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Using Mobile Agents for Handoff Tuning in Mobile WiMAX Networks

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Abstract. Leading to integrated networks, wireless communication brings major changes to networking – fully distributed mobile computing and communications, connectivity across a wide range of environments. Some of present chalenges refers to increasing demand for bandwidth, converged broadband services, and ubiquitos computing. Mobile agents, as intelligent entities, brings more effectiveness in distributed processing. Consequently, the present paper propose a solution which improve handoff process in mobile WiMAX networks using enhanced mobile agents (EMA).

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1. Introduction

The major challenge for the mobile wireless networks is to deliver services at fixed line quality with costs of IP technologies. IP-optimized mobile network, for all types of communications services, enables network and service consolidation on IP technology and simplify architecture in order to reduce total cost of ownership.

Today appears more packet-optimized radio technologies for mobile broadband which ensure full support of mobility, security and quality of service together with improved throughput, latency and cost per bit.

In wireless networks, Quality of Service (QoS) refers to the measure of the performance for a system reflecting its transmission quality and service availability. When considering QoS, the major hurdles to overcome in mobile WiMAX networks include:

- varying rate channel characteristics,
- bandwidth allocations,
- fault tolerance levels, and
- handoff (handover) support among heterogeneous wireless networks

Fortunately, QoS support can occur at the packet, transaction, circuit, and network levels. QoS will be able to be tweaked at these different operating levels, making the network more flexible and possibly more tolerant to QoS issues.

The network architecture of mobile WiMAX (Wordwide Interoperability for Microwave Access) is defined by the WiMAX Forum (`www.wimaxforum.org`). The first two layers are in the scope of the IEEE802.16e-2009 standard [1]. This standard specifies the air interface, including the medium access control layer (MAC) and physical layer (PHY), of combined fixed and mobile point-to-multipoint broadband

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wireless access (BWA) systems providing multiple services. The MAC is structured to support multiple physical layer (PHY) specifications, each suited to a particular operational environment.

The concept of mobile agent has been defined in [7], [3], [2]. The mobile agents technology promotes applications made up of network-aware entities (agents) capable of changing their execution environment by transferring themselves while executing (migration). In order for a mobile agent to be able to migrate, there must be a virtual place, the so-called mobile agent system that supports mobility.

Mobile agents are autonomous objects that can migrate during the execution from node to node, in a heterogeneous network. On each node, the agent interacts with local resources, and could cooperate with other mobile agents to accomplish its task. Usage of mobile agents has multiple advantages:

- by migration, an agent can access the computation resources locally eliminating the network transfer of important amount of data;
- in the situation of not so reliable network link, by migrating, an agent can continue executing even if the network link goes down;
- agents are more suitable for the distributed computing (which have communication errors and dynamic changes), than the classic usage of protocols which must be designed very careful to take into account all possible situation that could appear in communication between two peers.

The current interest in mobile agents is broadly justified by the advantages their presence provides in Internet applications:

- mobile agents can carry the code to manage remote resources and do not need the remote availability of a specific server, thus leading to a more flexible application scenario; Instead of moving large amounts of data to a single point where it is searched, information retrieval moves the data-searching code to the data.
- mobile agents can dramatically save bandwidth, by moving locally to the resources they need, instead of requiring the transfer of possibly large amounts of data;
- mobile agents do not require continuous network connection, because interacting entities can move to the same site when the connection is available and then interact without needing further network connection; as a consequence mobile agents intrinsically suit mobile computing systems;

Significant research and development into mobile agency has been conducted in recent years, and there are many mobile agent architectures available today. The AgentLink project (`www.agentlink.org`) maintains a list of ongoing projects with regard to any kind of agent-related topics and also maintains a list of available agent toolkits. There are multiple solutions, based on mobile agents, which address various issues mainly in the adhoc networks (MANET). In [4] authors proposed a framework used to implement Dynamic Source Routing in ad-hoc wireless network. Other approaches ([5]) target management problems in Bluetooth networks, or particulary mechanisms, like call admission control [6]. In [9] the proposed Enhanced Mobile Agents (EMA) architecture improves the basic structure of mobile agents and their advantages can be highlighted very clearly in case of master/slave mobile agents system.

The rest of the paper is organized as follows. We first describe the handoff issues in mobile WiMAX network and the implication of mobile agents in this process (section 2). Next, in section 3 an improvement of the handoff process is presented, together with a case study and results (section 4). Finally, are presented some conclusion and suggestion for future work (section 5).

2. Handoff Issues in Mobile WiMAX Networks

The handoff, referred also as handover, is a procedure to switch the network connection access point of the mobile station without data loss or disturbing the existing connections. The handoff (HO) mechanism implemented in WiMAX allows a movement of a Mobile Station (MS) from the air interface of one Base Station (BS) to the air interface provided by another BS. The IEEE802.16e standard defines HO only among BSs, and it does not consider Relay Stations (the RSs are generally simplified BSs and may be used either to extend a coverage of a BS or to increase of a capacity in the specific area).

