, next generation wireless networks will encompass 3G wideband CDMA (WCDMA) cellular systems; wireless local area networks(WLAN) such as the IEEE 802.11 family and HIPERLAN; digital video broadcasting (DVB); and broadband wireless access metropolitan area networks (MAN), such as IEEE 802.16. Therefore, CAC have to be revised to deal with the anticipated new composite radio wireless environment. [9,14]

In wireless mobile networks, as the cell size becomes smaller, handoffs become more frequent. To provide QoS...
guarantees to the mobile users, call admission control schemes must be carefully designed. Good CAC schemes have to balance the new call blocking and the handoff call blocking in order to provide the desired QoS requirements. If there is an ongoing call in one place, it may have potential impact on the resource usage in another place in the future. The concept of influence curve is introduced to characterize such influence that an ongoing call exerts on the adjacent cells. Since the channel reservation can be adjusted dynamically, mobility-based call admission control schemes can be designed to provide QoS in the wireless networks. [10,15]

The guard band policy (GCP), proposed in [11], keeps a certain amount of channels to handoff calls only while the rest of the channels can be shared by both new calls and handoff calls. Hence, handoff calls are given higher priority over new calls, and as a result the reduction in the handoff probability comes at the expense of higher blocking rate. Therefore, the guard band (number of channels) reserved for handoff calls must be properly chosen as a tradeoff between new call blocking probability (Pb) and handoff dropping probability (Pd).

It has been shown in [12] that the guard band policy can minimize a linear objective function of Pb and Pd. An enhanced version of guard channel policy, called fractional guard channel policy (FGCP), has been proven to be optimal in minimizing Pb with a hard constraint on Pd and minimizing the number of needed channels with a hard constraint on both Pb and Pd. In FGCP, a new call is admitted by a probability \( \beta \) which is a decreasing (or, more accurately, non-increasing) function of the cell state (i) defined as the number of occupied channels, while a handoff call is admitted as long as there is a free channel.

Limited FGCP (LFGCP) is shown to be more effective than the basic guard band policy in minimizing Pb and the number of needed channels while holding the constraint on Pd [12]. In the LFGCP, there are three possible admission probabilities for new calls (1, \( \beta \), 0) where \( \beta \approx 1 \). The first value (unity) is used as long as the cell state (i) is less than T. The second value is used when the cell state (i) is equal to T. The third value is used when the cell state (i) is greater than T where T is a design parameter.

It is evident that CAC should be introduced to Mobile IPv6 based network to guarantee the QoS for users. To handle mobility and handoff issues, we develop a reference architecture that implements a hierarchical access networks for mobile users. We consider the HMIPv6 based CAC schemes in the mobile networks. The rest of paper is organized as follows: Section 2 presents our HMIPv6 based CAC schemes. The simulation architecture and result discussion are described in section 3 and 4, respectively. Finally, section 5 concludes this paper.

2. The HMIPv6 based CAC schemes

Some of the mobility based CAC schemes that require extensive knowledge of the system parameters, such as user mobility which is challenging to obtain, moreover they sacrifice the scarce radio resources to satisfy the deterministic QoS bounds. The HMIPv6 extension headers can be combined with well-known CAC schemes, and the impacts of terminal mobility to the network performance will be discussed. The proposed method only requires few modifications on MAP functionality and slight change in binding update (BU) message formats.

The guard channel schemes described in section 1 are expanded to combine with the mobility information. A new call or a handoff call is identified from the new registered or updated HMIPv6 BU messages. The MN’s movement can be predicted by observing the variation of MN’s position in a fixed period. In Figure 1, a new flag C is added in HMIPv6’s BU message format, it provides the movement recording of MNs to future calculation in the MAP. The M flag is defined in HMIPv6, it indicates MAP registration. When a MN registers with the MAP, the M and A flags must be set to distinguish this registration form a BU being sent to the HA or a CN. An optional flag N indicates a lower hierarchical MAP registration in the mobile networks. When C is set, M and N should be set in the MAP.

\[
\text{Figure 1. Local Binding Update Message}
\]

In Figure 2, the lower hierarchy MAPs will cover many Access Routers (ARs) that locate far from the default MAP. When a MAP receives a BU from a MN, it will look up its binding cache at first. If there is no record, it will inform other MAPs. If there are no records in all MAPs, the call is identified as a new call. Because the IPv6 supports piggyback, the above procedure can use data messages to reduce the overhead of IPv6 headers.

