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A Location Management with Adaptive Binding Idle Lifetime Scheme for IP-based Wireless Network

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Abstract

We propose a location management with adaptive binding idle lifetime scheme for IP-based wireless network. In our proposed scheme, the binding idle lifetime value is adaptively varied according to user characteristics. The main idea is that the mobile node (MN) does location update (LU) even in idle state. Furthermore a sequential paging scheme is used to reduce the paging cost. The proposed scheme can be used in both cellular network and IP-based network.

I. Introduction

In cellular networks, location update (LU) and paging techniques are both used to minimize the location management cost and optimize mobility management. A number of location management schemes have been proposed in cellular networks [1]. However, in IP-based wireless networks, the current Mobile IPv4 (MIPv4) standard [2] and MIPv6 internet draft [3] only support simple registration without paging.

Recently several new schemes have been proposed to extend MIP with paging [4][5][6]. In [4], the authors have proposed paging extensions mobile IP protocol called P-MIP. The scheme uses non-overlapping and overlapping paging area construction. Also blanket polling paging method is used. However, in the scheme the user characteristics such as a mobile node's speed and call arrival rate are assumed to be the same for all of the mobiles. In [5], they use same protocol as [4] and do the analysis of active timer value. Most of the times, mobile node (MN) stays in an idle state rather than an active state. Therefore, it is more important to optimize the idle lifetime value. In [6], mobile nodes support optimum paging areas, where a paging area is adaptive on a per-mobile basis. However, mobile node computes its optimal paging area size whenever there is a change in Paging area. This impacts the power consumption of mobile nodes. Therefore, an efficient scheme is required in the IP-based wireless networks.

In this letter, an adaptive binding idle lifetime scheme with the aid of sequential paging is proposed to minimize a total location management cost in IP-based wireless networks. In this scheme idle mobile node periodically informs network on its current location. This makes the probability successful of first paging step (PSFS) high. Therefore, it allows the paging cost to reduce significantly and thus the total location management cost is minimized.

II. Adaptive binding idle lifetime scheme

Figure 1 shows the proposed location management scheme. An idle MN sends binding update message to a home agent (HA) and a paging agent (PA) when the MN crosses a location area (LA) boundary or receives a paging request, or the idle binding lifetime value is expired.

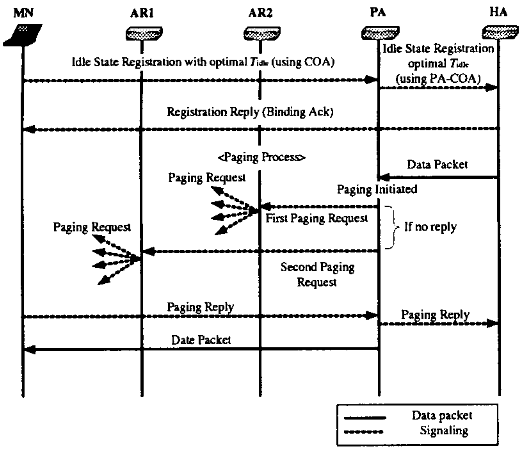

Fig. 1. The proposed location management scheme

The binding update message contains idle lifetime field which is adaptively calculated for high PSFS. Conventional schemes use a large idle lifetime value in order to reduce unnecessary location update. In our proposed scheme, the idle lifetime value is adaptively varied with respect to the user characteristic and affects the PSFS, which is the key parameter to reduce the paging cost. Small value of the idle lifetime induces the high PSFS, but this will increases the location update cost significantly.

If the binding message is accepted by the HA, the HA sends binding ACK to the MN. When a correspondent node (CN) sends data packet to the MN, HA intercepts the data packet. The HA determines whether the MN is in an active state or idle state. If this is in active state, the HA forwards the packet to the MN, if not, then it forwards to the PA. The PA buffers the received data and initiates the paging process. The last location update cell or second tier cells are paged first. If there is no reply for a certain time, then the rest of cells in the same LA are paged simultaneously. In our proposed scheme, simple 2-step sequential paging is used for simplicity. The MN receives the paging request and sends paging reply message to the PA, and the PA forwards the buffered date to the MN.

The essential advantage of the proposed scheme is that the total location management cost is significantly reduced than that of conventional schemes. Despite the location update cost is slightly increasing, lower paging cost with high PSFS can make that possible.

III. Performance analysis

The total location management cost is derived as below. [7]

$$C_T = c_p \lambda_c N_p + c_l / E[T] \qquad (1)$$

c_p and c_l denote the cost coefficients for paging and LU, respectively. λ_c (calls/hr) is the call arrival rate which is assumed to be Poisson distribution. N_p is the mean number of paged cells for each call arrival. $E[T]$ denotes an average LU interval, where T is a random variable of elapsed time till the MN is paged or a LU events occur from last LU. The first term in Eq. (1) represents the paging cost and the second term in Eq. (1) represents the location update cost. Let N be the number of cells in current LA. n and P_s stands for number of tiers in first paging area and the PSFS, respectively. Then we can have:

$$\begin{aligned} N_p &= P_s[1+3n(n-1)] \\ &\quad + (1-P_s)[N-1-3n(n-1)] \end{aligned} \qquad (2)$$

