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Adaptive Location Update and Paging Scheme for Mobile Broadband Wireless Access Networks

Jee-Hyeon Na, Hochoong Cho, Sangho Lee
IP Convergence Technology Research Team, ETRI,
Daejeon, Korea
jhna@etri.re.kr

YunWon Chung* and Sang-ha Kim**
*Soongsil University, Seoul, Korea,
** Chungnam National University, Daejon, Korea

Abstract— **In mobile broadband wireless access networks such as Mobile WiMAX, idle mode is defined to save radio resources and reduce power consumption when a mobile station is not involved in packet transmission and reception. In order to support idle mode, location update and paging should be supported, where location update and paging overheads are affected by paging group size. In this paper, we propose a hierarchical paging group ID structure, an adaptive location update algorithm based on the paging group structure, and a predictive paging scheme for large size paging groups. The performance of the proposed scheme is compared with conventional scheme from the aspect of location update and paging signaling overheads. Numerical results show that the proposed scheme performs well for varying the velocity of mobile stations.**

Keywords-component; Mobile Broadband Wireless Access Networks, IEEE 802.16e, mobile WiMAX, idle mode, paging, location update, hierarchical location management

I. Introduction

Mobile broadband wireless networks can provide cheaper data services than cellular networks, and support faster mobility and larger coverage area than WLAN networks. In the mobile broadband wireless networks, idle mode is defined to save radio resources and to reduce power consumption of a mobile station (MS) when it is not involved in packet transmission and reception. In order to save battery power, a MS in idle mode sends a location update message to the network when the position of the MS is changed and monitors radio information with longer monitoring interval than active mode. Thus, there are important issues on reducing the number of location update and paging messages sent from the MS because these messages incur significant power consumption of MSs in idle mode [1].

The location update and paging costs are affected by a paging group size, velocity of MSs, session arrival rates, etc. Thus, a great deal of research works have been performed to minimize the sum of location update and paging signaling costs considering these factors [2],[3]. Most previous researches have been based on layer 2 technologies of wireless cellular networks, or layer 3 technologies provided by IP layer independent on wireless access networks [4], [5]. Recently, hybrid approaches, which combine layer 2 technologies with layer 3 technologies, have been proposed. However, these researches only consider wireless cellular network and WLANs as target networks, and thus researches for mobile broadband wireless networks such as mobile WiMAX (Worldwide Interoperability for Microwave Access) are required

Although location updates and paging schemes are defined for mobile WiMAX in IEEE 802.16e [6] and mobile WiMAX NWG documents [7], [8], a new scheme considering factors such as velocity of MSs and session arrival rates is needed to provide better performance. Therefore, we propose a hybrid location management scheme, which is composed of a hierarchical paging group structure for mobile WiMAX in order to efficiently accommodate MSs with different mobility classes, an adaptive location update based on user-velocity adaptive paging group selection, and a prediction-based paging for large size paging group. Then, we analyze the proposed scheme in terms of location update and paging signaling costs.

The rest of this paper is organized as follows: Section 2 presents related works regarding idle mode management in mobile WiMAX. A detailed description of the proposed adaptive location update and paging scheme based on hierarchical paging group structure is given in Section 3. Performance evaluation results are given in Section 4. Finally, Section 5 summarizes and concludes this work.

II. Location Update and Paging in Mobile WiMAX

In this section, we describe mobile WiMAX network architecture, paging group ID, which is an identifier of paging group, and information flows for location update and paging. It is based on WiMAX forum Network Working Group (NWG) documents and IEEE 802.16e specification.

A. Network Architecture

Figure 1 shows network architecture in mobile WiMAX. There are two kinds of paging controllers (PCs) which administer the activity of idle mode MS. For each idle mode MS, there shall be a single anchor PC that contains the updated location information of the MS. There may also be one or more other PCs in the network which relay paging and location update messages between paging agent (PA) and anchor PC. PA is a functional entity that handles the interaction between PC and IEEE 802.16e specified paging related functionality implemented in the BS, and it is co-located with BS. Location register (LR) is a distributed location database with each instance corresponding to an anchor PC. LRs contain information about idle mode MSs.

