Handoff Trigger Table for Integrated 3G/WLAN Networks

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ABSTRACT

Vertical handoff is a switching process between heterogeneous wireless networks in a hybrid 3G/WLAN network. Vertical handoffs from WLAN to 3G network often fail due to the abrupt degrade of the WLAN signal strength in the transition areas. In this paper, a Handoff Trigger Table is introduced to improve the performance of vertical handoff. Based on this table, a proactive handoff scheme is proposed. Simulation results show that with the proposed scheme, the vertical handoff decisions will be more efficient so that dropping probability can be decreased dramatically.

Categories and Subject Descriptors

C.4 [**Performance of Systems**]: Design Studies; C.2.1 [**Network Architecture and Design**]: Wireless Communications—*Integrated 3G/WLAN Networks*

General Terms

Performance

Keywords

Wireless communications, vertical handoff, WLAN, 3G, integrated networks

1. INTRODUCTION

With the emergence of different wireless technologies, which are developed for different purposes, the integration of these wireless networks has attracted much attention from both academia and industry. Among them, the integration of 3G cellular networks and wireless local access networks (WLAN) has become a very active area in the development toward the

next generation wireless networks. WLAN access technology can offer high-speed data connections in a small coverage with relatively low cost. On the other hand, cellular networks can offer connectivity over several square kilometers but with relatively low data rate. Taking advantages of both networks will bring great benefits to both service providers and users.

One of the desired features of such a heterogeneous wireless network is to support seamless global roaming or vertical handoff. Traditionally, handoff is performed within the same wireless system, which is called *horizontal handoff*. In contrast, a *vertical handoff* takes place between different wireless networks [2]. In an integrated 3G/WLAN network, there are two directions in vertical handoff, one is from WLANs to 3G networks and the other is from 3G Networks to WLANs. In the first direction, the objective for handoff is to maintain the connectivity, i.e., switching to the cellular network before the WLAN link breaks while trying to stay in the WLAN as long as possible because of its relatively high bandwidth and low cost. Since a WLAN has smaller coverage and is usually covered by a 3G network, when the mobile terminal (MT) steps out of the WLAN area, the decay of the signal from the WLAN should be accurately detected. A timely decision of handoff should be made properly, and the MT should switch the connection to the appropriate 3G network successfully. In the second direction, the objective of handoff is usually to improve QoS and acquire higher bandwidth with lower cost. In this paper, we will focus on the first direction, which is the handoff from the WLAN to the 3G network.

For a WLAN, signal power is limited, which causes the signal strength to be quite easily influenced by physical obstruction and blocks. For example, if the MT passes some blocks or moves into the elevator, there will be an abrupt drop in its received WLAN signal strength. In this case, the MT may not have enough time to finish the WLAN-to-3G-Network vertical handoff procedure before the link to WLAN breaks. Therefore, how to effectively detect the signal decay to trigger the handoff becomes a very important issue.

In this paper, we propose to maintain a Handoff Trigger Table (HTT) at the Access Point (AP) to record some location information on transition areas in which vertical

handoffs occur. With the information of the HTT, a proactive handoff scheme is proposed to enable the MTs to start the vertical handoff procedure early enough to finish the vertical handoff procedure, thus the handoff call dropping probability can be decreased dramatically.

The rest of this paper is organized as follows. In Section 2, some related work is discussed. In Section 3, we propose a Handoff Trigger Table to assist making handoff decisions. The handoff scheme based on this table is also presented. Section 4 gives simulation results to demonstrate the better performance of the proposed scheme in comparison with the traditional one. Section 5 concludes the paper.

