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RESEARCH ARTICLE

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Access network selection strategy using position prediction in heterogeneous wireless networks

Abstract Access network selection (ANS) strategy is one of the most important issues in future heterogeneous networks. The current solutions for this issue are not very efficient because they do not consider the motion scenarios and cannot predict the next location for mobile node. In this paper, an effective ANS strategy based on global positioning system (GPS) is proposed. Making use of information such as position coordinates and moving velocity acquired by GPS, the ANS proposed can predict the next point of attachment for mobile node (MN), assist existing ANS strategy to make more reasonable decision, and achieve better performance.

Keywords position prediction, access network selection (ANS), heterogeneous networks, global positioning system (GPS)

1 Introduction

Access network selection (ANS) strategies have been researched for years, and there have already been lots of efficient schemes. The existing ANS mechanism focuses on the algorithm simplicity and efficiency [1–4] and tries to adopt effective ANS algorithm to make decisions based on network capabilities, application requirements, user preferences, and so on. As all the mechanisms proposed do not take into consideration the different motion scenarios with reference to motion speed and direction, the decision results are not very accurate and adaptive.

In this paper, we propose an effective ANS strategy using position prediction mechanism (PPM). PPM can locate every object by using the geographic coordinates (x, y) through global positioning system (GPS) and predict mobile node's (MN's) next point of attachment (PoA). Based on such information, PPM can instruct intelligent ANS strategy.

The rest of the paper is organized as follows: Sect. 2 introduces the PPM in details. In Sect. 3, we propose PPM aided ANS strategy. Simulation results are given in Sect. 4. Finally, Sect. 5 concludes this paper.

2 Position prediction mechanism

Nowadays, position estimation has been an important issue for researchers. Most studies in this field are based on sensorless control of reluctance motor drive. Reference [5] deals with a speed and position estimation method for the sensorless control of permanent magnet synchronous motors. Reference [6] presents the rotor position estimation of neural networks in switched reluctance motor control using current and/or voltage signals. Reference [7] proposes a novel sensorless position/velocity control system for an interior permanent-magnet synchronous motor. Reference [8] controls the magnitude of dc-bus voltage as a function of speed. Reference [9] applies "voltage model" to rotor position estimation for sensorless control of no salient permanent-magnet synchronous motors. These methods only focus on sensorless control of reluctance motor drive and are not applicable to cellular architecture.

GPS used to determine coordinates is equipped in many terminals. Coordinate divides all areas into horizontal and vertical parts, respectively, and we can locate every terminal. PPM takes advantages of GPS and can enable us to identify the movement speed and direction, as well as current serving network in which MN is located. Furthermore, we can predict which network MN is expected to enter.

The coverage area of each cellular cell is a hexagonal grid with radius R, and base station (BS) is located at the center of coverage area. Each BS knows its boundary, and R can be transmitted to MN by router advertisement

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[10,11]. MN can obtain its location information and calculate its speed and movement direction [12]. We assume that the speed v is uniformly distributed over the interval from 10 to 30 m/s, and the direction of movement is uniformly distributed over $[-\pi/2, \pi/2]$.

In PPM, it is very important to predict MN's next movement location. We define the threshold distance as r, which forms an inner circle, and $R = 200$. MN's trajectory is shown in Fig. 1.

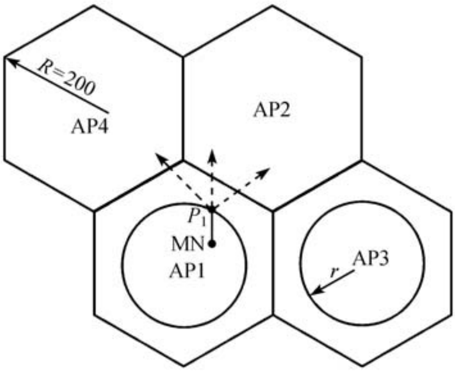


Fig. 1 Trajectory of MN

Point P_1, trajectory intersection with inner circle, is the point where ANS is initiated. By GPS, PPM can record current time and MN location (x, y) at any moment. We take three points of the path at a sequence of time interval Δt and try to predict the next position P_4. The three points are recorded as $P_1(x_1, y_1, t_0+k_1\Delta t)$, $P_2(x_2, y_2, t_0+k_2\Delta t)$, $P_3(x_3, y_3, t_0+k_3\Delta t)$. As the three points are at a small distance, the path function that describes trajectory through the three points should be a linear function:

$$y = ax + b.$$

In Fig. 2, we assume that MN moves along point P_1, P_2, P_3. If MN movement is rectilinear, the trajectory can be described by

$$y = ax + b,$$

$$\alpha = \arctan a, \quad \alpha \in [0, \pi/2].$$

It is assumed that MN is d away from AB and S away from B vertically. As in a general situation, MN would hardly take a sudden turn or even go back and forth, it is assumed that MN may go left or right with offset angle $\theta \in [-\pi/2, \pi/2]$. If MN moves along straight line, MN will enter cell_2. If MN moves along direction left_in, it turns left but will still enter cell_2, so does right_in situation. If θ is so large that MN moves along left_out or right_out, it will enter cell_4 or cell_3. By such calculation, we can predict the MN motion direction.