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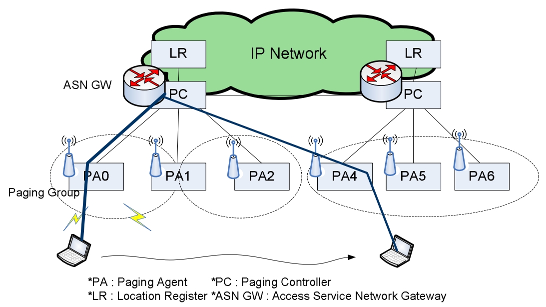

Figure 1. Network architecture for Location Update and Paging

B. *Paging Groups*

Paging group is characterized by paging group ID, where paging group ID is a 16-bit identifier of paging group which is used for location update and paging. The paging group ID is included the downlink channel descriptor (DCD) which is transferred to MSs at each frames or mobile paging advertisement (MOB_PAG-ADV) MAC message which is transferred to MSs during paging intervals. The MS compares the stored paging group ID with the received paging group ID, and determines whether its location has been changed or not.

A paging group is composed of one or more BSs in mobile WiMAX. The size of a paging group affects the number of location update messages and paging messages. If the size of a paging group is large, the number of location update messages is small but the number of paging messages is large. Thus, this is useful for high mobility MS. On the other hand, if the size of paging group is small, the number of location update messages is large but the number of paging messages is small. This is useful for low mobility MS.

C. *Location Update and Paging Procedures*

Location update procedure is used to confirm the location and status of an idle mode MS, and the location information of an MS is managed by paging group ID. Figure 2 shows location update procedure in mobile WiMAX. In IEEE 802.16e, four location update evaluation conditions are defined [8], i.e., paging group update, timer update, power down update, and MAC hash skip threshold update. The paging group update occurs when an MS moves between paging groups with different paging group IDs, but other location update conditions are not related to the paging group ID. Thus, we are only concerned with paging group update in this paper.

Paging procedures occur when packets are terminated to an idle mode MS. In mobile WiMAX, data path function (DPF) is defined for establishing and controlling data path. If Mobile IP is used, the DPF is located with foreign agent (FA). If the destination MS for terminated packets is in idle mode, then DPF generates Initiate_Paging_Req message and sends it to the anchor PC of the MS. The anchor PC initiates topologically aware or unaware paging procedure in the last location updated paging group. Figure 3 shows the procedures for paging in mobile WiMAX.

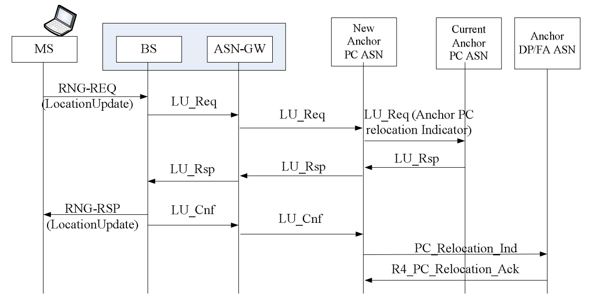

Figure 2. Location Update Procedure in Mobile WiMAX

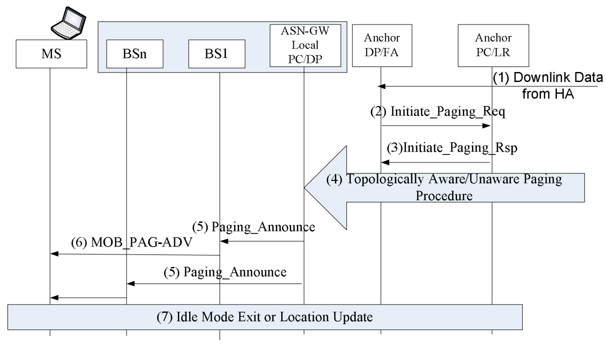

Figure 3. Paging Procedure in Mobile WiMAX

III. Adaptive Location Update and Paging Scheme

In section 2, we described messages and information flows of location updates and paging, which are defined in IEEE 802.16e and NWG of WiMAX Forum. Since there is tradeoff between location update and paging signaling costs based on paging group size, an appropriate paging group size should be designed. However, since the optimal size of paging group ID depends on many factors such as mobility characteristics of MS, session arrival rates, etc., a flat paging group ID structure is not appropriate to accommodate all MSs with different mobility characteristics. In this paper, in order to efficiently accommodate MSs with different mobility classes, overlaid paging group architecture for mobile WiMAX is adopted from previous works. Then, similar to [3], a paging group selection algorithm based on the mobility of an MS in hierarchical paging group architecture is proposed in WiMAX network.

A. *Hierarchical Paging Group ID Structure*

The size of paging group ID is defined as 16 bits in IEEE 802.16e. A BS belongs to one or more paging groups, and a paging group ID is composed of one or more BSs. We propose that paging group ID has a structure like figure 4. The paging group ID is composed of paging group level (PG Level) and local identifier. The paging group level can be one, two or three bits depending on the size of paging group. If the size of paging group is small, the first bit is only used for paging group level and other 15 bits is used as a local identifier. In case of large paging group, 3 bits are used for PG level and other 13 bits are used as a local identifier. It is possible that a BS is included in multiple paging groups. The reason why the paging group level is composed like figure 4 is because the smaller paging group ID needs more local identifiers.

