A QoS-Aware Vertical Handoff Algorithm Based on Service History Information

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***Abstract*—In future wireless communication networks, seamless handoff either by vertical or horizontal is an important issue in radio resource management. For a vertical handoff (VHO), each candidate network is evaluated as a function of multiple attributes such as available bandwidth, delay, data rate, and cost, etc. However, the variations of these parameters and distributed VHO decisions might cause the instability of VHO decisions, which is inefficient in utilizing network resources due to frequent handoffs. In this letter, we propose a service history-based VHO algorithm to reduce unnecessary handoffs and call dropping probability in addition to QoS parameter considerations. Simulation results show that the proposed VHO algorithm outperforms existing algorithms.**

***Index Terms*—Vertical handoff, QoS, ping-pong effect, service history.**

I. Introduction

In current wireless systems, various wireless networks [e.g., Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Area Networks (WLANs)] and various cellular networks [e.g., Wideband Code Division Multiple Access (WCDMA) and High Speed Packet Access (HSPA)] are coexisting. Future wireless systems will experience even more versatile networks, where for seamless services, vertical handoff (VHO) is inevitable to efficiently use system-wise radio resources. In any handoff execution or network selection, decision criteria will be a function of multiple system variables such as available bandwidth, delay, data rate, and cost, etc. To evaluate networks for VHO decisions, existing VHO algorithms have evaluated various candidate networks considering such system variables as well as user preference, resulting in reasonably combined and sensibly scaled functional values (see e.g., [1]-[2]). However, the variations of multi-attribute handoff metrics in these approaches may cause unstable handoff decisions, resulting in degraded network QoS such as frequent handoffs and high handoff dropping probability.

A modified received signal strength (RSS) based handoff decision algorithm with hysteresis consideration was proposed to reduce frequent handoffs due to ping-pong caused by the variation of instantaneous RSS [3]. However, by realizing the fact that hysteresis-based methods were ineffective under overlaid heterogeneous network environments, an adaptive VHO algorithms based on predicted RSS was proposed to reduce ping-ponging as well as handoff call drops in [4]. Yang *et al.* [5] proposed an adaptive SINR-based VHO algorithm by considering multi-attribute handoff metrics for higher throughput, lower handoff dropping probability as well as reduced operation cost. However, they did not consider ping-pong effects due to the variations of multi-attribute handoff metrics as compared to [4]. In [6], an optimal centralized VHO algorithm was proposed to support load balancing while reducing handoff call drops. In [7], a Markov Decision Process (MDP) based VHO algorithm was proposed to support network QoS which assumes that all users can estimate and share the variations of handoff metrics after handoff decisions. However, VHO algorithms in [6] and [7] are hard to be implemented in real systems due to complexity and system overhead. In distributed VHO decisions, since each user simultaneously selects target networks based on shared handoff metric information ignoring other users' decisions, he/she might experience high congestion by blindly choosing a network with the highest functional value of its own. Thus, networks might not provide users with a satisfactory QoS level which causes handoff call drops and handoffs to other networks.

As a remedy, we propose a VHO method taking into account the service history of user traffic, which plays a key role in mitigating instable handoff decisions. The proposed method can be adopted easily and combined with existing VHO algorithms. Simulation results show VHO algorithms combined with the proposed method outperform existing VHO algorithms in terms of the number of handoffs and handoff dropping probability. As far as our extensive examination on VHO algorithms is concerned, there has been no such algorithm using the service history as suggested up to date.

The rest of this letter is organized as follows. Section II introduces the proposed VHO algorithm using service history information. Performance evaluation is presented in Section III. Finally, conclusions are drawn in Section IV.

II. Service History Based VHO Algorithm

In this section, we describe how the idea is implemented through optimization problem. Network selection of each decision is carried on through maximizing the overall objective function value, which is a weighted sum of functional value of any existing VHO algorithms and the proposed evaluation function for service history.

A. *Objective Function*

We consider two parameters from service history information: t_0^S, a cumulative service time since the last handoff at a

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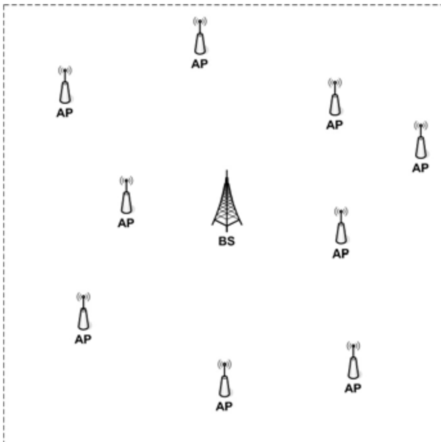

Fig. 1. System model.