Probability density function of directions for MNs is

$$f(\theta) = \begin{cases} 0.5\cos\theta, & -\dfrac{\pi}{2} \leqslant \theta \leqslant \dfrac{\pi}{2}, \\ 0, & \text{others}, \end{cases}$$

$$\text{s.t.} \int_{-\infty}^{\infty} f(\theta)\mathrm{d}\theta = 1. \tag{1}$$

We define MN turning left if $\theta \in [0, \pi/2]$, and MN turning right if $\theta \in [-\pi/2, 0]$. The motion directions are divided into four kinds, as shown in Fig. 2: left_in, which means MN turns left but still enters cell_2; left_out, which means MN turns left and enters cell_4; right_in, which means MN turns right but still enters cell_2; and right_out, which means MN turns right and enters cell_3. The probabilities for the four situations are

$$P_{\text{left\_in}} = \int_0^{\arctan\frac{R-S}{d}-\alpha} 0.5\cos\theta\mathrm{d}\theta, \tag{2}$$

$$P_{\text{right\_in}} = \begin{cases} \displaystyle\int_{-\alpha-\arctan\frac{S}{d}}^{0} 0.5\cos\theta\mathrm{d}\theta, & \alpha + \arctan\dfrac{S}{d} < \dfrac{\pi}{2}, \\ \displaystyle\int_{-\frac{\pi}{2}}^{0} 0.5\cos\theta\mathrm{d}\theta, & \alpha + \arctan\dfrac{S}{d} \geqslant \dfrac{\pi}{2}, \end{cases} \tag{3}$$

$$P_{\text{left\_out}} = \int_{\arctan\frac{R-S}{d}-\alpha}^{\frac{\pi}{2}} 0.5\cos\theta\mathrm{d}\theta, \tag{4}$$

$$P_{\text{right\_out}} = \begin{cases} \displaystyle\int_{-\frac{\pi}{2}}^{-\arctan\frac{S}{d}-\alpha} 0.5\cos\theta\mathrm{d}\theta, & \alpha + \arctan\dfrac{S}{d} < \dfrac{\pi}{2}, \\ 0, & \alpha + \arctan\dfrac{S}{d} \geqslant \dfrac{\pi}{2}. \end{cases} \tag{5}$$

They are shown in Figs. 3 and 4.

Probability for MN to enter cell_2 is

$$P_{\text{in}} = P_{\text{left\_in}} + P_{\text{right\_in}},$$

as shown in Fig. 5. We can see that as α decreases, the probability to enter cell_2 increases.

A probability threshold is set to assist efficient ANS based on probabilities for MN to enter different neighbor cells. The threshold can be adaptively adjusted according to different values for d and v. As d increases and v decreases, the probability threshold will be advanced, and vice versa. If the probability to enter a certain cell is above the threshold, MN will select this cell as access target and prepare handoff in advance.

In general, mobile users should move along an proximate straight line, with little chance to take a sudden turn or even go back and forth. We assume that the average distance for MNs to move straightly is

