A REACTIVE VERTICAL HANDOVER APPROACH FOR WIFI-UMTS DUAL-MODE TERMINALS

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ABSTRACT

In this work we describe a reactive algorithm for management of mobile controlled vertical handover (VHO) in dual-mode terminals provided with UMTS and IEEE 802.11 network interface cards (NICs). The VHO aims at providing service continuity and maximize throughput while limiting the so called “ping-pong effect”. We collected experimental results and provided an assessment of its performance. Namely, in the presented statistics is discussed how channel bandwidth estimation and limitation of handover frequency can affect maximization of throughput.

Index Terms—Vertical handover, ping-pong effect, goodput, weighted exponential average.

1. INTRODUCTION

Heterogeneous access through multiple network interfaces is the current trend in the new generation of mobile devices. Managing the complexity of different access schemes, amount of bandwidth and cell coverage in multiple-interface devices is becoming a critical aspect to face. Namely, with multiple-mode mobile devices it is necessary to provide seamless mobility support not only during changes of cells of the same access network, but also during movement between access technologies.

Traditionally, a handover is initiated on changes of the RSSI (Received Signal Strength Indication) level, though other approaches can be used. In [1] a Quality-of-Service (QoS) based VHO is presented where handover decision is driven by quality, either subjective and objective. In addition, handover decisions can be taken when the observed quality metrics reaches a critical value (reactive approach). Also, a handover decision can be anticipated if the handover algorithm is able to predict the future dynamics of the observed metrics (proactive approach).

The VHO classical approaches include two main classes, which differ in the initiator and controller of the process, i.e. the Mobile Terminal-Controlled Handover (MCHO) and the Network-Controlled Handover (NCHO) [2]. A MCHO is in fact the most common case. IEEE 802.11 handover is a good example of MCHO. On the other side, a NCHO is the typical operator approach for resource optimization and load management to preserve the best possible QoS level. More recent technologies developed frameworks supporting both approaches, (i.e. WiMax Forum considers an architecture that integrates both NCHO and MCHO).

Some variants to the classical MCHO and NCHO are also possible. In [3] a Network-Assisted MCHO (NAMCHO) is presented, where VHO decisions are negotiated between the serving network (SN) and the mobile terminal (MT). Namely, the MT decides handovers taking into account also measurements provided by the SN. In [4] a new VHO for next-generation heterogeneous networks considers a neighbor node (NN) to decide the initiation of VHO. Namely, the NN takes over the VHO procedures from the MT and carries out handover procedures requiring large latency such as registration and authentication before handover initiation. Then, in [1] and [5] the VHO from UMTS to WLAN is driven by a functional entity, called as Network Interworking Unit (NIU) and a QoS-based Decision Engine (QDE), respectively. In [5], the QDE is in charge of the QoS based handover, and the MT exchanges information between network entities and the QDE.

In this paper, we propose a MCHO algorithm for WiFi-UMTS dual-mode MT. It adopts a reactive approach and includes measures to limit handover frequency. It is based on estimation of goodput as quality metrics, as Section II shows. In Section III, the VHO algorithm procedures are described by a flowchart, while a simulation scenario and performances are shown in Section IV.

2. CHANNEL GOODPUT ESTIMATION

The proposed VHO algorithm is focused on the comparison of the instantaneous goodput reachable from an MT with a UMTS or a WiFi interface, while moving in an area with simultaneous UMTS/WiFi coverage. The assessment of the goodput experienced through two interfaces can be done with various channel estimation methods, such as a weighted Moving Average (MA) of the last K samples of the amount of data g received simultaneously from the two interfaces, as in (1), where GP_N is the estimate of the channel goodput at time N.
In this case, the weights \( a_i \) assigned to \( g_t \) are the same and are equal to \( 1/N \). As an alternative, a second order Exponential Smoothing Average (ESA) technique based on Eq. 2 can be adopted,

\[
\begin{align*}
GP_i^1 & = g_t \\
GP_i^2 & = w_1 \cdot g_t + (1 - w_1) \cdot GP_i^1 \\
GP_i^N & = w_1 \cdot g_t + w_2 \cdot GP_i^{N-1} + w_3 \cdot GP_i^{N-2} & N > 2 \quad (2)
\end{align*}
\]

where the goodput estimate \( GP_i \) is a weighted sum of the last collected goodput sample \( g_t \) and the previous two estimates \( GP_{i+1}, GP_{i+2} \). It can be shown that the adjustment of the data samples \( g_t \) to the goodput estimate \( GP_i \) decreases exponentially vs. time. The speed at which the older samples are smoothed is higher for increasing values of \( w_1 \) and decreasing values of \( w_2 \) and \( w_3 \).

