A Heuristic-based Vertical Handover Algorithm using MIH for Individual Users

Seokjoon Hong, Minchul Shin, Inwhee Joe
Division of Computer Science and Engineering
Hanyang University
Seoul, 133-791 South Korea
+82-02-2220-1088
iwjoe@hanyang.ac.kr

ABSTRACT
Current wireless networks include various wireless technologies such as 3G (WCDMA), 4G (LTE), WLAN, WiMAX. The movement of a user within or among different types of networks requires vertical handover. There are many existing algorithms for predicting and executing vertical handover considering various network parameters. However, they usually don’t consider the individual mobile user. Generally, an individual mobile user has a unique moving and using network pattern in a day. So, if we consider this personal moving and using pattern, we can predict the next handover network. Thus, we propose a heuristic based vertical handover prediction and MIH (Media Independent Handover) based handover algorithm for individual users. By using this algorithm, we can reduce handover preparation delay and prevent unnecessary handovers. Also, we provide proof of the performance of the proposed algorithm via OPNET simulation results.

Categories and Subject Descriptors
C.2.3 [Computer Communication Networks]: Network Operations – network management, network monitoring.

General Terms
Algorithms, Management

Keywords
Vertical handover, individual mobile user, pattern, MIH

1. INTRODUCTION
Mobile communication has become more popular due to the increased availability of portable devices and advanced wireless technology. Moreover, the core network of heterogeneous wireless access networks, e.g., WLAN [1], WiMAX [2,3], and 3GPP (WCDMA, LTE); they are evolving into all-IP based network.

The IEEE 802.21 has proposed the Media Independent Handover (MIH) services [5] to enhance the handovers across heterogeneous access networks, i.e., vertical handover, and to optimize the service (or session) continuity during handovers, i.e., seamless handover. For this reason, MIH provides generic link layer intelligence and other related network information to upper layers. Particularly, MIH offers a framework of the message flows between handover-related entities to provide information on handover candidate networks and to deliver handover commands.

The information service provides a framework and corresponding mechanisms by which a MIH function entity can discover and obtain network information existing within a geographical area to facilitate the handovers. The information service primarily provides a request/response type of mechanism for information transfer. The information may be stored within the MIH layer or maybe presented to some information server from where the MIH layer can access. The information service provides access to static information such as neighboring networks, helping in network discovery. Also, the service may provide access to dynamic information which may optimize link layer connectivity with different networks. This could include link layer parameters such as channel information from where the MIH layer can access. The information service also provides access to dynamic information retrieved from the network and terminal side entities, such as the user preferences, running services, mobile nodes characteristics and available network resources.

It is clear that in current and future environments, dynamic context information from network side entities is very important for the vertical handover decision procedures. Context-aware media independent information server is also proposed for optimized seamless handover procedures [6]. The paper addresses a new concept of a context-aware information server that is able to store, manage and deliver real-time dynamic information retrieved from the network and the terminal side entities, such as the user preferences, running services, mobile nodes characteristics and available network resources.

Furthermore, for seamless and QoS guaranteed vertical handover, the network selection is critical and there are many proposed algorithms about that. A network selection in an integrated wireless LAN and UMTS environment using mathematical modeling and computing techniques are proposed for integrated cellular/wireless LAN systems [7]. The proposed scheme comprises two parts, with the first applying an analytic hierarchy process (AHP) to decide the relative weights of evaluative criteria set according to user preferences and service applications, while the second adopts grey relational analysis (GRA) to rank the network alternatives with faster and simpler implementation than AHP. The proposed technique can effectively decide the optimum network through making trade-
offs among network condition, user preference, and service application, while avoiding frequent handoffs. A network selection algorithm considering power consumption in hybrid wireless network is another algorithm which apply AHP and GRA scheme. It considers not only QoS but also lifetime of mobile node. If user preference is lifetime, the proposed algorithm selects the network that stays longer due to low power consumption [8].

Mobility prediction is also important in vertical handover. There are some previous works in the area of mobility prediction. Tabbane’s proposal [9] suggests that the mobile’s location may be determined based on its quasi-deterministic mobility behavior represented as a set of movement patterns stored in a user profile. A pattern matching/recognition-based mobile motion prediction algorithm (MMP) [10] is suggested which used to estimate the future location of the mobile. The paper treated the problem by developing a hierarchical user mobility model that closely represents the movement behavior of a mobile user, and that, when used with appropriate pattern matching and Kalman filtering techniques, yields an accurate location prediction algorithm, hierarchical location prediction, which provides necessary information for advance resource reservation and advance optimal route establishment in wireless ATM networks.

Generally, an individual mobile user has a unique moving and using network pattern in a day. For example, a man gets up at his home in the morning, goes to his company through public places such as road, station (bus or train), etc. (Figure 1)

For predicting a handover, first, the mobile node maintains its special stack memory buffer for restoration of handover history. The contents of handover history are information such as time, location, direction as shown in Figure 2.