The operation procedure of the MAP is shown in the Figure 3. When a MAP receives a BU with C flag set, it records the current registration time \( (t_i) \), next times’ registration time \( (t_{i+1}) \), and next two times’ registration time \( (t_{i+2}) \). The MAP also calculates \( T_1 = t_i - t_{i+1}, T_2 = t_{i+1} - t_{i+2} \). The value of \( T_2 \) and \( T_1 \) represent MN’s cell residency time in the current and next handoff cells. We define \( T_{th} \) as the critical threshold residency time. If both \( T_1 \) and \( T_2 \) are smaller than \( T_{th} \), this call is recognized as a higher-mobility MN. In this case, the MAP uses MN’ LCoA to identify which AR serves to the MN, and calculates the number of higher-mobility MNs and all MNs. The above procedure can reveal the MN density in the ARs and future movement patterns.
The mobility information is combined with GCP, FGCP, and LFGCP to three proposed CAC schemes. It is evident that a high mobility MN needs much more capacity. When the number of high mobility MN is larger than a certain ratio, the capacity of the cell will be exhausted. The ratio of higher-mobility MNs is defined to be:

\[
\text{The ratio of higher - mobility MNs} = \frac{\text{(the total number of higher-mobility MNs in the cell)}}{\text{(the total number of MNs in the cell)}}
\]

The parameter “nuth” is defined as the threshold of the ratio of higher-mobility MNs, the parameter “adjust” as reserved capacity, and the parameter “adjust_1” as random adjustable value. Three mobility based CAC schemes are proposed in this section, and the complete description of these schemes is in the following.

2.1. Mobile IPv6 based guard channel policy (MBGCP)

The operation procedure of MBGCP is shown in the Figure 4. When a call comes in the MAP, this call can be identified a new call or a handoff call from the new registered or updated HMIPv6 BU messages. If it is a handoff call, it will be accepted or dropped by checking the free capacity of the service cell. If the call is accepted, the registration time and the total number of MNs in the cell are recorded. Then this call is identified as a higher-mobility MN or not, and the total number of higher-mobility MNs in the cell are recorded. The formula (1) is used to calculate the ratio of higher-mobility MNs.

The procedure described below will be used to adjust the value of the parameter “adjust”: If the ratio of higher-mobility MNs in the adjacent cells are all smaller than the parameter “nuth”, the parameter “adjust” of the center cell will change to “gc”(guard channel). If any cell’s ratio of higher-mobility MNs is larger than “nuth”, the “adjust” of the center cell will change to 0. If it is a new call, the capacity of the service cell should minus the “adjust” value. The remainder of the procedure is same as the handoff call except that new call doesn’t need to record the number of the higher-mobility MN.

2.2. Mobile IPv6 based fractional guard channel policy (MBFGCP)

The operation procedure of MBFGCP is shown in the Figure 5. The ratio calculation of higher-mobility MNs and the main procedure are same as in MBGCP. But MBFGCP will not reserve fixed capacity (gc) to a handoff call, it will use $\beta$ to identify the priority of a new call and a handoff call. The parameter $\beta$ is defined as same as in GFCP. The parameter “adjust_1” will be b or 0.

If the ratio of higher-mobility MNs in the adjacent cells are all smaller than “nuth”, the parameter “adjust_1” of the center cell will change to b ($0 < b < 1$). Then $\beta$ will be set according the residual capacity of the cell. If it is a new call, the capacity of the service cell should be checked at first. If there is enough capacity, we use probability of $\beta$ to accept a call or reject a call. The following procedure is the same as the handoff call except that a new call doesn’t need to record the number of the higher-mobility MN.

2.3. Mobile IPv6 based limited fractional guard channel policy (MBLFGCP)

The operation procedure of MBLFGCP is shown in the Figure 7. The MBLFGCP combines MBGCP and MBLGCP, as same as the LFGCP combines GCP and LGCP.