3. VHO PROPOSED APPROACH

In Figure 1 the proposed VHO algorithm’s flowchart is illustrated.

When connectivity is not available from any of the network, the algorithm perform attempts to select a network at regular interval of times. Namely, every time an attempt to move to a new network fails a movement to the other network is attempted after a suitable waiting time, which is set different for the UMTS and WiFi network, i.e. \( T_{W,U,T-R-min} \) for UMTS and \( T_{W,T-R-min} \) for WiFi. The waiting time is introduced to limit the ping-pong effect. Namely, the grater is the waiting time the smaller will be the number of vertical handovers. When connectivity is available only through one NIC, this is selected automatically. Finally, whenever WiFi and UMTS connectivity are both available an assessment of the best network interface is performed. The proposed algorithm is based on several time parameters, working as hysteresis factor to reduce VHO frequency. Ping-pong effect depends not only on limited hotspots coverage, but also the time parameter settings in VHO algorithm. So, the frequency of search for a new interface is still limited by the parameter \( T_{W,U,T-R-min} \) and \( T_{W,U,T-R-min} \) in order to limit the ping-pong effect. Connection is then moved from the current interface to the new one, only if two following conditions are satisfied:

1. the estimated goodput of the new interface is greater than that currently selected;
2. the measured power on the new interface is greater than a minimum value (i.e. \( P_{W,T-H} \) for UMTS or \( P_{U,T-H} \) for WiFi) which is bigger than its sensitivity, (i.e. \( P_{W-min} \) or \( P_{U,min} \) for WiFi and UMTS, respectively).

The algorithm then adopts two measures for limiting the ping-pong effect, i.e. using both the VHO waiting times, \( T_{W,U,T-R-min} \) and \( T_{U,U,T-R-min} \), and the power thresholds, \( P_{W,T-H} \) and \( P_{U,T-H} \) for WiFi and UMTS, respectively.

Goodput estimation can be performed in various ways. One possibility is to transmit a sequence of probing packets at the maximum allocated capacity from both WiFi and UMTS interfaces. In order to save battery power by the two parameters, \( T_{W,U,T-R-min} \) and \( T_{U,U,T-R-min} \) which fix the minimum interval of time between two channel estimations when connection is on the WiFi or UMTS network respectively.

4. EXPERIMENTAL RESULTS

To validate the VHO performance and tune the algorithm parameters, we realized a Matlab simulation environment, consisting of 3 UMTS cells and 30 WiFi hot spots. In the simulate environment an MT moves randomly at 0.5 m/s speed in a region of 2 Km x 2 Km modeled with a map of 400x400 zones of 5 m x 5 m. In Figure 2 is depicted a random path of an MT on the described map. In the map are also shown the zones where the 30 WiFi hot spots and 3 UMTS cells are located. The WiFi and UMTS cell sizes are set on 120 and 600 m, respectively assuming an outdoor scenario.
In the simulations, we set the following parameters:
- the transmitted power in the middle of UMTS cell is about 43 dBm, according to UMTS cell requirements;
- the UMTS/WiFi receiver sensitivities are set at $-100$ dBm, according to UMTS/WiFi cell requirements, respectively;
- the $P_{U-TH}$ and $P_{W-TH}$ parameters are set at $-100$ dBm, equal to the UMTS/WiFi sensitivity, $P_{U/W-min}$, respectively;
- to save battery life, $T_{W-BT-min}$ parameter is set at 10 s.

Then, for the channel model, we considered a typical AWG (Additive White Gaussian) one, and referred to the Okomura-Hata model for the signal power attenuation [6].

