A Proactive Horizontal Handover Algorithm for WiFi-WiMax Interoperable Networks

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***Abstract* — Two important high bandwidth wireless certifications in our days are *Worldwide Interoperability for Microwave Access* (*WiMax*) and *Wireless Fidelity* (*WiFi*). They can interoperate to form a geographical wider network in wchich Mobile Client (MC) can move. We suppose a combination of two WiFi *Access Points* (*AP*) and a WiMax *Base Station* (*BS*) that interoperate putting a WiMax *Wireless Network Interface Card* (*WNIC*) in the WiFi AP. The BS can request real time video or *Video on Demand* (*VoD*) from a server allocated in the fixed network (to which the BS is connected). In order to model the movement of the MC, we build a diagram state to represent the areas in which MC can be and from what area to which one the MC passes. Classifying the areas in connected and disconnected ones we can discover the different actions that are achieved by different entities of a simple protocol that are allocated in the BS and the AP. These entities are in charge to control the buffers to efficiently support disconnections due to handover and out of coverage situations (disconnected states). Up to our knowledge, no other authors have studied this complex problem.**

***Index Terms* — Multimedia, Buffer Management, Streaming, Disconnections Prediction, WiFi, WiMax.**

I. Introduction

Physical properties of *WiMax* and *WiFi* channels make difficult to maintain client connections and guarantee the necessary *Quality of Service* (*QoS*) [1] for multimedia services.

The *Received Signal Strength Indicator* (*RSSI*) is used to define different areas of coverage. In outdoors, in an open area with no obstacles, it starts at 100% powerful surrounding the WiFi *AP* or WiMax *BS* and decreases as user moves far from the AP (BS), until it arrives fewer than 10% where is the end of the coverage area. In this last part of the coverage area, channel conditions deteriorate, data are lost, and the medium saturates with retransmitted failed data, which cause poor multimedia reproduction quality at the *MC* [2]. As a result, sporadic disruptions could occur.

In our days MC are provided from fabric with several *WNIC* to allow them to access to different wireless technologies [3] to extend the area in which they can be connected (but there is no one with WiFi and WiMax). When MC starts to loss its connection to the AP it is connected and stops receiving data for several seconds [2], it searches for another AP or BS to associate with. This process is named roaming [4] and handover [5, 6, 7, 8], that is required to maintain channel connection and frame transmission while MC movement. Handover is classified, from the BS technology point of view [5, 9] as *Vertical Handover* (*VH*) that occurs when MC moves between different networks that use different technologies, and *Horizontal Handover* (*HH*) when these networks use the same technology [10]. Depending on its procedures it is classified as *Reactive Handover* (*RH*) that delays Handover as much as possible i.e. Handover starts only when MC completely loses their current AP signal, and *Proactive Handover* (*PH*) which triggers Handover before the complete loss of original cell signal. Two strategies under this type are available: *Hard Proactive* (*HP*) and *Soft Proactive* (*SP*) [6, 11].

Many continuous multimedia services like *VoD*, *Voice over IP* (*VoIP*), and *Real Time Chatting* communicate a continuous flow of packets. Handover influences multimedia services in more degree than roaming, because many parameters such as: bandwidth, security, traffic shape, RSSI, packet loss and service connection recovering are influenced by it. If the handover process takes a long time, then a lot of packets will be lost and the user of MC will not follow the video or audio adequately [4]. Efficient proactive HH design considering multimedia communication is a big challenge.

In this paper we present a proactive HH theoretical mechanism designed for WiFi networks of which AP are connected to a WiMax BS considering a Random Walk Mobility Model based [12] (we do not include special profile, e.g. streets or tunnels). To complete the study of possible disconnections, we also analyze the case the MC losses the connection because it goes out of coverage. Different possibilities of disconnections are also considered: the MC is doing handover but it goes out of coverage and returns to an area of coverage of another AP, for example.

The mobility management system proposed in [1] may keep connections based on the end-to-end principle by incorporating an intelligent network status detection mechanism. Although it

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in general considers QoS it does not focus on multimedia applications such as VoD.

The Handover algorithm proposed in [7] depends on the estimated mobility using RSSI. This algorithm is able to avoid ping-pong effect and to enhance overall Handover process performance. But they have not shown how it affects on packet lost and multimedia applications. In our algorithm, RSSI is used to keep transferred video while handover.

In [10] it is introduced a new concept named *Takeover* in which the *Neighbor Node* (*NN*) takes over *Mobile Node* (*MN*) handover operation. They have defined signalling messages and protocol for Takeover operations and applied it to the proposed VH scheme. Authors found that Takeover fails when connection between the nodes is broken or Takeover process maximum time is finished before mobile node (that we call MC) receives the completion message. In our opinion, one disadvantage of it is the ability of NN to deny the request message of Takeover, or MN can not connect to any mobile for any reason e.g. if it was in unreachable area. In the present paper, we do not use any other MC; we depend mainly on the BS or AP which MC is associated to.