Figure 4. Structure of paging group ID.

Figure 5 shows an example of hierarchical paging group architecture with the proposed PG IDs. Based on the PG ID, it is possible to distinguish the paging group size. In figure 5, it is shown that a BS can be included in three different kinds of paging group levels, i.e., small, medium, and large areas. An MN can select these paging group levels based on its mobility pattern.

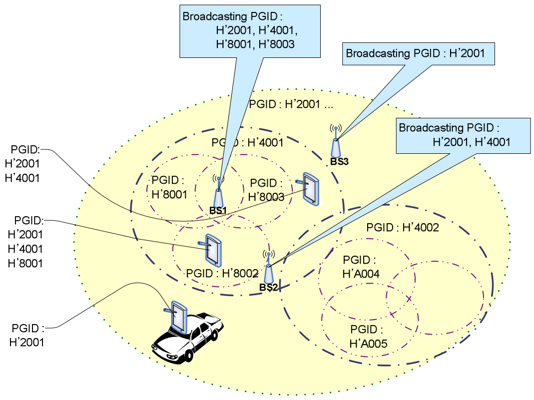

Figure 5. Example of paging group architecture.

B. *Velocity Adaptive Location Update Algorithm*

Similar to [3], we propose a paging group selection algorithm which changes the paging group level based on the mobility classes of an MS. We assume that paging groups are overlaid as shown in figure 5. In this algorithm, we newly define a T_{lu}, which is a predefined threshold to indicate a representative paging group crossing time related to the velocity of an MS and the radius of a BS. This value is predefined by following equation; $T_{lu} = (3600/v)*d$, where v is a velocity per hour and d is a distance of each paging group level. We also define a I_{lu} that is an average location update interval. The I_{lu} and T_{lu} values are used for transition among paging group levels. Figure 6 shows paging group level transition diagram based on these values. It means that a fast MS has a large size paging group level and a slow moving or fixed MS has a small size paging group level.

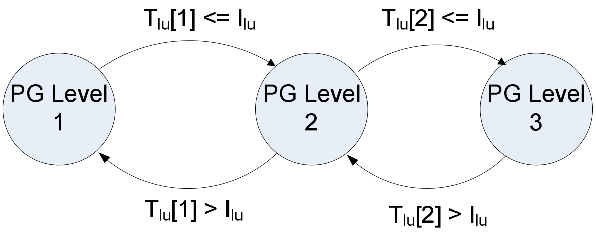

Figure 6. Paging group level transition diagram.

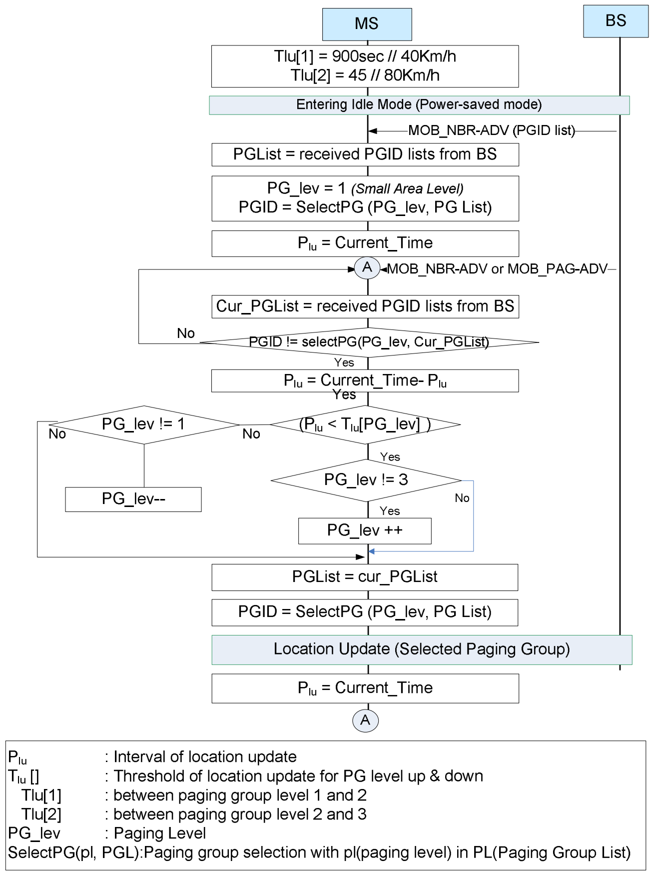

Figure 7. Adaptive location update algorithm.