3. Simulation Model and Description

The simulation model is shown in the Figure 8.
hierarchy of HMIPv6 is limited to one hop, and it is prohibited to selecting more than one MAP and forcing packets to be sent from the higher MAP down through a hierarchy of MAPs. Here, we used two levels of MAPs due to the following reasons:

4.3.1 The mapping of RCoA_{level_1} and RCoA_{top} is maintained when MN moves in the same MAP_{level_1} domain. Only LCoA will change. The handover latency will not increase very much.

4.3.2 We do not impose any constraints on the location of MAPs and ARs, and we assume that MNs can decide to bypass any levels of hierarchy if appropriate.\[13\]

When a MN registers with the MAP_{top}, the M flag must be set. When a MN registers with the different MAP_{level_1}, the N and M flag must be set. If the movement is in the same MAP_{level_1}, the N flag must be set. When a BU message with M and N flag sent to MAP_{level_1}, this BU message will be forwarded to MAP_{top}.

**Table I. The parameters are defined in the simulation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Radius</td>
<td>250m</td>
</tr>
<tr>
<td>Capacity of a cell</td>
<td>50</td>
</tr>
<tr>
<td>The Average Arrival time of the New calls (T_{new})</td>
<td>4.5 - 3.5 - 2.5s</td>
</tr>
<tr>
<td>The Average Residency time of the Calls (T_{res})</td>
<td>24 - 60s</td>
</tr>
<tr>
<td>The Average Service time of the Call (T_{serv})</td>
<td>450s</td>
</tr>
<tr>
<td>The Average Arrival time of the Call from other networks</td>
<td>20s</td>
</tr>
<tr>
<td>T_{th1}</td>
<td>30s</td>
</tr>
<tr>
<td>T_{th2}</td>
<td>45s</td>
</tr>
</tbody>
</table>

The simulation parameters are shown in Table1. The parameters T_{th1} and T_{th2} are the critical threshold residency time of MNs with velocities 60km/hr and 40km/hr, respectively. The T_{th} was defined in section 3. Because MNs will not always move in a straight line, we use these thresholds (T_{th1} and T_{th2}) as references to adjust the value of T_{th}. We assume that MNs are going to stop if T_{2} < T_{th1} and T_{1} > T_{th2}; MNs slow down to a medium speed if T_{2} < T_{th1} and T_{th1} < T_{1} < T_{th2}; MNs keep in high speed if T_{2} < T_{th1} and T_{1} < T_{th1}. When 1000 calls entered every cell, the simulation terminated. The numerical results took average of 10 times of simulation.

\[ P_d = \frac{\text{handoff dropping calls}}{\text{all calls in an AR}} \] (2)

\[ P_b = \frac{\text{new blocking calls}}{\text{all calls in an AR}} \] (3)

\[ P_b & d = \frac{\text{dropping or blocking calls}}{\text{all calls in an AR}} \] (4)

4. Performance Evaluation and Simulation Results

4.1. GCP vs. MBGCP (guard channel=1)

We compared blocking and dropping probabilities P_b(GCP), P_d(GCP), P_b(MBGCP) and P_d(MBGCP) under different T_{new-call} (average arrival time of new call) and different “nuth” (the threshold of the ratio of high frequent handover MNs). Some of the simulation results are shown in Figure 9. There is a tradeoff between increased P_b and decreased P_d according to the different values of the parameter “nuth”. When the number of handoff is small, MNs have higher probability to be with higher-mobility ratio > 0.9. Therefore, P_d increases due to that the parameter “adjust” often equal to zero. When “nuth” is 0.96, we find that the decreasing ratio of P_b is larger than the increasing ratio of P_d. When the arrival rate of new calls is higher (e.g. T_{new-call} is 2.5), the MBGCP has similar P_b and P_d performance with GCP. We also find that the MBGCP has the most obvious performance improvement when T_{new-call} is 3.5.

![Figure 9. T_{new-call}=3.5s MBGCP(nuth=0.9) vs. GCP](image)

The Pb&d in different schemes is shown in Figure10. The GCP has the higher Pb&d due to the reservation channels, and the “uncontrolled” scheme has the lower Pb&d. The MBGCP’s Pb&d increases when the value of the parameter “nuth” increases. Many calls are blocked when the guard channel is free, and some of the system resource is wasted. We defined the ratio of blocking calls in full loads = (blocking calls in full loads / all blocking calls in an AR). The value of the ratio due to overloading is shown in Figure11. We find that the lower “nuth” can reduce the probability of the new call blocking and limit the handoff dropping probability.

