Improvement of Handoff in Mobile WiMAX Networks Using Mobile Agents

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Abstract: One of the challenges of the communication industry today is wireless data transfer with great speed. If the traditional Wireless Local Area Network (WLAN) is the leader for indoor usage (coverage and mobility on short distance), the mobile WiMAX is planned to be the adequate solution for the outdoor (when the user exist the hotspots coverage area). In this paper we propose a solution, based on mobile agents usage, to speed-up the handover process in mobile WiMAX networks. Also, we show that the presence of mobile agents could be exploited to tune the handover process, based on past accomplished handoffs.

Key–Words: Mobile WiMAX network, handoff, handover, mobile agent.

1 Introduction

In the last decade, mobility – which allow users to have access to the communication services no matter where they happen to be – was a very rapidly trend in communications.

The network architecture of mobile WiMAX (Wordwide Interoperability for Microwave Access) is defined by the WiMAX Forum [1]. The first two layers are in the scope of the IEEE802.16e-2009 standard [2]. 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 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.

In such networks a mobile device must have the ability to change its serving base station with another one if there exists. One of the motives could be, for example, achieving of a better link quality. 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.

Mobile agents are autonomous objects that can migrate during the execution from node to node, in a heterogenous 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.

There are multiple solutions, based on mobile agents, which address various issues mainly in the ad-hoc networks (MANET). In [7] authors proposed a framework used to implement Dynamic Source Routing in ad-hoc wireless network. Other approaches ([8]) target management problems in Bluetooth networks, or particulary mechanisms, like call admission control [5].

The rest of the paper is organized as follows. We first describe a mobile WiMAX network and the handoff 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).

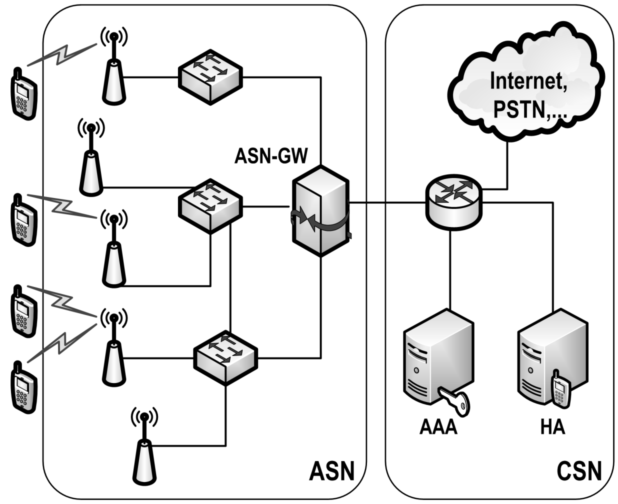

Figure 1: Mobile WiMAX Network Structure

2 Mobile WiMAX Networks

As we mention before, the IEEE802.16e-2009 standard defines only the air interface, while the network connecting and providing the access to the Internet is service providers job. Nevertheless, the WiMAX Forum has established a Network Working Group (NWG) that defines a Network Reference Model [3], and a structure to be used when constructing a mobile WiMAX network (see Figure 1). The mobile stations (MS) are connected via air to the base stations (BS). The BSs connect to an access gateway which make the link with Connectivity Service Network (CSN). The connections from BSs are in the most of the cases wired (optical cable).

All the needed network components to offer radio access to a WiMAX subscriber are provided by the Access Service Network (ASN). Its job is to ensure WiMAX-L2 connectivity to a WiMAX-MS. Also, ASN transfers the authentication, authorization, and accounting information to the home network service provider. The effective radio resource usage are also handled within the ASN.

The general role of the CSN is to provide IP connectivity services to the WiMAX subscribers. The CSN can allocate the MS IP address and other endpoint parameters and usually is the one providing Internet access for the users and could include the AAA (Authentication, Authorization, Accounting) proxy or server. The connection between ASN and CSN is realized via the Access Service Network Gateway (ASN-GW).

In a mobile WiMAX network, for a handoff to be even possible, we need to have at least two BSs, the currently serving and the handoff target(s), and an MS who can reach both BSs. The handoff usually is

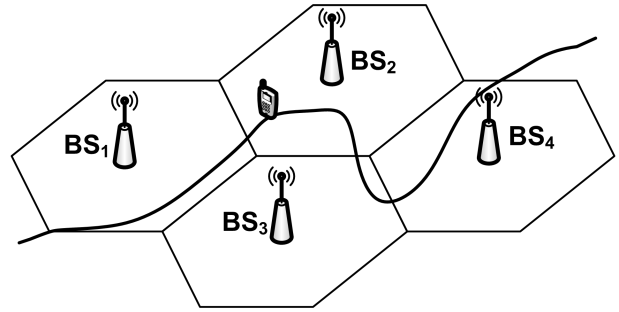

Figure 2: Mobile WiMAX Network

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 intra-cell 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 2.