Figure 7 illustrates a flow chart for an adaptive location update algorithm in hierarchical paging group architecture. Basically, we assume that there are three different kinds of paging group levels and the whole service area of WiMAX is covered simultaneously by each paging group level. Thus, an MS can always receive paging group IDs of three paging group levels indicating small, medium, and large paging group areas. We classify the mobility classes of an MS into low, medium, and high classes. Thus, after estimating the mobility of MSs, small, medium, and large paging groups are assigned to low, medium, and high mobility MSs, respectively. In this algorithm, we use time interval value of location update for estimating user's mobility and also define a value of threshold for changing paging group level.

C. *Predictive Paging Algorithm for Large Paging Group Size*

In the proposed adaptive location management algorithm, MN selects the largest paging group level when user's velocity is very high. In this case, location update overheads are reduced but paging overheads will be increased in a large paging group area.

The large paging group should be nearby road like highway, expressway or trail of train because we assume that the large paging group is used by rapid users. A new paging algorithm in paging controller is proposed based on the above assumptions. The algorithm can predict the BS which is accessed by the MS to be paged using user's velocity, direction and topologically-aware paging group information. In this algorithm, we introduce a predictive BS and candidate BS concept. Figure 8 shows numerical expression for the decision of predictive or candidate BS. The BSs are obtained by entering time in the paging group, the number of BSs in the paging group and average velocity of the MS in the large paging group. Figure 9 is a paging algorithm for large size paging group ID using the predictive and candidate BSs. The algorithm reduces paging overheads by sending paging request message to the predictive and/or candidate BSs in the large paging group.

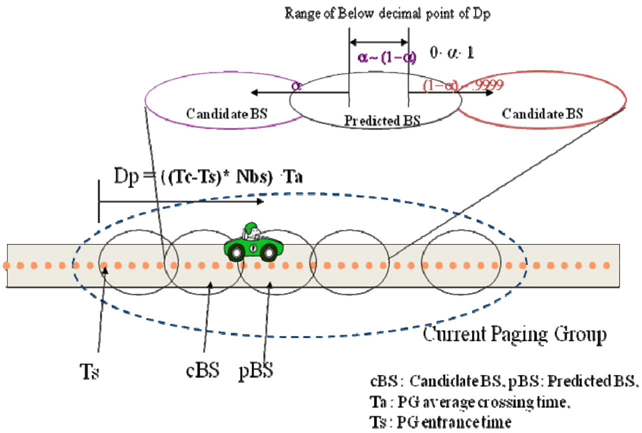

Figure 8. Predictive and candidate BSs decided by D_p

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If session arrival to an idle mode MS, then
    Dp = (Ts/Ta) *Nbs
    pBS = BSList(PGid, Dp+1)
    if  (α<=below decimal of Dp < (1−α))
        Send PagingRequest to pBS
    Else if (α > below decimal of Dp)
    {
        cBS = BSList(PGid, Dp);
        Send PagingRequest to pBS and cPS;
    } else {
        cBS = BSList(PGid, Dp+2);
        Send PagingRequest to pBS and cPS;
    }