2. RELATED WORK

In traditional handoff schemes, the received signal strength (RSS) has been used as an indicator for making handoff decisions. Some of the traditional approaches are as follows: [5]

- *RSS:* handoff takes place if the RSS of a candidate point of attachment is larger than the RSS of the current point of attachment ($RSS_{new} > RSS_{current}$);

- *RSS plus threshold*: handoff is made if the RSS of a candidate point of attachment is larger than that of the current point of attachment and the latter is less than a certain pre-defined threshold T ($RSS_{new} > RSS_{current}$ and $RSS_{current} < T$);

- *RSS plus hysteresis*: a handoff takes place if the RSS of the candidate point of attachment is larger than the RSS of the current one with a pre-defined hysteresis margin H ($RSS_{new} > RSS_{current} + H$);

- *Algorithm plus dwell timer*: sometimes a dwell timer can be added to the above algorithms. This timer is started when one of the above conditions happens, and the handoff takes place if the condition is met for the entire dwell timer interval.

For the vertical handoff process, it may not be very reliable to make handoff decisions based only on the RSS of the point of attachment (e.g., AP of the WLAN) and the candidate point of attachment (e.g., base station of the 3G network) because of the asymmetric nature of the handoff problem [6].

As mentioned before, the handoff from WLAN to 3G network is expected to be efficient and effective. Some methods have been proposed to achieve this goal. One of them is the Fast Fourier Transform (FFT)-based decay detection [1]. This approach tries to estimate the signal decay, and will trigger the handoff after the signal is confirmed to be decreased to a certain threshold. However, this approach has high calculation complexity with the need of frequent sampling, and suffers from estimation errors. In [2], handoff triggering nodes are used to notify the mobile terminal to start the handoff. These special nodes are data stations installed in WLAN/cellular transition regions where vertical handoffs occur. When an MT moves close to it, the handoff triggering node will send a handoff trigger command to trigger the link layer handoff. Using handoff trigger node can be good at triggering the handoffs, but if they are needed in many places within a WLAN, it will be costly to set up many trigger nodes. In addition, if there are new blocks appearing in the WLAN, it is hard to determine where the additional trigger nodes should be installed. Therefore, this approach is not very flexible. The Fuzzy logic based handoff algorithm [3][4] is proposed to assist making handoff decisions. This algorithm decreases handoff delay and the number of unnecessary handoffs by changing the RSS average window according to the MT speed. It is worth mentioning that some fuzzy logic based algorithms are complex and may not be easy to be implemented in practical systems.

3. HANDOFF TRIGGER TABLE FOR 3G/WLAN NETWORKS

Recently, WLAN has been expected to provide user location information [6]-[10], which is helpful for making vertical handoffs. We propose to use a Handoff Trigger Table (HTT) to store such location information at the AP and utilize it to trigger the WLAN-to-3G vertical handoff explicitly. Based on this table, a proactive handoff scheme is proposed to assist MTs to handoff in the right places at the right time. With this scheme, handoff decisions can be more efficient and handoffs are more likely to succeed compared with the traditional schemes which trigger the handoff mainly based on the received signal strength at the MTs.

3.1 Handoff Trigger Table

A typical integrated 3G/WLAN network is shown in Fig. 1. The HTT is normally implemented at the APs of WLAN and used to record the user location information which will be helpful to make handoff decisions as explained later. An example of the HTT is given in Table 1.

Table 1: An example of Handoff Trigger Table

$X_1 + D > x > X_1 - D$	$Y_1 + D > y > Y_1 - D$
$X_2 + D > x > X_2 - D$	$Y_2 + D > y > Y_2 - D$
$\cdots$	$\cdots$
$X_n + D > x > X_n - D$	$Y_n + D > y > Y_n - D$

In the HTT, the information of the locations where an MT needs to handoff is given. We defined Black Holes (BH) the small areas in which the received signal strength at an MT decreases abruptly and the link to the AP breaks in a very short time. In such BHs, if the MT does not switch the connection to the 3G network, it will not be able to keep the connectivity to its correspondence node. Each BH is proposed to be covered by a slightly larger area, namely, proactive area. When MTs move into a proactive area, the AP will send a message to notify the MT to start proactive handoff (detailed in Section 3.2), regardless of the current received signal strength at the MT. In Table 1, ($X_i, Y_i, i = 1, 2, \cdots, n$) are the location coordinates of the center of the BHs, and D is the distance between the center of the black hole and proactive area edges. ($X_n + D > x > X_n - D, Y_n + D > y > Y_n - D$) is an example of possible ways to describe the proactive area. Note that other types of proactive areas such as circles can also be adopted. Fig. 1 illustrates the above two concepts, wherein A, B and C are three BHs within the WLAN, and A', B', C' are the corresponding proactive areas.