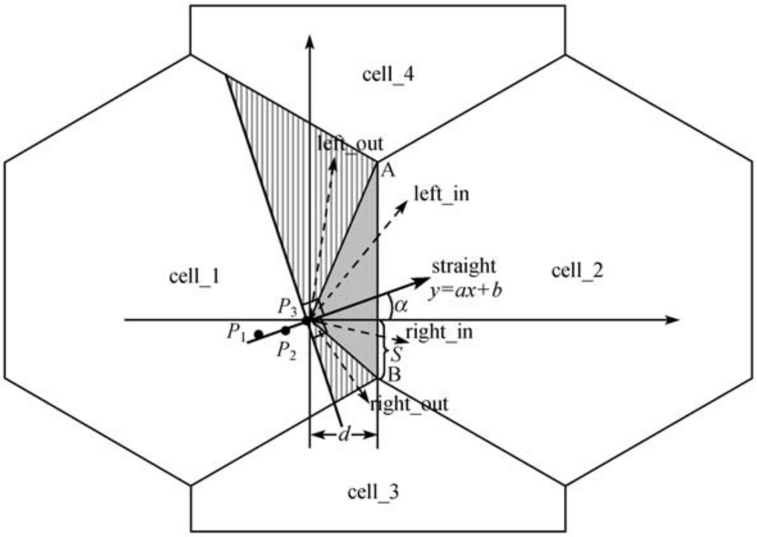
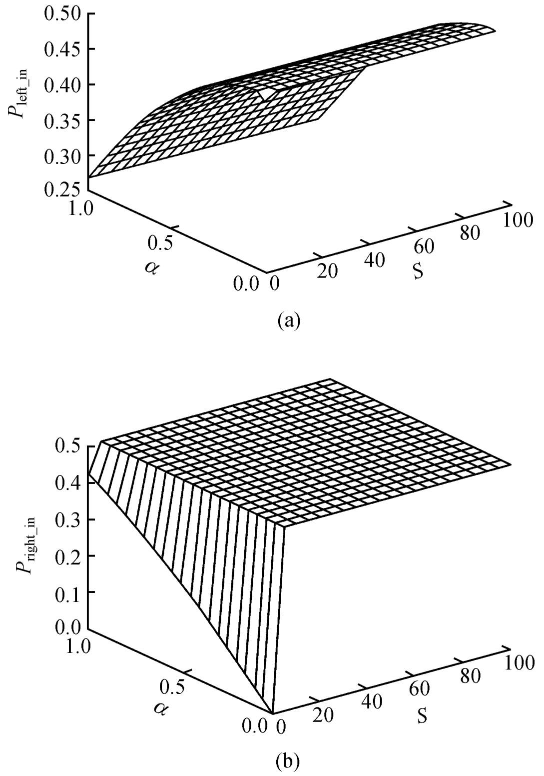


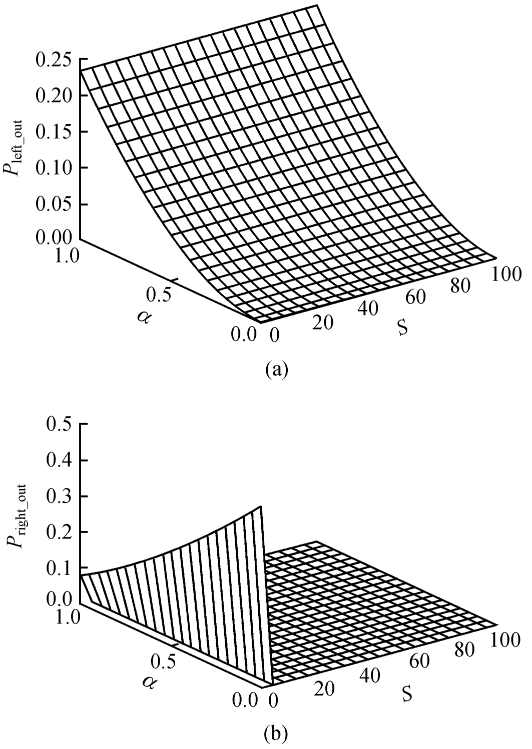
Fig. 2 Motion prediction model



(a)

(b)

Fig. 3 Left_in and right_in probability. (a) Left_in probability; (b) right_in probability



(a)

(b)

Fig. 4 Left_out and right_out probability. (a) Left_out probability; (b) right_out probability

$$\bar{l} = \bar{v}\bar{t},\ \bar{l} \in [200,\ 1000].$$

According to queuing theory, distance l in which an MN moves along a straight line is negative exponential distributed with mean value $\bar{l}$. Therefore, l has a probability density function (PDF) and a cumulative density function (CDF) as follows:

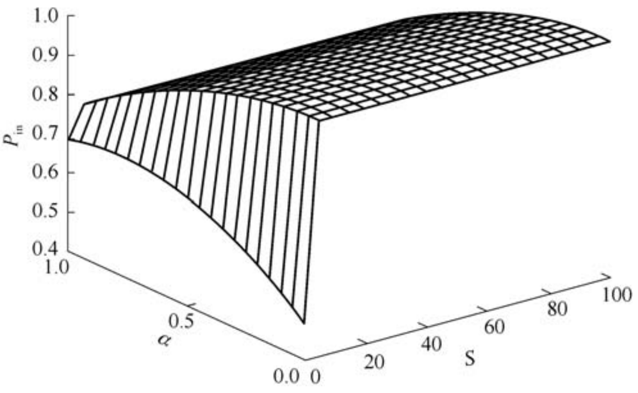


Fig. 5 Probability for MN to enter cell_2

$$\text{PDF}: f(l) = \begin{cases} \frac{1}{\bar{l}} \mathrm{e}^{-\frac{l}{\bar{l}}}, & l \geqslant 0, \\ 0, & l < 0, \end{cases} \tag{6}$$

$$\text{CDF}: F(l) = \begin{cases} 1 - \mathrm{e}^{-\frac{l}{\bar{l}}}, & l \geqslant 0, \\ 0, & l < 0. \end{cases} \tag{7}$$