![Figure 2. Stack of mobile node for restoring handover history](image)

When current network’s RSSI (receive signal strength indication) of MN is decreasing, 1 element pushed stack memory. If handover occurs, the stack memory buffer restores its buffer memory to handover history tables which include handover network and previous network. Figure 3 shows handover previous history points and handover execution point.

![Figure 3. Handover previous history points and handover execution point](image)

| Table 1. Handover table (After MN handover from A to B) |
|---|---|---|---|---|---|
| Prev Net | HD Net | RSSI (Prev) | Time (h,m,s) | Location (Lon, Lat) | Uw |
| A | 20% | 0 | 215 | 13.18 | 127.041/37.558 | 120 | 1.1 | 0.4 |
| B | 2 | 210 | 13.45 | 127.042/37.557 | 140 | 1.2 | 0.5 |
| C | 2 | 217 | 13.67 | 127.043/37.558 | 150 | 0.9 | 0.3 |
| D | 3 | 140 | 13.10 | 127.042/37.556 | 140 | 1.0 | 0.7 |
| E | 4 | 137 | 13.11 | 127.041/37.556 | 180 | 1.1 | 0.6 |
| F | 5 | 109 | 14.20 | 127.040/37.554 | 200 | 1.0 | 0.7 |
| G | 6 | 64 | 14:26.44 | 127.039/37.553 | 150 | 1.1 | 0.8 |
| H | 7 | 55 | 14:30.15 | 127.037/37.552 | 180 | 1.2 | 0.2 |
| I | 8 | 36 | 14:31.30 | 127.036/37.551 | 170 | 1.3 | 0.2 |
| J | 9 | 23 | 14:31.35 | 127.035/37.550 | 160 | 1.1 | 0.3 |

The network utilization rate of network i in a week can be calculated by formula (1).
And handover priority of the network is assigned according to $U_w$ as Table 2. Higher priority of network has large value. If $U_w$ is zero, then priority is also zero. This means that handover to the network should be preventive. On the other hand, if $U_w$ is greater than 0.5(50%), then we can think that the network is frequently used by user and handover is preferred.

### Table 2. Handover priority table

<table>
<thead>
<tr>
<th>$U_w$ (value or range)</th>
<th>Priority</th>
<th>HO Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Preventive</td>
</tr>
<tr>
<td>0 &lt; $U_w$ &lt; 0.5</td>
<td>1</td>
<td>Normal</td>
</tr>
<tr>
<td>0.5 &lt; $U_w$ &lt; 1</td>
<td>2</td>
<td>Preferred</td>
</tr>
</tbody>
</table>

$$T_u(i,j): \text{Average used time per week of } i \text{ network on } j \text{ day (0~6 means Sunday to Saturday)}$$

$$T_u(i,k): \text{Residence time of } i \text{ network on } k \text{ day}$$

$$U_w(i) = \frac{\sum_{j=0}^{6} T_u(i,j)}{\sum_{k=0}^{6} T_u(i,k)}$$  \hspace{1cm} (1)$$

$$D_{max}(j) = X(i,j,k) - D_{min}(j)$$

$$N_D(i,j,k) = \frac{D_{max}(j) - X(i,j,k)}{D_{max}(j) - D_{min}(j)}$$  \hspace{1cm} (2)$$

$$\text{Avg } N_D(i) = \sum_{j=0}^{4} \sum_{k=0}^{9} N_D(i,j,k)$$  \hspace{1cm} (3)$$

We can calculate normalized difference value and average normalized value of network $i$ between current stack data and previous handover table data by using formula (2), (3). And the difference range of each entity of MN is as Table 3. If the average normalized difference value of network $i$ has lowest value among the candidate networks, then in all probability the network $i$ will be the next handover network.

### Table 3. Difference between previous data of each entity

<table>
<thead>
<tr>
<th>MN Entity (i)</th>
<th>Difference with history (D) range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSI(0)</td>
<td>0 ≤ D ≤ 255</td>
</tr>
<tr>
<td>Time(1)</td>
<td>0 ≤ D ≤ 3600 (second)</td>
</tr>
<tr>
<td>Location(2)</td>
<td>0 ≤ D ≤ 2R (R: radius of cell)</td>
</tr>
<tr>
<td>Degree(3)</td>
<td>0 ≤ D ≤ 360</td>
</tr>
<tr>
<td>Speed(4)</td>
<td>0 ≤ D ≤ 40 (m/s)</td>
</tr>
</tbody>
</table>

#### 2.2 The mobile-initiated handover procedure using MIH

The mobile-initiated handover preparation procedure operates as follows and shown in Figure 4.

#### 2.2.1 Mobile-initiated HO procedure using MIH

1. The mobile node queries information about neighboring networks by sending an MIH_Get_Information request message to the Information Server.
2. The mobile node triggers a mobile-initiated handover by sending an MIH_MN_HO_Candidate_Query request message to the Serving Network. This request contains the information of potential candidate networks.
3. The serving network queries the availability of resources at the candidate networks by sending an MIH_N2N_HO_Query_Resource request message to one or multiple candidate networks.
4. The candidate networks respond with an MIH_N2N_HO_Query_Resources response message and the serving network notifies the mobile node of the resulting resource availability at the candidate networks through an MIH_MN_HO_Candidate_Query response message.
5. The mobile node decides on the target of the handover and notifies the serving network of the decided target network information by sending the MIH_MN_HO_Commit request message.
6. The serving network sends the MIH_N2N_HO_Commit request message to the target network to request resource preparation at the target network.