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. The fully controlled handoff procedure is depicted in figure 3.

We can notice two phases: preparation phase and action phase. In preparation phase the MS, based on measured condition, initiate a handoff procedure via `MOB-MSHO-REQ` message, which contains a list with aimed target BSs. The serving BS sends `HO-Req` for each target BS from the list. Target BSs, after receiving handover request message, will initiate a context retrieving procedure to obtain MS related information. After that each of them will decide if can accept the MS and send the decision within `HO-Rsp` message. The serving BS will aggregate all decisions and will send the list with target BSs that accept the handoff to the initiating MS, via `MOB-MSHO-RSP`, message that ends the preparation phase.

The action phase starts with `MOB-HO-IND` message sent by MS to the serving BS, indicating the target BS selected for the handover. The serving BS sends `HO-Cnf(Cancel)` to all target BSs that was not selected for the handover, and `HO-Cnf()` to the selected target BS. All the target BSs will respond with an acknowledge. Only the selected target BS will continue by initiating the context retrieval pro-

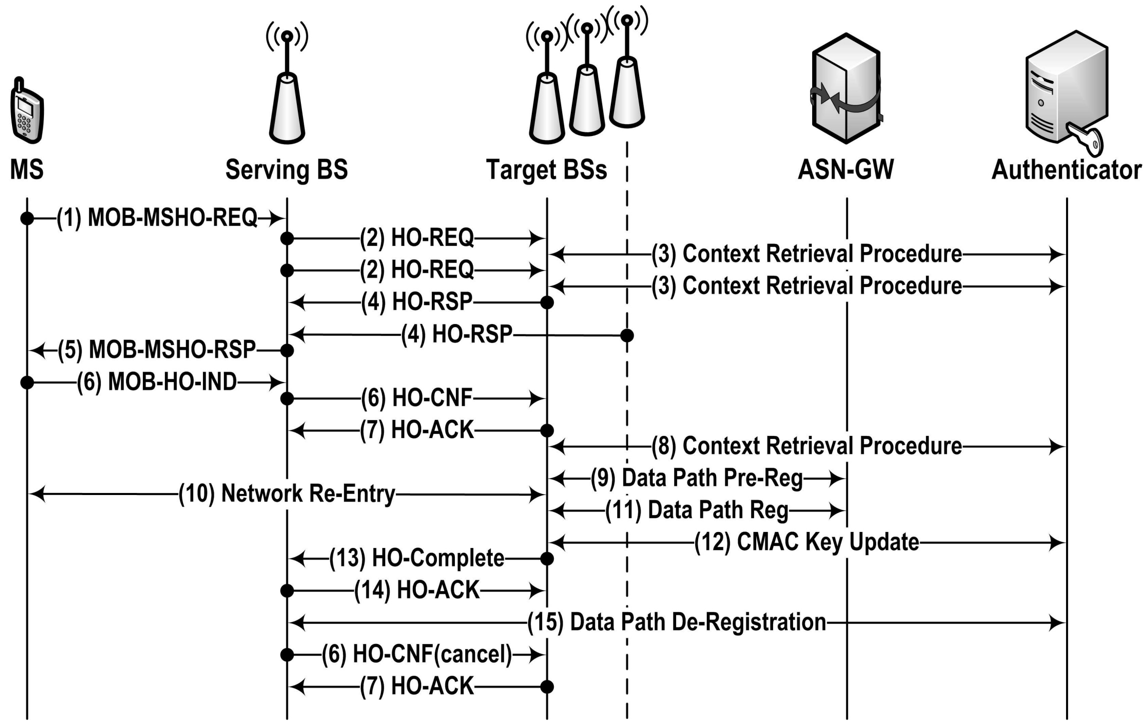

Figure 3: WiMAX Fully Controlled Handover

cedure to obtain the updated MS related information, and next with data path pre-registration.

After sending handover indication, the MS start network re-entry procedure with the selected target BS. After reaching the operational state, the service flows are created according to QoS parameters, and the encryption keys are updated. When this last exchange ends the selected target BS send `HO-Complete` message to serving BS, indicating that handover is complete and from now on the selected target BS will become the new serving BS. After an acknowledge the old serving BS perform data path de-registration procedure to release the resources occupied by the MS.