The HTT will be initialized when the AP is installed in the WLAN, then it will be dynamically updated. In the initial stage, MTs will handoff in a traditional way, i.e., handoff
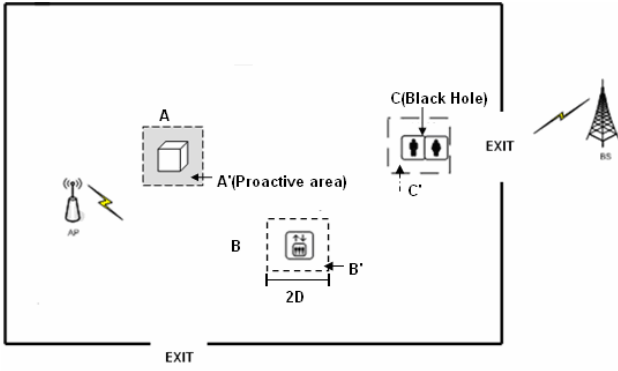
Figure 1: An example of WLAN with Black Holes

Figure 2: Traditional handoff scheme for Hybrid Networks

when the received signal strength decreases to a threshold. In addition, the MT sends out a handoff notification to the AP, and the AP will record the coordinates of this handoff location into the HTT. Usually BH is not a dot, but a small area. Therefore, for each BH, the HTT will store many coordinates of points where vertical handoffs occur, then the AP will try to merge these coordinates to form a corresponding proactive area and put it into the HTT. After the initialization stage, the HTT will only contain the description of proactive areas instead of individual coordinates of BHs. Meanwhile, the AP will often check the HTT to decide whether any MT enters the proactive areas. When a new BH appears, the AP will be able to record its proactive area into the HTT after some vertical handoffs take place near this BH, similar to the initial stage. When a BH disappears due to some reasons (e.g., restructure in the WLAN), there will be no vertical handoffs occur in the corresponding proactive area. As a result, the AP will remove the entry of this proactive area from the HTT after some predefined time, which can be decided by the system administrator. With the above methods, the HTT is maintained dynamically and can adaptive to the change of the environment.

3.2 Proactive Handoff Scheme

Based on the Handoff Trigger Table, we propose a proactive handoff scheme to achieve better handoff performance. In the traditional scheme, the handoff decision mechanism is that a handoff will be triggered when the current RSS is lower than a threshold (THm) or RSS from the candidate network is higher than a threshold (THw). The procedure is illustrated in Fig. 2.

In the proposed scheme, we divide the handoff into two stages, a proactive handoff stage and a handoff stage. In the proactive handoff stage, when an MT moves into a proactive area, the AP will send it a proactive handoff message. Following that the MT will send out a binding update message to the AP and start this network layer handoff. The procedure is given in Fig. 3.