In [13] authors divided the handover process into two steps: the discovery of new AP by passive or active scanning, and the re-authentication that involves authentication and re-association to new AP. They have demonstrated clearly that delay variability is due to scanning phase while re-authentication delay is constant, and the delay can be reduced by the proper choice of the AP position. The system can support VoIP that is sensitive to the delay and jitter. Up to our knowledge this technique is not appropriated for video streaming. Scanning is a hard process that wastes time, and it is not needed in our proposed paper. Measuring RSSI is enough to decide handover necessity.

The handover mechanism proposed in [14] is based on a priori knowledge of other networks depending on combined handover probabilities. It increases handover success rate of up to 22% compared to classical blind handover. But in our opinion, these probabilities change rapidly because MC changes its position frequently. In our proposed algorithm measuring RSSI is just in the case that MC position is changed which reduces time and memory needed to store these data.

Anticipating, as much as possible, the information about MC movement is crucial for reactive handover. In [11] a migration process of mobile proxies in advance to the wireless cells where MC is going to reconnect is proposed (they increase the size only when a client handover is going to occur and reducing the size when handover is not near which reduce memory and bandwidth usage). These authors also propose mobility prediction solutions depending on the Grey Model [15] and a way to exploit handover prediction to optimize client side prefetching buffers usage for streaming data depending on client side RSSI from the visible AP [16] (their solution depends on reducing the buffer size needed to keep continuous streaming and to impose a very limited overhead by exploiting RSSI data already available at client). In [17] it is shown that Forward Handover using Partial Re-establishment is better that using the Backward one (using "Full Re-establishment, Multicasting, Connection Extension"). They propose a packet discarding mechanism where the information carried by high priority packets is considered by the buffers to be more important than information carried by low priority packets. We predict handover depending on MC position in three possible areas of coverage we defined depending on RSSI values. We store the video when Handover is expected to happen, in *Mobile Client Buffer* (*MCB*) or in *Base Station Memory* (*BSM*) in order not to loss frames.

The rest of the paper is organized as follows. In section 2 we outline the network architecture and mobility a pattern of MC. Section 3 is devoted to present our mechanism that contemplates handover and also areas with no coverage. We briefly present some ideas about the next state prediction that is crucial for our mechanism in section 4. Finally, we summarize our conclusions and present directions for further research.

II. THE NETWORK ARCHITECTURE AND MOBILITY PATTERNS

We consider a network that combine infrastructure WiFi cells of wchich AP are connected to a WiMax BS. The AP has two WNIC: one for the WiFi cell, and another for communicating the BS. The BS is connected to a wired backbone (wired Internet). In Internet there is a VoD server that streams multimedia packets to the MC connected to the WiFi AP. The Server and the Client use *Transmission Control Protocol* (*TCP*) and User *Datagram Protocol* (*UDP*) for signalling and multimedia data communication respectively. Over these protocols other multimedia protocols like *Real Time Streaming Protocol* (*RTSP*) for video communications can be used.

We suppose all the MC outdoor and no important obstacles are present in the surrounding area. We do not take into account the presence of complex buildings, cars or other elements that provoke strong interferences in wireless channels. Under these assumptions the wireless channel behavior is not strongly chaotic, because the interferences and path loss conditions are moderated.

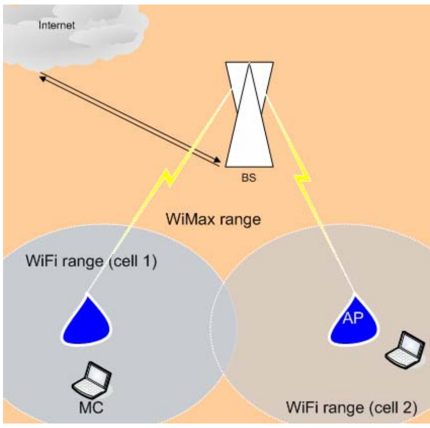

Fig. 1. Physical range of wireless networks interconnection.

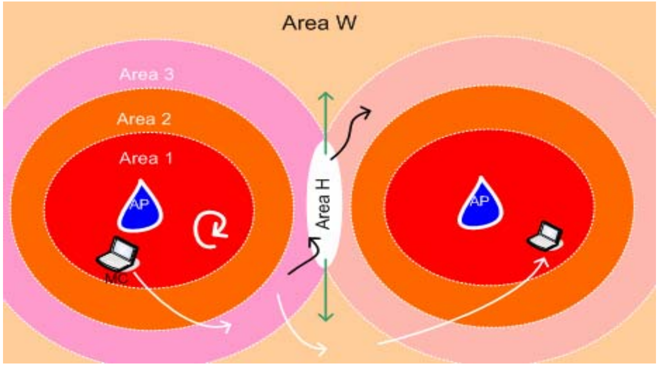

Fig. 2. Coverage area parts and MC mobility patterns.

In Fig. 1 we show a graphic representing the above assumptions.

In IEEE 802.11 standard the driver of the WNIC is in charge of measuring the RSSI as an integer ranging from 0 to 255 (1 byte of size). Real vendors choose a set of these 256 values ranging from 0 to a maximum value (*RSSI_Max*) defined by them. For example Cisco chose RSSI_Max=100, while Atheros choose RSSI_Max=60. It does not represent a power value in decibels (*dB*) or dB referenced to one mili Wat (*dBm*).