Let t_c and t_R be random variables of an inter-call arrival time and a MN's remaining residence time in the current LA, which are exponentially distributed with mean $E[t_c] = 1/\lambda_c$ and $E[t_R] = N^{1/2}/\lambda_r$, respectively. The λ_r (number of cell crossing/hr) means a cell crossing rate and $1/\lambda_m$ is the mean of t_m, where t_m is a random variable of the remaining residence time in the area of n^{th} tier. Therefore $E[t_m]$ can be expressed as

$$E[t_m] = [1+3n(n-1)]^{1/2} / \lambda_r \qquad (3)$$

The mean value of T is

$$E[T] = \frac{1}{\lambda_c + \lambda_r / \sqrt{N}} [1 - e^{-(\lambda_c + \lambda_r / \sqrt{N}) T_{idle}}] \qquad (4)$$

where T_{idle} is the binding idle lifetime value. Subsequently, we are going to derive the PSFS. For simplicity, it is assumed that if the MN moves out of the current registered cell, it never comes back. Then the PSFS can be calculated by

$$P_s = 1 - \int_{t_c=0}^{E[t_i]} \int_{t_m}^{t_c} \lambda_m e^{-\lambda_m t_m} dt_m \lambda_c e^{-\lambda_c t_c} dt_c \quad (5)$$

where $E[t_i]$ is the mean value of $min(T_{idle}, t_R)$ and is represented by

$$E[t_i] = \frac{1}{\lambda_r / \sqrt{N}} (1 - e^{-\lambda_r T_{idle} / \sqrt{N}}) \quad (6)$$

Thus the total location management cost C_T can be obtained.

IV. Numerical results and discussions

In this section, we show a relationship between the PSFS and T_{idle}, an optimal idle binding lifetime value for minimizing C_T. Here, it is assumed that $c_p = c_l = 1$, the number of cells $N = 100$. The parameters λ_c, λ_R, λ_r are varied.

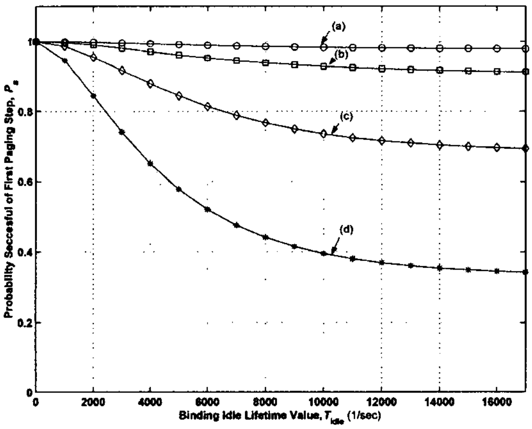

Fig. 2. The Probability Successful of First Paging Step according to the binding idle lifetime value.

(a) $n = 3$, $\lambda_r = 1/10\text{hr}$, $\lambda_c = 1/1\text{hr}$

(b) $n = 1$, $\lambda_r = 1/10\text{hr}$, $\lambda_c = 1/1\text{hr}$

(c) $n = 3$, $\lambda_r = 1/30\text{min}$, $\lambda_c = 1/1\text{hr}$

(d) $n = 1$, $\lambda_r = 1/30\text{min}$, $\lambda_c = 1/1\text{hr}$

Figure 2 shows the PSFS as a function of T_{idle} under different λ_r and n. The PSFS decreases as the T_{idle} increases and the PSFS slightly increases when paging area is getting larger. When the T_{idle} is close to zero, the LU happens frequently and the MN always locates in the last LU cell when call arrives. Therefore, the first paging always succeeds. When the MN moves very slowly, the PSFS is close to 1. And the PSFS decreases as the MN moves fast.

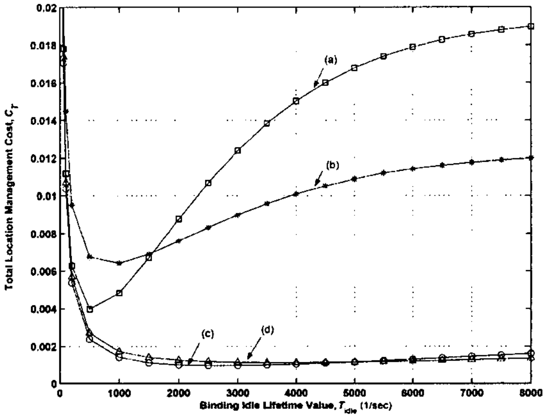

Fig. 3. The total location management cost according to the binding idle lifetime value.

(a) $n = 3$, $\lambda_r = 1/1\text{hr}$, $\lambda_c = 1/30\text{min}$

(b) $n = 1$, $\lambda_r = 1/1\text{hr}$, $\lambda_c = 1/30\text{min}$,

(c) $n = 3$, $\lambda_r = 1/1\text{hr}$, $\lambda_c = 1/10\text{hr}$,

(d) $n = 1$, $\lambda_r = 1/1\text{hr}$, $\lambda_c = 1/10\text{hr}$,

Figure 3 plots the total location management cost with respect to the T_{idle} when the incoming call rate increases and the first paging area is different. It can be observed that there exists optimal binding idle lifetime value to minimize total location management and the optimal T_{idle} increases as the call arrival rate decreases. According to the first paging area, the optimal idle lifetime value is different. When T_{idle} is very small, the C_T becomes high due to the frequent LU, regardless of the λ_c. Meanwhile, when T_{idle} is large, the λ_c plays a dominant role in determining total location management cost.

V. Conclusions

In this letter, an adaptive binding idle lifetime scheme with the aid of sequential paging is proposed to reduce total location management cost in IP-based wireless networks. The adaptive binding idle lifetime value which is determined by call arrival rate, cell residence time, and the size of the first paging area is derived to minimize the total location management cost. The proposed scheme can be used in both cellular network and IP-based network.

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