In a mobile WiMAX network we need to have at least two BSs, the currently serving and the handoff target(s), and an MS who can reach both BSs. This is the minimal condition for a handoff to be possible. The handoff usually is seen as a change of serving BS, but in some cases the handoff can occurs within the same BS, though within different channels. This type of handoff is called intracell handoff, while the other option is called inter-cell handoff. Also, we deal with a horizontal handoff if it happens within a single technology network, and with vertical handoff when the network type is changed. The typical deployment of a mobile WiMAX network is shown in figure 1.

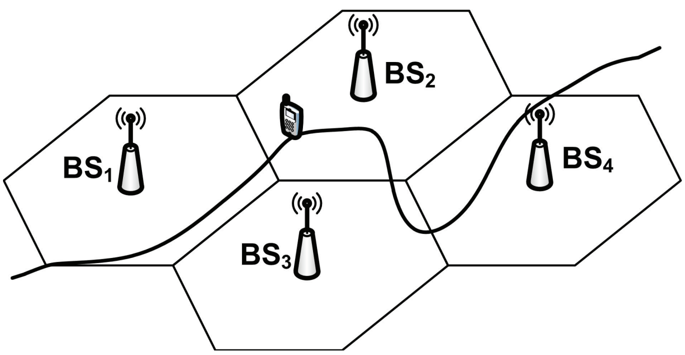

FIGURE 1. WiMAX Mobile Network Deployment

Generally, the decision for a handoff can be determined based on various properties and values: network conditions, system performance, application types, power requirements, MS conditions, user preferences, security, and costs. The MS conditions are measured constantly and, if a certain level of degradation is noticed, the handoff decision can be initiated. These parameters may include signal strength, BS coverage area, data rate, service cost, reliability, security, battery power, network latency.

To improve the handoff process, in [8] was applied mobile agents technology to the WiMAX network components. The proposed solution improves fully controlled handoff procedure using two kind of agents: BS-Agent and MSAgent. The BS-Agent is created in the BS environment and will migrate on each served MSs.

The structure of both agents is based on enhanced mobile agent (EMA) architecture [9]. The recorded agent information refers in this case to handoff parameters. When handoff process ends, recorded agent information could be sent to a control entity which can learn and tune the future handoffs by setting appropriate values for the thresholds. Besides the handoff thresholds, the BS Agent contains the list of neighbor BSs determined from network topology. This neighbor list is essential for any served MS to initiate a handover. The MS Agent is created in the MS environment and will migrate on the serving BS after data traffic connections are established.

In the following section we extend handoff capabilities of the systems by introducing a mechanism to adjust the threshold values of the parameters involved in handoff process.

3. Handoff Improvement using Mobile Agents

During the handover the MS seeks for a suitable target BS or BSs that are appropriate to be added into the diversity set, via a scanning procedure. The scanning of neighborhood is done in the scanning intervals that interleave a normal operation of the MS. The results of scanning procedure are included in `MOB-MSHO-REQ` message which initiate the handoff.

The target BS is selected in the cell reselection procedure based on the channel parameters – usually CINR (Carrier Interference + Noise Ratio) is used as a HO trigger – and QoS provided by the possible target BSs. Besides CINR, other additional parameters such as RSSI (Received Signal Strength Indicator), relative delay or RTD (Round Trip Delay) can be used for make a HO decision. When one of these thresholds is met by the neighboring BS, the HO procedure can start.

In our approach, when handoff process ends, Recorded Agent Information (RAI) is used to improve future handoffs by setting appropriate values for the thresholds. Moreover, the threshold values are considered together with applications types resulting a set of threshold values for each application type (voice, data, video, web, etc.). The determined threshold, values broadcasted by BS, will be selected by each MS depending on it's active services. Next those values are updated, in this way trying to avoid a "congestion" at the BS level by simultaneously sending of handoff request.

The proposed enhancement has two parts:

- BS Agent determines threshold values for the parameters involved in handoff process based on cell current status (i.e. number of mobile stations grouped by applications types), and communicates those values to BS MAC Layer. Next, BS broadcasts via air interface all thresholds.
- Each MS Agent select from the broadcasted thresholds the appropriate ones depending it's provisioned applications. Next, will determine it's particular threshold values based on a backoff algorithm which tries to avoid BS dealing with simultaneously handoffs initiated by various MSs. The final threshold values are uploaded to MS MAC Layer to be used in the handoff process.

The structures of a BS Agent and a MS Agent are presented in algorithm 1 and algorithm 2.