If there is no PagingResponse during Tp, then
    Send PagingRequst to remained BSs in the PG.
else
    Send data to the Idle mode MS.
```

Figure 9. Paging algorithm in a paging controller

IV. PERFORMANCE ANALYSIS

We use Qualnet 4.0 simulator for analyzing the proposed location update and paging algorithm [12]. Qualnet 4.0 supports advanced wireless network library which consists of MAC and PHY layers of IEEE 802.16 including 802.16e. However, idle mode and paging features are not yet supported in the advanced wireless library of Qualnet 4.0. Therefore, we implemented location update, paging and idle mode management functions into the Qualnet 4.0. And then, we simulate conventional schemes having various numbers of BSs in a paging group ID and the proposed adaptive paging group selection scheme using Qualnet 4.0. The simulation parameter values for the performance analysis are shown in Table 1.

Table 1. Simulation parameter values

parameters	value
network size	6000 * 6000 meters
Number of BSs	36
radio range of MSs	1000 meters
Number of MNs	10
paging group level	3 levels (small, medium, large)
Velocity of MNs	Uniform [4 ~ 100] km/hour
Mobility model of MNs	random way point
Threshold time values for changing paging group level in the proposed scheme	Level 1 → level 2 (up 4Km): 900seconds Level 2 → level 3 (up 80Km) : 45 seconds

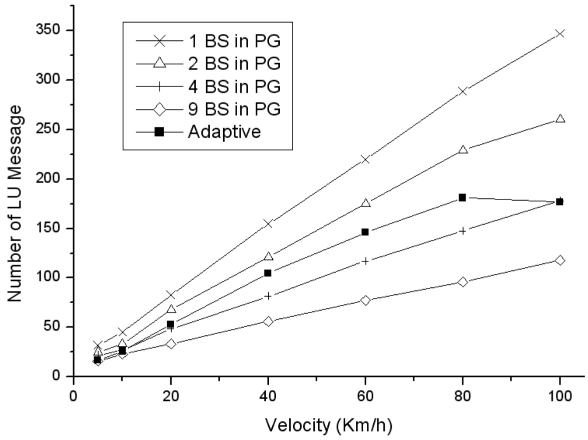

Figure 10. Number of location update messages for varying the MN's velocity.

Figure 10 shows the number of location update messages for varying the velocity of MSs. As the value of the velocity of MSs increases, the number of location update message increases. For a fixed value of velocity, the number of location updates increases as the number of BSs in a PG decreases. The performance the proposed adaptive scheme is better than PG with 1 BS and 2 BSs but the location update schemes having PG with 4 BSs and 9 BSs performs better than the proposed scheme. We note that if the MN's velocity is high, the performance of the proposed scheme is almost the same with the conventional scheme having PG with 4 BSs.

Figure 11 shows location update and paging overheads for elapsing the simulation time. Paging is assumed to occur once for every 500 seconds in the simulation. As the figure shows, only the conventional scheme having PG with 4 BSs performs better than the proposed scheme, and the proposed scheme outperforms all other schemes. Based on the results, it can be said that the performance of the proposed scheme is suboptimal. Since the optimal number of BSs changes from situation to situation, it is not feasible to have the optimal number of BSs in a PG all the time. Thus, it can be said that the proposed scheme has its merit to adaptively change the size of PGs depending on the velocity of MNs.

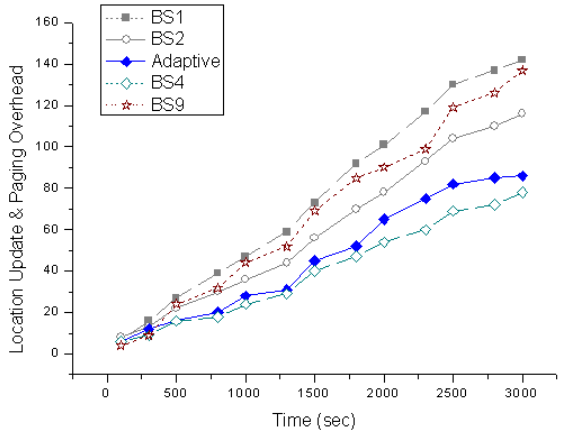

Figure 11. Location update and paging overheads for elapsing simulation time.

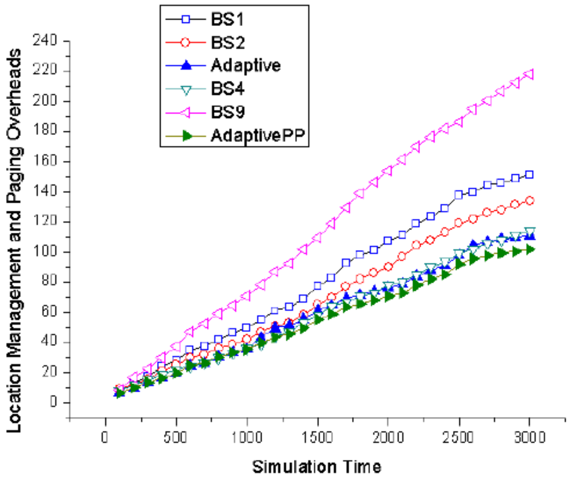

Figure 12. Location update and paging overheads for slasing simulation time (Paging Interval = 100sec*(0.5/10))

Figure 12 the sum of location update and paging overheads for elapsing the simulation time. Paging is assumed to occur once for every 100 seconds per 20 MSs in the simulation. The graph shows that the proposed adaptive location management scheme including the proposed predictive paging scheme has less signaling overheads than other schemes.

V. CONCLUSIONS

In this paper, we proposed adaptive location update and paging scheme with newly defined hierarchical paging group ID structure. Then, a paging group selection algorithm based on the mobility of an MS is proposed in mobile WiMAX, which estimates MS's mobility using the time interval between two consecutive small paging group changes. The performance of the proposed algorithm was compared with conventional algorithm from the aspect of location update and paging signaling costs. Results show that the proposed algorithm outperforms the conventional algorithm and the proposed algorithm is valid. As a further study, works on improving paging overheads using the proposed algorithm will be carried out.

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