We define $E(l) = F(l)$ to estimate the error for assuming that MN moves straightly. We can calculate $E(l)$ numerically, as shown in Fig. 6. Since $l = 2v\Delta t$ is usually small, the actual prediction accuracy is acceptable.

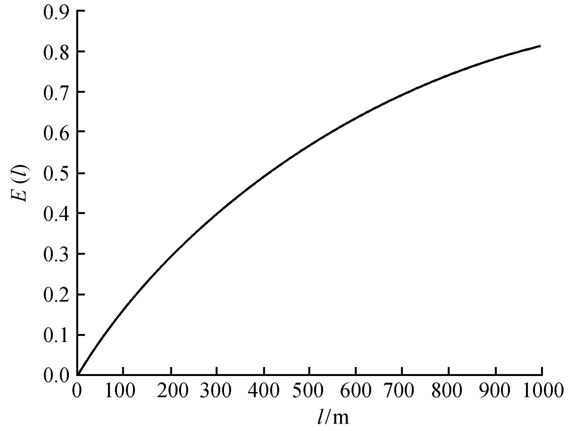


Fig. 6 Prediction error estimation function

3 PPM aided ANS strategy

The final goal of next-generation networks is to offer mobile users the best service at any time from anywhere, which has been defined as always best connection (ABC) [13]. ANS mechanism is an effective approach to achieve that goal. In traditional ANS study, attentions are paid to the algorithm design, not considering the concrete ANS scenario. We will discuss some neglected but very important information such as motion direction for ANS procedure in this section.

Present ANS studies only focus on ANS procedure design and algorithm optimization, which are localized to "the current location, the current moment". As mentioned above, PPM can easily identify the motion direction and calculate which cell MN is going to move into. When MN stands still, the traditional ANS method can select proper target network to enter into. However, when MN is in motion status, especially at a high speed, it becomes important for MN to select a target network, considering a predicted target access network. It is obvious that to access network that MN is moving toward is the best solution for ANS problem.

4 Simulation and analysis

In this section, we simulated PPM aided ANS strategy by NS-2.

In this simulation, we consider an area in which there are two wireless local area network (WLAN) access points (APs) (referred to as WLAN1, WLAN2) and a universal mobile telecommunications system (UMTS) BS, as shown in Fig. 7. The conditions of networks are shown in Table 1. To take all these parameters into consideration, the Tchebycheff method is adopted as ANS algorithm [14]. Figure 7 shows ANS selection results without/with PPM mechanism.

Figure 7 indicates that the ANS result with PPM is different from the one without PPM between point B and point C. In this simulation scenario, PPM can calculate that user equipment (UE) is moving from WLAN1 to WLAN2. Point B to point C corresponds to the overlapped area of WLAN1 and WLAN2. When MN reaches point B, traditional ANS triggers ANS algorithm and selects WLAN1 as target network because of its better capabilities. Obviously, such selection is not proper, because at point C, UE will lose connection with WLAN1, and just begin to register to WLAN2. This will introduce a long handover delay and bring in poor system performance. On the other hand, at point B, ANS with PPM will calculate UE motion direction and predict that UE is going to enter WLAN2. So ANS with PPM will select WLAN2 as target access network, and start prehandover procedure. As UE is still in the overlapped area of WLAN1 and WLAN2, it can adopt soft handover to reduce handover delay and packet loss ratio. In short, ANS with PPM can provide better selection results than ANS without PPM. This also proves the correctness and efficiency of PPM we proposed.

For constant bit rate (CBR) application, results are shown in Table 2.