We collected statistics on goodput and number of vertical handovers on different WiFi and UMTS maps generated randomly. We simulated an MT moving for 5000 steps at a speed of 0.5 m/s, (e.g. a man walking). In order to obtain a comprehensive analysis of the algorithm performance, we analyzed the mean behavior of the system and performed an optimization of the parameters and of the goodput estimation function, which impacts the handover frequency and the available bandwidth. Goodput estimation was performed using the presented ESA approach by choosing different values for the weights, (i.e. $w_1=0.1$, $w_2=0.4$, and $w_3=0.5$), and an MA with $N=5$ samples. Figure 3 shows the number of vertical handover performed by the algorithm vs. the waiting time. We considered the same values for WiFi and UMTS waiting times, 
\[ T_{W/U-TR-min} = 30 \cdot i, \quad i = 1, 2, ..., 5. \] (3)

Two curves obtained with the ESA and MA approaches are compared. With the ESA approach the number of handovers are generally greater than those with the MA approach. We do not consider the number of VHOs as a performance parameter to be minimized but rather used it in order to assure a limitation of the VHOs, being the waiting time $T_{W/U-TR}$ a precise constraint to satisfy.

Table 1 collects the number of vertical handovers from WiFi to UMTS and viceversa, during the whole simulation, (i.e. from the first step to the 5000th). The number of VHO is also called as VHO frequency. It strictly depends on the choice between MA and ESA approaches, and the $T_{W/U-TR}$ time.

<table>
<thead>
<tr>
<th>VHO</th>
<th>MA</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>150</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESA</td>
<td>6</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1. Values of VHO-MA/ESA occurrences, for several $T_{W/U-TR}$ values.

In Figure 4, the total amount of bit received is a function of the waiting time parameter, and performance of the ESA approach appears better than that of the MA one. Again, we chose the same values for $T_{W-TR}$ and $T_{U-TR}$.

On the whole, we can conclude that the greater number of handover experienced with the ESA approach for channel estimation brought about better performances.

Then, in Figure 5 is depicted the number of received bit over the MT steps in 4 cases:
1. the MT is provided only with a WiFi NIC, (see curve WiFi Rx bits);
2. the MT is provided only with a UMTS NIC, (see curve UMTS Rx bits);
3. the MT is provided with a WiFi and UMTS NIC and is able to instantaneously estimate the best channel and select the network with the current best goodput, (see curve Theoretic VHO Rx bits);
4. the MT is provided with a WiFi and UMTS NIC and performs the algorithm described in Section III, where limitations to the VHO frequencies are posed by the parameter $T_{W-TR-min}$ and $T_{U-TR-min}$ set both to 30 seconds, (see curve VHO-ESA Rx bits).

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As expected, the curve relevant to the presented algorithm denotes better performance of both the cases of UMTS and WiFi single-mode mobile terminals. Surprisingly, the novel VHO algorithm exhibits performance which are also slightly better than the case when no measure for the ping-pong effect is applied. This shows that waiting a few seconds prior performing a handover can be useful not only to reduce the ping-pong effect, but also to avoid moving to a network where performance can degrade rapidly. This is the typical case when an MT wanders at the boundary of a WiFi cell and moves frequently out of range. So, the best choice of time parameters is for low $T_{W, TR-min}$ values, not exceeding the number of VHO occurrences, and VHO-ESA approach for high $w_3$ values, (i.e. $w_3 = 0.5$).

4. CONCLUSION

We investigated into a novel MCHO algorithm, based on estimation of the WiFi/UMTS channel goodput. The system is able to limit VHO frequency to avoid the ping-pong effect and maximize the total amount of data received. The presented algorithm adopts various thresholds to limit ping-pong effect by modulating the waiting time thresholds. Then, we showed that to some extent the limitation of the ping pong effect can bring about better performance also in terms of throughput. Future works are multi-user scenario and an extension of heterogeneous network environment, (i.e. adding WiMax hot spots). Finally, simulations with different values of $P_{U/W, TH}$ and $T_{W, TR-min}$ parameters can be perform.

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6. REFERENCES