serving network 0, and $t_i^F (i \neq 0)$, time duration since the last handoff blocking from network *i*. Realizing the fact that both the premature completion of a service and frequent handoff switchings are not beneficial to systems, one can conclude that the smaller the t_0^S and t_i^F, the less efficient the handoff execution. Therefore, it is natural to keep an user in service by the currently serving network if t_0^S is small and not to consider handoff to network *i* with small t_i^F to prevent handoff call drops. Thus, the proposed evaluation function for service history information can be expressed as

$$E_i^h(t_i^S) = \begin{cases} \exp(-t_i^S) & \text{if } i = 0,\ 0 < t_i^S \leq T_C \\ 0 & \text{otherwise.} \end{cases}$$
$$E_i^h(t_i^F) = \begin{cases} -\exp(-t_i^F) & \text{if } i \neq 0, 0 < t_i^F \leq T_C \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Time unit for t_i^S and t_i^F is minute. T_C denotes the predetermined maximum effective time of service history information. Note that the threshold T_C can be set differently for t_i^S and t_i^F.

B. VHO Decision

In addition to an evaluation function of QoS related parameters introduced in previous works, we take the evaluation function which takes available service history information into account for VHO decisions. For VHO, a network i^* is selected which maximizes an objective function, that is,

$$i^* = \arg\max_i \quad \alpha E_i^e + \beta E_i^h(t) \tag{2}$$

where E_i^e is a normalized evaluation value for network $i \in [0, .., I]$ by any of the existing VHO algorithms (e.g., [1]-[5]) and $E_i^h(t)$ is the proposed evaluation function with $t \in t_i^S, t_i^F$ representing service history information in networks. α and β are considered as weighting factors. For simplicity, we set $\alpha = \beta = 1$ in our evaluation. Here, $i = 0$ represents a current serving network.

III. Performance Evaluation

In this section, we investigate the efficiency of our proposed VHO algorithm by comparing performance with existing VHO algorithms such as Simple Additive Weighting (SAW) [1] and Multi-dimensional Adaptive SINR based Vertical Handoff algorithm (MASVH) [5], where VHO metrics consist of bandwidth utilization, SINR and operation cost for VHO decisions. It is assumed that the weight of all handoff metric parameters is fixed to 1.

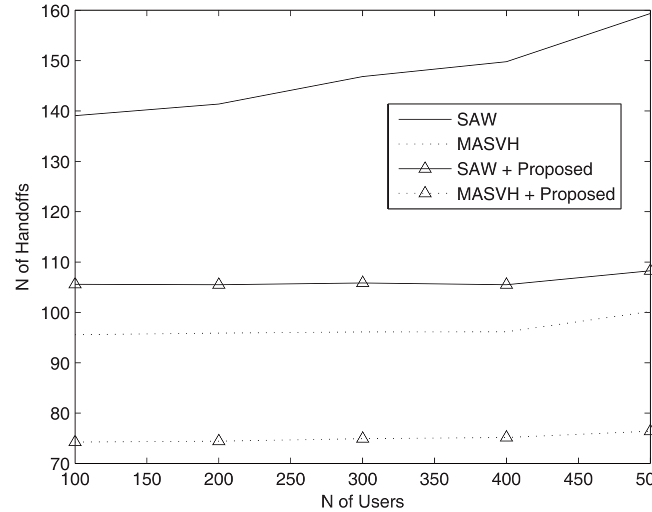

Fig. 2. The number of handoffs vs. the number of users in a system.

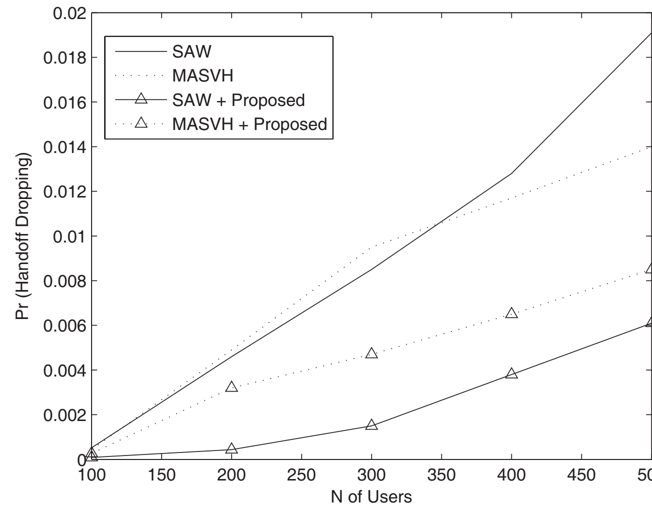

Fig. 3. Handoff dropping probability vs. the number of users in a system.