3 Mobile Agents based Handoff

To improve the handoff process, described before, we apply mobile agents technology to the WiMAX network components. The proposed solution is based on usage of two kind of agents: BS-Agent and MS-Agent.

The BS-Agent is created in the BS environment and will migrate on each served MSs. The structure of the agent is based on enhanced mobile agent (EMA) architecture [6]. The recorded agent information refers to handoff parameters. The structure of a BS Agent, implemented using Tracy toolkit [4], is presented in what it follows.

```
//Base Station Agent
import de.fsuj.tracy.agent.*;
import java.io.Serializable;
...

public class BSAgent extends Agent
       implements Runnable, Serializable{
 ...
 BaseStationList NeighborList;
 Threshold HandoffThresholds;
 RecordedAgentInformation HandoffParams;

 protected void migrateToMS(MSAgent MS){
   // Defines how the agent should
   // be transferred to the served MS
   ...
 }
 private void record(){
   // Define how and when the handoff
   // related values are collected from
   // 802.16e MAC/PHY, and stored to
   // HandoffParams
   ...
 }
 private void sendHandoffParams
                    (Agent LearnAndOptimize){
   // send recorded HandoffParams to
   // an agent which is intended to
   // optimize the handoff process
   ...
 }
 ...
}
```

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. The structure of a MS Agent, implemented in Tracy is presented in what it follows.

```
//Mobile Station Agent
import de.fsuj.tracy.agent.*;
import java.io.Serializable;
...

public class MSAgent extends Agent
       implements Runnable, Serializable{
 ...
 WimaxContext MSContext;
 boolean WimaxContextUpdatePerformed;

 private void migrateToServingBS(){
   // Defines how the agent should be
   // transferred to serving BS
   ...
 }
 private void copyAndMigrate(DestinationList dl){
   // Defines how the agent should be
   // transferred to another BS or to
   // Authenticator
   ...
 }
 private void acceptAndNotify(){
   // Performs the processings based on what
   // the agent, will decide to accept
   // the transfer of the MS
   //
   // At the end will trigger the notification
   // of the serving BS
   ...
 }
 private void updateContext(){
   // Defines how the MSContext of the agent
   // which resides on Authenticator is updated
   // by the network level
   ...
 }
 private void remoteUpdateContext(){
   // Defines how we perform synchronization
   // of MSContext field, between the current
   // MSAgent and Authenticator resident agent
   //
   // Data transfer are performed only if
   // WimaxContextUpdatePerformed is TRUE
   ...
 }
 ...
}
```

By applying mobile agents technology the handoff process take place in this way:

1. MS knows from the hosted BS-Agent the neighbors list and could initiate a handoff when monitored parameters does not fit anymore in thresholds values. MS initiate the handoff via `MOB-MSHO-REQ` which contains the list of target BSs.

2. The serving BS will initiate migration (`copyAndMigrate` method) of the hosted MS-Agent to all target BSs from the list, and to authenticator. In this way every indicated target BS will know the MS related information needed to decide if accept to serve that MS. Also, the authenticator could update MS related information (`updateContext()` method). First improvement consists in avoiding necessity of taking place of context retrieval procedure to make the acceptance decision. The target BS could answer very quickly ending preparation phase in a significantly shorter time.

3. MS starts the action phase by sending `MOB-HO-IND` message to the serving BS, indicating the target BS selected for the handover. As in original procedure the serving BS sends `HO-Cnf(Cancel)` to all target BSs that was not selected for the handover, and `HO-Cnf()` to the selected target BS. All the target BSs will respond with an acknowledge.

4. The selected target BS will continue by obtaining the updated MS related information. Instead to perform every time the context retrieval procedure, the hosted MS agent invoke the `remoteUpdateContext()` method which check first if a data transfer is necessary due to changes in MS related information and this is the second improvement which also will determine a shorter action phase.

5. The rest of steps are performed like in the original procedure.

4 Experimental Results

To evaluate the advantages of the proposed scheme we use a number of computers connected in a network as is depicted in figure 4. The role of each computer could be easily understood: we considered one mobile station role computer, three base station role computers, and one authenticator. Every BS is considered to be in neighborhood relationship with all other BSs. The initial state is: MS_0 is the served mobile station and BS_0 is the serving base station. MS_0 hosts the mobile agent created and sent by BS_0. BS_0 hosts the mobile agent created and sent by MS_0.