![Figure10. T_{new-call}=3.5s uncontrolled GCP and MBGCP’s Pb&d](image)
4.2. GCP vs. MBGCP (guard channel=2)

Because as the number of the guard channel increases, Pd will decrease and Pb will increase. GCP can keep Pd to a low range, but increase Pb. According to Figure12, the benefits of MBGCP are more obvious when the number of the guard channel increases. Because GCP let hand off calls more smooth with the sacrifice of accepting new calls, we see the benefit of the MBGCP.

4.3. FGCP vs. MBFGCP

FGCP has been described in section 2, a new call is admitted by a probability \( \beta \) which is a decreasing function of occupied capacity; a handoff is accepted if there are free channels. We set \( \beta \) to be 0.04 as shown in Figure13. Some of the simulation results are as shown in Figure14 and Figure15. When the “nuth” is small (e.g.”0.8”), the curves of Pb and Pd approach to “uncontrolled”. When the resident time \( T_{dwell} \) is short, \( \beta \) becomes small due to the nearly full loading. Because the probability of admitting new calls is low, FGCP let Pb unnecessarily increase when the guard channel is free. The MBFGCP obviously let Pb decrease. We can find that the MBFGCP can make better utilization of resources than the FGCP.

4.4. LFGCP vs. MBLFGCP (guard channel=2)

We set \( b \) to be 0.3, \( \text{gc}=1, \beta=1-((0.3/50)*(50-1))=0.706, \) and \( \text{gc}=2, \beta=0.712. \) According to Figure16 and Figure17, we can find that the MBLFGCP can make better utilization of resources than other CAC schemes. Because the LFGCP has combined the advantage of the GCP and the FGCP, it’s hard to find the improvement opportunity from MBLGCP. The difference between the MBLGCP and the LFGCP is not obvious as the difference between the MBGCP and the GCP. We find that the performance of the MBLGCP is still slightly better than the LGCP.
4.5. MBGCP vs. MBFGCP vs. MBLFGCP

We assume that the parameters of each CAC scheme are selected to achieve the optimized performance. The comparison of Pb (blocking probability) under these CAC schemes is shown in Figure 18. The MGCP will reject any new call when the parameter “adjust” equals to “gc” and the number of free channels is 1 or 2. The MBFGCP uses β to do admission control of new call, so Pb of the MBFGCP is far lower than the MBGCP. The MBLFGCP uses β to do admission control when the “adjust_1” equals to b. The Pb of the MBLFGCP is lower than that of the MBGGCP except when the average residence time is smaller than 40 second. The comparison of Pd (dropping probability) under these CAC schemes is shown in Figure 19. Because only the handoff call can be accepted when the parameter “adjust” equals to “gc” and the number of free channels is 1 or 2, the MBGCP can get the lowest Pd at the sacrifice of much increasing Pb. While both Pb and Pd are taken into consideration together, Pd is only slightly different under the CAC schemes. Because Pb of the MBLFGCP is much lower than that of the MBFGCP and MBGCP, the MBLFGCP should be the best solution among these CAC schemes.

5. CONCLUSION AND FUTURE WORK

In this paper, we extend HMIPv6 Binding Update message to support CAC schemes. These CAC schemes can reduce the probability of the handoff dropping and cell overload, and limit the new call blocking probability. We focus on network layer handoff here, and assume linker layer handoff has been under control. In future work, we will enhance the threshold adjustment procedure so that our CAC schemes can accommodate themselves to the drastic changes of mobility patterns in the heterogeneous mobile networks. The usage scenarios can be applied to many mobile broadband wireless access networks.

References


Figure 4. MBGCP
\[ \beta = (1 - \left( \frac{\text{adjust}_1}{\text{capacity}} \right) \times \left( \text{capacity} - \text{residual capacity} \right) ) \]
\[ \beta = (1 - \left( \frac{\text{adjust} \_1}{\text{capacity}} \right) \times \left( \text{capacity} - \text{Residual capacity} \right)) \]

Figure 7. MBLFGCP