When an MT enters the WLAN, the RSSs in sampling intervals will be measured and their averages are computed. At the same time, the AP will check if the MT is in any proactive area. If yes, it will send a control message *Pre-Handoff-CMD* to the MT. After receiving this message, the MT will start to send the cellular network a message to request a connection. When the signal decreases to a certain threshold R_t, the link-layer handoff starts, and the MT will
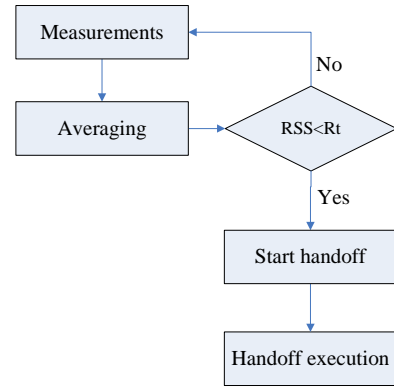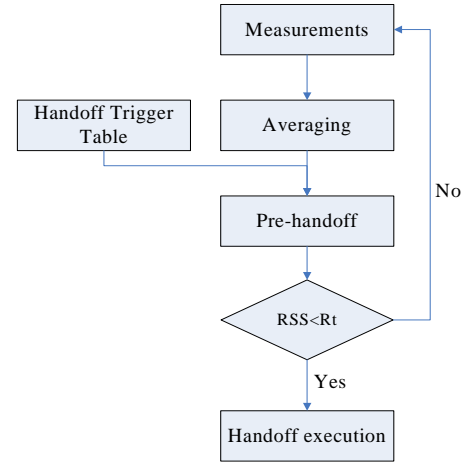

Figure 3: Proactive handoff scheme for Hybrid Networks

switch the connection to the cellular network. When the received signal strength decreases to R_t, but the MT still does not receive the *Pre-Handoff-CMD*, it will send a message to inform the AP to add this location coordinate into the HTT. The threshold R_t is a design parameter that can be set by the administrator to best enable vertical handoff procedure under the WLAN-specific physical situation.

4. PERFORMANCE EVALUATION

In this section, we compare the performance of the proposed vertical handoff scheme with HTT and the traditional handoff scheme by simulation. Consider the simplified network model for 3G/WLAN networks shown in Fig. 1. We assume that the 3G network covers the WLAN area. The RSS of the WLAN signal at an MH is assumed as a function of the distance d between the MH and the AP[11]: $RSS(d) = PT \cdot L \cdot 10n \log(d) + f(\mu, \sigma)$ dBm, where PT is the transmitted power, L is a constant signal power loss, n is the path loss exponent, and $f(\mu, \sigma)$ represents shadow fading modeled as zero mean Gaussian random variable with mean μ and standard deviation σ. In the WLAN, there are a number of BHs, in which the RSS will decrease to almost zero immediately and the MT will have to handoff to the 3G networks.

The popular Random Waypoint mobility model [12] is used to simulate the mobility of the MTs in the WLAN. At the beginning, the MTs' positions in the WLAN are uniformly distributed. Each MT will move at a random speed V, which is uniformly distributed in $[Vmin, Vmax]$, and in a random direction. After random time Tm, the MT will stop and stay for random time Ts, with both Tm and Ts uniformly distributed in $[0, 2s]$. The MT will continue the movement as described above. Any MT that moves out of the WLAN will be eliminated, and a new MT will be generated in the WLAN with a randomly chosen location. Some other parameters used in the simulations are given in Table 2.

Table 2: Parameters for the numerical examples

Parameter	Value
PT	100mW
R_t	-85dbm
n	3.3
σ	7dB
Handoff time	2s
Velocity range	$0 - 2$ m/sec
Number of BHs	≥ 3
WLAN area	100m $\times$ 100m

We define the *transition time* as the time from when an MT starts handoff to the moment it moves into a BH, and *handoff time* as the time from when an MT sends out the binding update message to the moment it receives the first package from the Base Station. The drop of a call only happens when the transition time is less than the handoff time.

In Figs. 4, 5 and 6, we present the dropping probability of the proposed scheme and the traditional handoff scheme based on different proactive distance, D, and two values of user mobility rate, V, respectively. Fig. 4 illustrates the
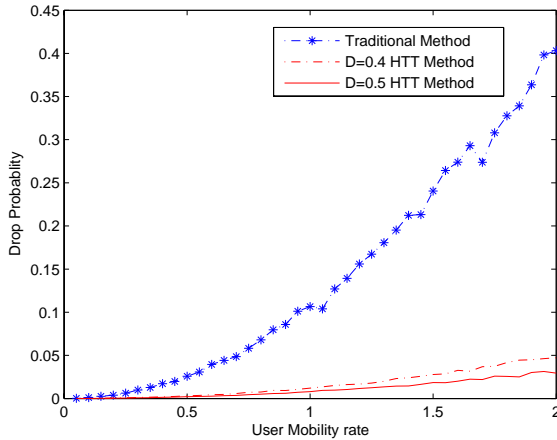
Figure 4: Effect of user mobility