On the other hand, with our proposed vertical handover algorithm, a heuristic based vertical handover prediction can take the place of MIIS functionality for searching neighbor network as shown in Figure 5.

So, vertical handover preparation delay of mobile node and network traffic load for communicating with MIIS can be reduced with the proposed algorithm.
Figure 5. Proposed heuristic based vertical handover preparation signaling flow.

Figure 6 shows proposed vertical handover algorithms. It is composed of the heuristic based vertical handover prediction and the mobile-initiated handover procedure using MIH.

If current network is in previous network of handover table and current network RSSI is decreasing, the process input the data of current MN entities to stack memory. After that, it calculates average normal difference between current network and all CNL (Candidate Network List). If the average normal difference is smaller than predefined similarity difference (default setting: 0.5), $S_D$ and RSSI is greater than handover threshold, it checks the priority according to utilization of network.

If there is priority 2 network, the process executes handover to the network by using heuristic based handover algorithm based on MIH. And if there is priority 0 network (blacklist), the process discard the network among the candidate network list. In other case, it execute normal handover algorithm based on MIH and MIIS server.

2.3 The energy efficiency scheme based on proposed handover algorithm

Because our proposed algorithm can predict the next handover network, it also can save battery consumption by turning on the modem for the handover network before handover and turning off the other network modem except the modem for current network after handover.

Figure 7 shows proposed handover based energy efficiency scheme flowchart.

3. PERFORMANCE EVALUATION

In this section, we describe the performance evaluation of the proposed algorithm through simulation using the OPNET simulator. Figure 8 shows the network model of hybrid network that consists of various networks such as 3G(WCDMA), 4G(LTE), WLAN, WiMAX. And for simulating vertical handover, we suggested five trajectories of MN.
Figure 8. OPNET network model

Table 4 shows assumed values of the simulation parameters for OPNET simulation. And we also assumed average power consumption using real modem specification reference [11-14].

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average mobile node speed</td>
<td>10km/h</td>
</tr>
<tr>
<td>Cell radius (LTE, WCDMA, WiMAX, WLAN)</td>
<td>3, 2, 1, 0.1 km</td>
</tr>
<tr>
<td>Trajectory of mobile node (Only one trajectory at a time)</td>
<td>Uniform Distribution (A–E)</td>
</tr>
<tr>
<td>Link delay in network node</td>
<td>1ms for wired link (per link) No delay for wireless link</td>
</tr>
<tr>
<td>Handover preventive network (Blacklist, Utilization of network: 0%)</td>
<td>AP4, AP5, WiMAX1</td>
</tr>
<tr>
<td>Handover preferred network</td>
<td>All networks except Blacklist</td>
</tr>
<tr>
<td>MN battery capacity</td>
<td>2000 mAh</td>
</tr>
<tr>
<td>Average power consumption (LTE, WCDMA, WiMAX, WLAN)</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>500mA, 450mA</td>
</tr>
<tr>
<td>Idle (Standby)</td>
<td>65mA, 45mA, 300mA</td>
</tr>
</tbody>
</table>

Figure 9 shows total handover numbers of the mobile node with number of replications in simulation. Because the existing MIH based vertical handover algorithm considers receive signal strength (RSSI) mainly, the mobile node executes handover frequently in this network model.

However, the proposed vertical handover algorithm predicts and prepares the handover network by previous restored handover history table. It can also prevent unnecessary handover by using blacklist concept. Hence, the total handover number is smaller than the existing vertical handover algorithm.

Figure 10. Vertical handover preparation delay with number of replications in simulation

Figure 10 shows vertical handover preparation delay with number of replications in simulation. If MN uses the MIH based conventional vertical handover algorithm, MN needs to communicate with MIIS (Media Independent Information Server) for preparing handover.

But because MN can predict the next handover network for itself by using proposed algorithm, MN doesn’t need to communicate with MIIS. Therefore handover preparation delay can be reduced.

Figure 11. Battery remaining capacity (mAh)

And the last result, figure 11 shows power consumption of MN as increasing simulation time (hour).

If MN uses existing handover algorithm, it consumes active mode power of current network and idle mode power of the other network. But if energy efficient applied handover algorithm is used, MN can save idle mode power by turning off the other network modem.

4. CONCLUSIONS

In this paper, we proposed a heuristic-based vertical handover prediction process and MIH based handover algorithm for individual user. We also demonstrated the performance of the proposed algorithm through simulation using OPNET simulator. The OPNET simulation results showed lower handover preparation delay as well as total handover number with the proposed algorithm than with the existing vertical handover algorithm. And it also can save battery power consumption by applying energy efficiency scheme to proposed algorithm. The results show that the proposed algorithm is efficient than existing vertical handover algorithm.
5. ACKNOWLEDGMENTS
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