Algorithm 1 BS Agent

```
......
Based on N_i, i = 1,NoOfAppType
        Determine scanning thresholds S_i
        Determine handoff thresholds HO_i
Send S_i, HO_i values to BS MAC Layer
```

Algorithm 2 MS Agent

......
Receive S_i, Ho_i, $AppType$ from MS MAC Layer
Based on $AppType$ select $ScanningThreshold$, $HandoffThreshold$ from S_i, Ho_i
Backoff($ScanningThreshold$, $HandoffThreshold$)
Send $ScanningThreshold$, $HandoffThreshold$ to MS MAC Layer

4. Experimental Results

To evaluate the advantages of the proposed optimization we use the experimental setup, depicted in figure 2. Also, we made the things simpler without significant loss in terms of measured performances. We consider only one type of application, so each MS could pass traffic or not. Consequently, the number of MSs present in a cell could be divided in two sets: MSs which pass traffic and MSs which are registered only. Also, we consider that a cell becomes crowded if the numbers of MSs is more than $N_C = 33$. Accordingly, the generic algorithms presented in previous section are customized as in algorithm 3 and algorithm 4.

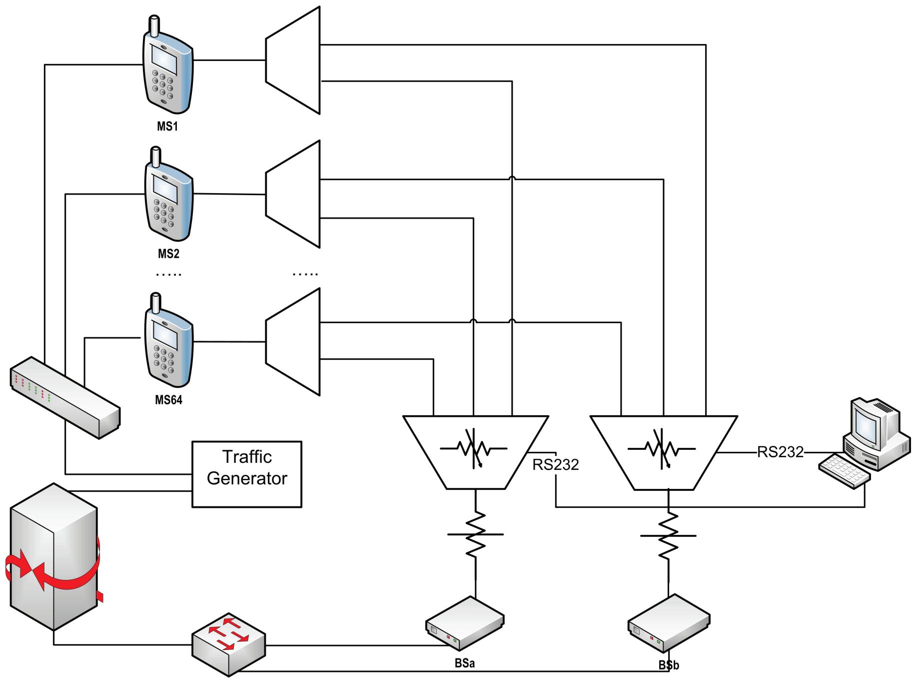

FIGURE 2. Test Setup

The experimental setup was functional for 24 hours continuously; the handoff was triggered by controlling the channel attenuations by certain scripts ran in test environment. The results regarding handoff durations measurements are summarized in Table 1.

Algorithm 3 BS Agent - experimental test

$N = N_1 + N_2$
$ScanningThreshold = 12;$ //[dB]
if $N < N_C$ **then**
  $HandoverThreshold = 5;$ //[dB]
else
  $HandoverThreshold_1 = 11;$ //[dB]
  $HandoverThreshold_2 = HandoverThreshold_1 - round(6N_1/N);$ //[dB]
end if
Send to BS MAC Layer Scanning and Handover Thresholds

Algorithm 4 MS Agent - experimental test

//AppType, Scanning and Handover Thresholds
......
if $HandoverThreshold_2 != NULL$ **then**
  if $AppType == 1$ **then**
    $Level = random(1, HandoverThreshold_1 - HandoverThreshold_2/0.5)$
    $HandoverThreshold = HandoverThreshold_1 - 0.5 \cdot Level$
  else
    $Level = random(1, HandoverThreshold_2 - 5/0.5)$
    $HandoverThreshold = HandoverThreshold_2 - 0.5 \cdot Level$
  end if
end if
......
Send to BS MAC Layer Scanning and Handover Threshold

Table 1. Experimental results

Method	**No. of accomplished HO**	**Min**	**Max**	**Avg**
Original	70856	58.27	88.53	61.14
Improved	74343	53.78	62.90	58.43

5. Conclusions and Future Work

In this work we have presented a solution to improve the handoff process in mobile WiMAX network. The proposal is based on usage of mobile agents which adjust threshold values for the parameters involved in handoff process, depending of cell curent status, and the obtained results confirm the corectness of the method.

To further improve the performance of the handoff we intend to develop an adaptive control entity which will ensure more sensitivity in adjustment process which means an increased capacity of reaction.

Another future direction consists of making the adjustments of the threshold values more accurate by considering an increased number of factors which can influence the handoff process.

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