effect of user mobility on the connection dropping probability. In this figure, the dropping probabilities for proactive distance $D = 0.4$ and $D = 0.5$, are given. In these results, handoff time is 2s. From the figure, we can see that the handoff probability has been reduced with the explicit

handoff trigger in the proposed scheme, because mobile terminals can have more time to execute the handoff. When the proactive distance increases, the dropping probability decreases. This is due to the fact that when the proactive distance is larger, the time for the MT to execute the handoff will be longer. We can also see that when the MTs move faster, dropping probability will increase as well, because shorter time is made available for the MT to execute the vertical handoff given the same D. Compared with the HTT scheme, the traditional scheme is more sensitive to the user mobility rate, and the dropping probability increases rapidly as the mobility increases.
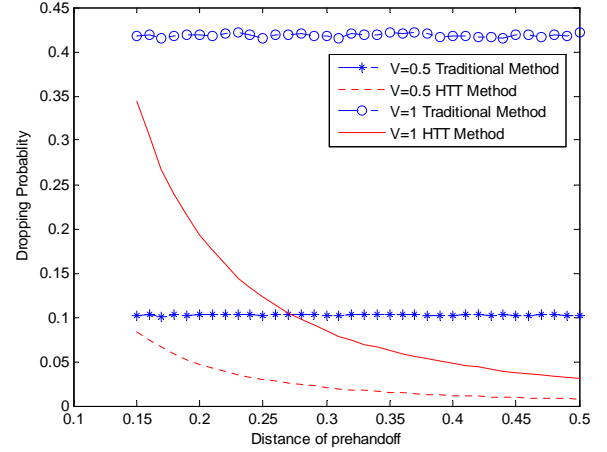
Figure 5: Effect of proactive distance

Fig. 5 shows that as the proactive distance increases, the dropping probability of HTT scheme decreases very fast and it is quite sensitive to the distance increasing. When the user mobility rate increases, the dropping probability will also increase, which conforms with the results in Fig. 4. Fig. 6 shows the impact of the handoff time (in practical value range) on the dropping probability. With a given transition time, if the handoff time increases, the dropping probability will be higher, as expected.