The activity of the BS Agent hosted by MS_0 can be summarized as follows:

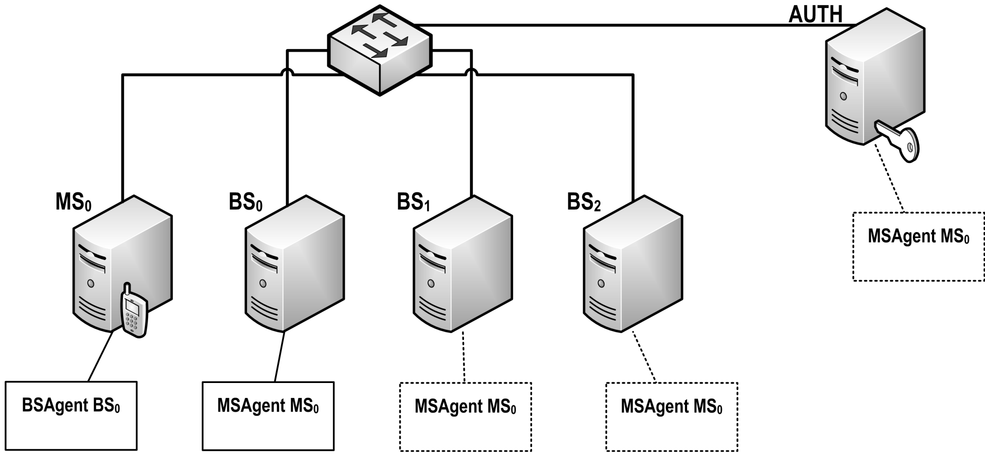

Figure 4: Simulation Environment

1. Record handoff parameters until MS_0 perform network re-entry and data path registration.

2. Send recorded handoff parameters to control entity.

3. Destroy itself.

Similarly, the activity of the MS Agent hosted by the serving base station BS_0 can be summarized in this way:

1. When receive `MOB-MSHO-REQ` messages invoke `copyAndMigrate` method with argument list of specified target base station. Invoke `copyAndMigrate` method with argument network authenticator.

2. When the data path de-registration procedure ends destroy itself

Every MS agent which is hosted on specified target base stations (which migrates from serving base station) performs the following steps:

1. When arrive on target BS invoke `acceptAndNotify` method which can determine if the mobile station could be accepted as served MS.

2. When receive `HO-Cnf()` message invoke `remoteUpdateContext` method to retrieve the most updated context for the MS

3. When receive `HO-Cnf(Cancel)` message destroy itself.

The MS Agent hosted on authenticator execute:

1. When something related to the MS is modified the authenticator invoke `updateContext` method which will change the `MSContext` appropriately.

2. When its method `remoteUpdateContext` is invoked send the `MSContext` to the caller.

Based on above defined mobile agents the simulation – from the MS_0 point of view – pass repeatedly through the following steps:

1. Send `MOB-MSHO-REQ` message. Start the HO-DURATION timer. Wait to receive `MOB-MSHO-RSP` message.

2. Receive `MOB-MSHO-RSP` message. Check the list of target base stations which accepted handoff. Select one of them (we select the bases station with the minimum index)

3. Send `MOB-HO-IND` message containing the selected target base station.

4. Perform network re-entry with selected target base station. Create data traffic connections. Stop the HO-DURATION timer.

There were performed 10000 handoffs and we calculate the average durations in both situations: original handoff procedure, and improved handoff procedure. We noticed that both optimizations regarding the MS context retrieval work well, and in 64% the `remoteUpdateContext` method returns immediately.

The results are summarized in the table 1.

Table 1: Experimental results

Procedure	Minimum	Maximum	Average
Original	54.1ms	62.3ms	58.12ms
Improved	47.8ms	55.2ms	50.39ms
Improvement			13%

5 Conclusions

In this work we have presented a solution to improve the handoff process in mobile WiMAX networks. The proposal is based on usage of mobile agents which can migrate between network components: mobile stations, base stations, authenticators and the obtained results confirm the correctness of the method.

Another important thing that must be mention is the possibility of using it also, in the situation when the handoff is initiated from the network layer. This means that radio resource management entity, monitoring the network resources could decide that by moving a mobile station from one base station to another, the resource usage could be optimized and/or could be assured better QoS values for the user.

To further improve the performance of the handoff we intend to develop a control entity which could make the adjustments of the threshold values used by mobile stations to decide if is necessary to change the serving base station. For this purpose we use the enhanced mobile agent (EMA) architecture in definition of the base station mobile agent. Thus, based on the Recorded Agent Information component of the BS Agent, this control entity could react and change, for example, the moment when the mobile station will initiate the handoff. A dynamic change of the handoff triggers could mean both important savings in terms of costs, and growths in terms of quality of services.

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