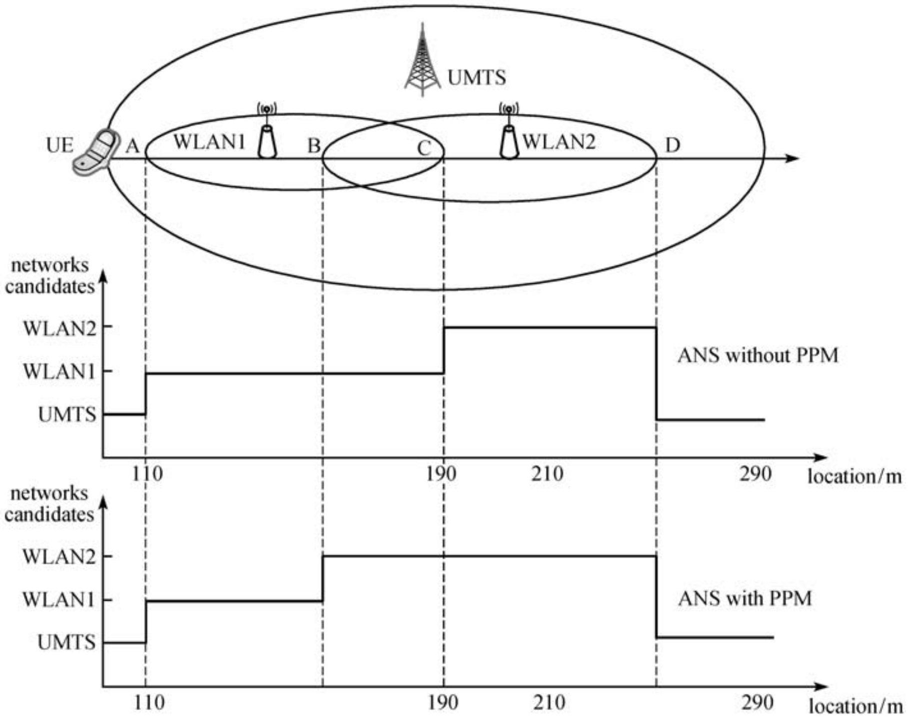


Fig. 7 ANS results without/with PPM

Table 1 Network parameters

quality of service (QoS) parameters	UMTS	WLAN1	WLAN2
bandwidth/Mbps	1.9	25	15
delay/ms	19	45	35
jitter/ms	6	10	10
security/level	8	7	6
bit error rate/%	10^{-1}	10^{-3}	10^{-4}
packet loss ratio/%	7	3	5
cost/level	0.9	0.4	0.2

Table 2 Packet loss ratio for CBR application

whether adopt PPM	yes	no
packet loss ratio/%	1.9	7.8

It can be concluded that ANS using PPM can reduce packet loss ratio by 75.6%. This is because at point B, ANS with PPM chooses WLAN2 as access network and configures a new care-of-address ahead of time, which will drastically reduce IP layer handover delay.

With reference to TCP application, handoff between different networks will decrease the TCP window size drastically, and the window size will increase slowly as indicated by congestion avoidance. Simulation results are shown in Fig. 8. Figure 8 shows the trace of congestion window (cwnd) size of ANS without PPM and with PPM at the speed of 20 m/s. For ANS with PPM, MN will select WLAN2 at point B inducing less latency, which will make window size recover sooner. In the whole coverage area of WLAN2, the window continues to increase, making TCP sender aggressively increase its congestion window size and raise transmission rate as no congestion is detected. For ANS without PPM, UE will select WLAN2 at point C, which experiences longer interruption, and only leaves less time for window size to increase until it reaches point D, which will definitely influence TCP performance.

5 Conclusion

An access network selection strategy is proposed in this paper. Position prediction mechanism makes use of location information acquired from GPS and predicts which network MN is expected to enter into. PPM can help select reasonable access network for MN according to predicted direction. Simulation results show that the proposed PPM aided ANS strategy can work more efficiently in future heterogeneous networks.

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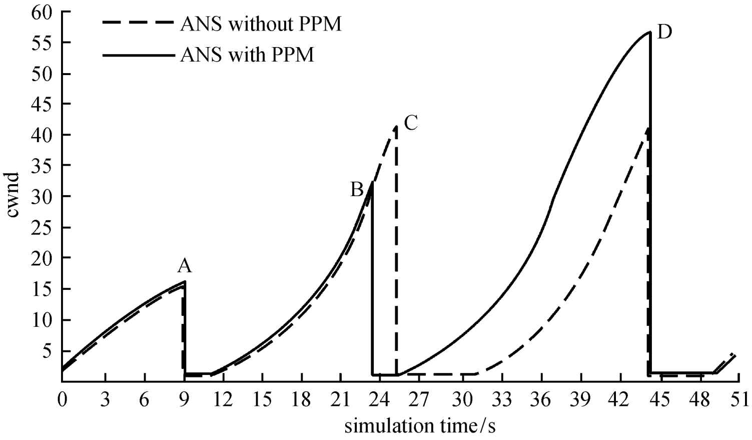

Fig. 8 Window size tracing of ANS

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