Fig. 7 shows that the impact of the distance between AP and BH on the dropping probability. The signal strength decays with the distance to the AP in WLANs. In the proposed scheme, MTs start network layer handoff in advance according to the parameter D and regardless of the RSS, so the performance of the proposed scheme is independent from the distance d between the BH and the AP. However, for a given RSS threshold, the performance of traditional handoff scheme relies heavily on d, and it has better performance for the BHs which are far from the AP. This is because the signal strength is relatively high near the AP, and MT will normally find that its RSS is above the threshold. As the MT enters the BH, the signal strength degrades so abruptly that the MT does not have enough time to do handoff, which leads to high dropping probability. In contrast, the RSS of an MT moving around a BH that is far from the AP will be relatively low and may be close to the threshold, hence a handoff decision may be easily triggered before the MT enters the BH. In this case, the MT gets longer time to conduct the handoff procedure so a relatively lower dropping probability can be achieved.
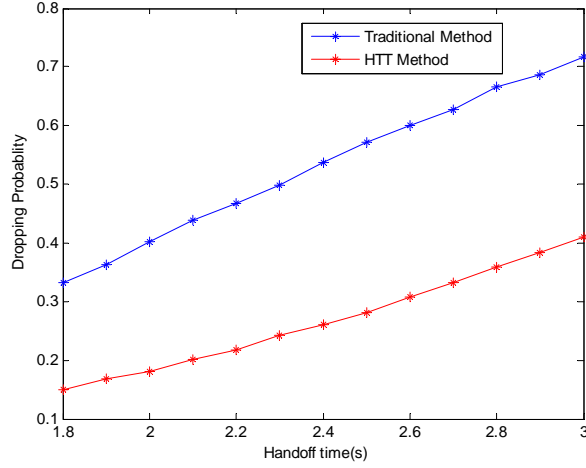
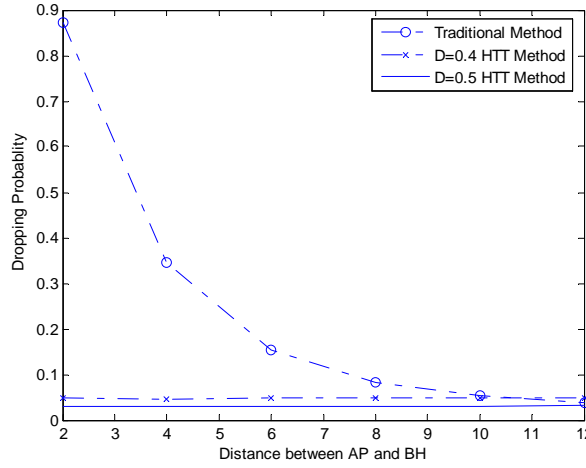**Figure 6: Effect of Vertical handoff time**

Figure 8: Effect of number of BHs

5. CONCLUSIONS

In this paper, vertical handoffs from WLAN to 3G cellular network has been investigated. To support making proper handoff decisions, a Handoff Trigger Table (HTT) has been proposed to be implemented at the AP of WLAN to record the location information of BHs. Based on this table, a proactive handoff scheme has been proposed. Simulation results have been given to show that with the information in the HTT, the vertical handoff decisions can be made more efficiently and dropping probability can be decreased significantly. Possible future work include making the proactive distance D a variable for different environments and further investigating the unnecessary handoff events in different pre-handoff schemes. The HTT scheme can also be used in system discovery to assist reducing MH power consumption.

6. ACKNOWLEDGEMENTS

Figure 7: Effect of distance between AP and BH

From Fig. 7, we can also see that for the proposed scheme, the proactive distance D should be set properly. Similar requirement applies to the setting of the threshold in the traditional scheme. If D or the threshold is set to be high, there will be many unnecessary handoffs although the dropping probability will decrease. On the other hand, if D or the threshold is too low, the dropping probability will increase. However, the dependence on d of the traditional handoff scheme cannot be eliminated by simply adjusting the threshold, which makes the selection of a proper threshold in the traditional scheme even more difficult.

We further study the performance of the two schemes in the WLAN with different number of BHs. The locations of the BHs are set to be uniformly distributed within the WLAN. From Fig. 8, it can be seen that for both schemes the dropping probability is not sensitive to the number of BHs when their locations are uniformly distributed. The case for BHs with non-uniform distribution is left as future work.
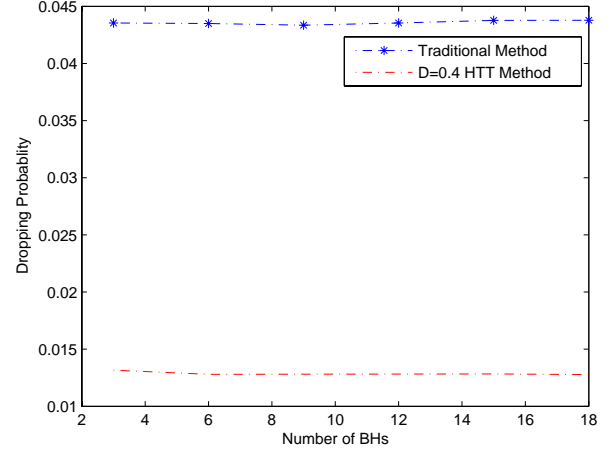
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