A. System Model

Fig. 1 shows our system model, which contains a single HSDPA BS and ten WLAN APs. The BS covers all network area of 1200 m x 1200 m. We focus on downlink system where HSDPA and WLAN system parameters and a propagation model are the same as in [5]. The operation cost of a user in HSDPA and WLAN is assumed to be 0.8 and 0.4 per second, respectively [5]. The mobility is UMTS30.03 model for vehicular environment [8]. Video traffic of 384 kbps per each user is generated by a Poisson distribution with mean arrival rate 0.001 and the service time is assumed to be an exponential distribution with a mean session duration of 60 seconds. We limit the maximum capacity of the BS and each AP by 13 Mbps and 11 Mbps, respectively. Note that handoff

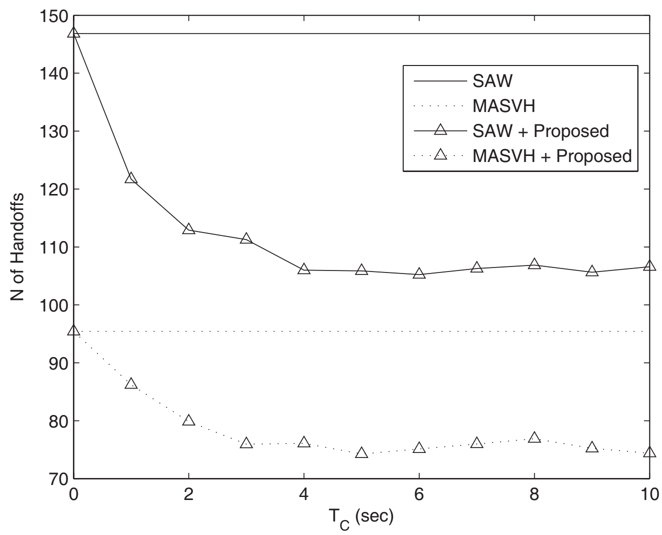

Fig. 4. The number of handoffs vs. T_C.

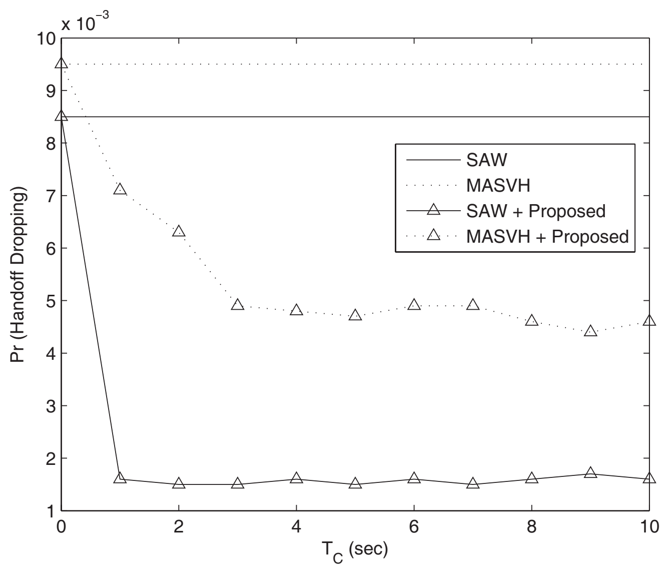

Fig. 5. Handoff dropping probability vs. T_C.

call drops occur when the maximum capacity of BS and each AP is reached.

B. Simulation Results

For comparison, we investigate network performance in terms of the number of handoffs per user and handoff dropping probability with respect to the number of users in a system where T_C is fixed to 5 sec. Fig. 2 and 3 show that the proposed algorithm always outperforms existing algorithms. Our proposed algorithm combined with SAW [1] (MASVH [5]) achieves better performance by up to 33 (24) % and 91 (51) % in terms of the number of handoffs per user and handoff dropping probability, respectively over the existing algorithms. Especially, Fig. 3 shows that the proposed algorithm becomes more effective in reducing handoff dropping probability under heavy traffic environment. It is expected that the improvement gets even larger considering the control traffic for handoffs or future wireless networks consisting of more various networks.

Secondly, we examine network performance of the proposed algorithm according to T_C where the number of users in a system is fixed to 300. Fig. 4 and 5 show that the number of handoffs per user and handoff dropping probability in the proposed algorithm decrease as T_C increases. When T_C has a small value, it shows dramatic performance improvement. However, as T_C gets increased, the performance improvement becomes smaller and gets negligible. The reason is that as t_i^S and t_i^F have large value at increased T_C, the evaluation function in (1) has small value and then, it becomes relatively less effective in (1). Simulation results also reveal that the operation cost of the proposed algorithm is slightly less than or equal to that of MASVH [5] at all simulation cases.

IV. CONCLUSION

We propose a service history based VHO algorithm to support QoS through preventing instable VHO decisions in heterogenous networks. Various simulation results show that the proposed VHO algorithm provides significant performance improvements by decreasing the number of handoffs, lowering handoff dropping probability and reducing operation cost over existing algorithms. Our algorithm can also be easily implemented in any other VHO schemes. It is also expected to be more effective as a network gets more complex, and with more QoS parameters such as delay into account. Other performance enhancements may also be expected considering the switching cost incurred by handoff such as signaling overheads and throughput loss. Mathematical analysis by modeling traffic streams based on stochastic processes remains to be done as a further work.

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