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Markov-based vertical handoff decision algorithms in heterogeneous wireless networks ☆

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A B S T R A C T

In this paper, we propose a received signal strength (RSS)-based single-attribute handoff decision algorithm at first, and investigate handoff decision model based on connection lifetime, which can keep mobile terminals (MTs) staying long enough in the preferred network. Since the preferred quality of service (QoS) parameters may be distinct among different MTs, we then formulate the vertical handoff decision problem as a Markov decision process, with the objectives of maximizing the expected total reward and minimizing average number of handoffs. A reward function is constructed to assess the QoS during each connection, and the G1 and entropy methods are applied in an iterative way, by which we can work out a stationary deterministic handoff decision policy. Numerical results demonstrate the superiority of our proposed schemes compared with other existing algorithms.

1. Introduction

Over the past decade, much work has been focusing on improving the performance of communication networks [1,2,20]. Heterogeneous wireless networks (HWNs) contain a variety of wireless access networks, which can provide users with different access technologies, multiple data transmission rates and different kinds of services. Thus, the HWNs can satisfy users' requirements better than traditional networks. Seamless and effective handoff decision is one of the most important techniques in HWNs, and generally speaking, handoff decision can be classified into horizontal handoff decision and vertical handoff decision. The former means the handoff happens between the same types of access networks, for example, between different cells in a global system for mobile communications (GSM) network. The latter means the handoff occurs between different types of access networks, such as between 3G networks and wireless local area (WLAN) networks. Since the access network keeps same in horizontal handoff, it is a symmetric process, while vertical handoff is asymmetry because the access network has changed after the handoff. Therefore, the support of vertical handoff in mobility management becomes very challenging in HWNs.

The vertical handoff decision methods mainly focus on the following research aspects: (1) received signal strength (RSS)-based decision method combined with other parameters such as network load; (2) cost function, such as available bandwidth and network cost, based method of evaluating the performance of all the available networks; (3) multi-attribute analysis based decision algorithms, such as gray correlation algorithm and level analysis algorithm; and (4) artificial intelligence technology based handoff decision method. Vertical handoff can be triggered in the following situations: (1) mobile terminal (MT) moves out from the current access network to another network; (2) MT switches to another network based on their preferences; (3) HWNs redistribute network load for system performance improvement. We consider MT-triggered

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vertical handoff in this paper. In order to make efficient handoff decisions, we jointly consider MT's quality of service (QoS) requirements, network performance and network cost (such as energy consumption in MT and occupied bandwidth) in HWNs.

In recent years, researchers have conducted a lot of work on designing effective vertical handoff decision algorithms. Based on the RSS-based vertical handoff decision method [3,4], some additional parameters, such as hysteresis, are added to avoid ''Ping-Pong'' effect. When the difference of RSS values between a candidate network and the current one exceeds a certain threshold, vertical handoff will occur. However, this strategy has some difficulties in RSS prediction, which decreases the efficiency of handoff. Therefore, we should jointly consider other parameters to conduct handoff decision.

Cost function based decision strategy makes cost comparisons between the current network and the candidate network, and let the MT to switch to the network with the minimum cost. Some other methods select the access network with the maximum network reward. In [5–8], the authors used a cost (or reward) model to select the network with the minimum (or maximum) cost (or reward). These algorithms set a stabilization period to extend the decision making time, and reduce the number of handoffs; however, they do not consider how to adjust the corresponding cost function according to the QoS parameters.

In HWNs, since MTs have multiple service requirements, vertical handoff decisions should depend on the combination of many factors, such as available bandwidth and delay, instead of any single factor. In [9], the authors applied the gray relational analysis (GRA)-based algorithm to divide the available networks into different levels, and selected the best one as the ideal network to provide the terminal with the best available QoS. Some other references [10,11] proposed artificial intelligence based algorithms through combining fuzzy logic and neural network, which selected the network attributes and clients as the inputs of a fuzzy controller, and conducted vertical handoff according to the predefined fuzzy reasoning judgment. Although the proposed multi-attribute handoff decision algorithms have taken a number of factors into account, they cannot handle the problems with uncertain properties according to MTs' preferences.

Handoff decision strategies are frequently conducted in multi-attribute algorithms based on the Markov process. In [12], the authors proposed a forecast polynomial problem based on RSS and analyzed it under a Markov process. The proposed algorithms reduce the number of handoffs and improve network resource utilization. In [13], the authors proposed a cost function based network selection method in a neural network, and conducted handoff decision according to the combination of cost function and other network parameters. Although the network performance in the neural network is better, the environmental parameters have to be collected in advance which increases complexity.

Most existing vertical handoff methods only consider RSS as the judgment index; however, the RSS-based method is rather simple and apt to produce ''Ping-Pong'' effect in the switching area. Besides, the fixed handoff threshold cannot maximize network utilization. Therefore, we consider RSS as the primary judgment index, and take some auxiliary decision factors, such as the velocity of the MT and the WLAN lifetime, into account for network performance improvement. We propose a RSS-based Markov-based Single-Attribute Vertical HandOff (MSA-VHO) decision method at first, which can effectively extend the service time in the preferred network for the MT, and adjust the handoff threshold according to the MT's velocity. Since the MT may have multiple QoS requirements and one vertical handoff decision process may depend on the combination of many factors in HWNs, we furthermore propose a Markov-based Multi-Attribute Vertical HandOff (MMA-VHO) decision method. We firstly construct a reward function, in which the weights of QoS factors are computed by the G1 and entropy methods, then we employ an iterative algorithm to obtain the stationary deterministic policy, after which the MT switches to the preferred network to maximize reward.

The rest of this paper is organized as follows: Section 2 introduces the MSA-VHO decision algorithm based on RSS. The Markov decision process based MMA-VHO decision algorithm is described in Section 3. Section 4 presents the numerical results, and Section 5 concludes this paper.

2. Markov-based single-attribute vertical handoff algorithm

In order to overcome the shortages of the existing single-attribute decision algorithms, we propose a novel algorithm based on RSS and Markov mobility model in this section. We investigate a lifetime-based handoff module which can keep users stay longer in the preferred network. A dynamic handoff method is also proposed to adjust the handoff threshold based on users' velocity for network performance improvement.

2.1. Network model

We consider a cellular network which can provide universal coverage. One WLAN network, whose signal is provided by an access point (AP), is within the 3G network, and mobile IP is adopted to conduct mobility management as demonstrated in Fig. 1.

In the network model, the WLAN is selected as the preferred network due to its lower cost compared with the 3G network. Three situations can be defined in the vertical handoff methods: moving into (MI) the preferred network; moving out (MO) of the preferred network and passing (P) through the preferred network. In HWNs, the MTs always want to connect with the preferred network as long as possible to satisfy its application requirements. Generally speaking, there are two kinds of mobility management methods, namely loose coupling and tight coupling. We adopt the former one, where the