The RSSI does not represent the full actual power received by the WNIC what led many vendors to implement mapping tables to convert RSSI to dBm. IEEE 802.11 indicates that RSSI can be defined using relative values to RSSI_Max as: $RSSI\_Rel = (RSSI * 100) / RSSI\_Max$.

RSSI_Rel is used to assert if MC is inside coverage area of a particular WiFi AP. Moreover, categorizing its values we can discriminate the part of the coverage area in which MC is. Let us note that a *Global Position System* (*GPS*) set in the MC it is not necessary because we are not interested in the exact position of the MC. We also do not need an accurate localization method. We think it is appropriated to categorize the coverage area in three different parts:

- *Area 1* defined by the inequality $100 \geq RSSI\_Rel > 60$, is the most near part to AP, where coverage is very strong (ranging from excellent to very good level) and MC is in the best state of connection.
- *Area 2* defined by the inequality $60 \geq RSSI\_Rel > 40$, is the middle part, where the coverage is not so strong (ranging from very good to good level) and MC is in a good state of connection.
- *Area 3* defined by the inequality $40 \geq RSSI\_Rel > 20$, is the farthest part, where the coverage is weak (ranging from less than good to cuasi no connection level) and MC is close to a bad state of connection.

Before transmitting, the WNIC of the MC checks if current measured RSSI is less than *Clear Channel Threshold* (*CCT*). If it is greater or equal than CCT then wireless channel is not clear to transmit. When the MC is ready to receive, its WNIC must test if the RSSI (transformed in dBm) received (in the WiFi frame) is greater than *Reception Sensitivity Threshold* (*RST*) that is measured in dBm (a value very close to 0 but not 0). If RSSI is equal to RST, the WNIC can not differentiate between noise and signal [18]. In any part of coverage areas above classified these conditions must be assured. Let us note that, precisely in Area H and Area W (Fig. 2) these conditions are not maintained.

Regarding to the movement of the MC, we consider the following suppositions:

- The movement pattern is the most conservative: in any point the MC can proceed to any direction and with any speed.
- The MC defines a smooth movement, that is, it can pass from Area *i* to Area *i+1* or *i-1* ($1 \leq i \leq 3$, *i=H* or *i=W*) but it can not jump between none "consecutive parts of area". Let us note that the MC can be in the same area along the time or simply change to another consecutive area. For simplicity we name this area as *Area W* (for WiMax).
- As a consequence of the above supposition, the MC can cross from the Area 3 of an AP to the Area 3 of another AP. Also it can cross from Area 3 to the AW: in this case the MC can not communicate because it is out of WiFi range.

Let us now think about the case the MC crosses between Area 3 of the different AP. In this case, the MC that is associated to an AP can move its connection to another one, if the signal level received from this AP drops to a low value which is called the *Roaming Threshold* (*RT*). In that case a roaming or handover process must start. We call this special area the handover area, for simplicity we identified it as a new Area named *Area H*. Taking this into account, we can discover that when MC is in Area 3, and a handover process starts then MC is in Area H. It could cross to Area H of the other AP and then to Area 3. Let us note that with this consideration, MC can not cross from Area 3 of one AP to Area 3 of the other AP directly.

In Fig. 2 we show the different parts of coverage areas in the different AP and also the Area H that is the same for the two AP. Also we show the movement pattern of the MC.

III. The Handover Mechanism and Buffer Management

While a particular MC is crossing from WiFi cell 1 to WiFi cell 2, it can experiment disconnections due to different situations: a) it is in Area H, so it can loss during sometime the connection, although it has wireless connection, but it is trying to reconnect to the appropriate AP. b) It is in Area W and it loss wireless connection. In this case it can reconnect to the AP it was connected or to a new one. In both cases, the result is a loss of video reception during some time.

The challenge is to anticipate predicted information to the MC in order not to loss video during the above disconnections. This challenge exhibits different solution for real time video and for VoD. To do this, we consider a mechanism that every Δt discovers the Area in which the MC is and anticipates the Area in which it can be immediately after this time. This amount of time is related to the speed of movement of the MC (if we want to discover all the areas in which the MC will be, we will have to accurate this value, if the speed is slow then this value can be reasonable large). Also it must inform about this to different entities allocated in the AP, the BS and MC in order them to do some protocol actions. The first, named *AP Proxy* (*APP*) is a simple proxy that forwards signaling information from MC to BS and data from BS to MC, the second is the *BS Buffer Manager* (*BSBM*) and the third is the *MC Buffer Manager* (*MCBM*).

These three entities cooperate using a state protocol. In Fig. 3 it is shown the states and the transitions between states. In this state diagram is captured the idea that MC only can cross to consecutive parts of the coverage area or continue in the same part. Annotating the amount of time a MC is in any of these states is very simple and gives us an idea of the space and time trajectory of the MC. Following the transitions we easily discover that the MC starts in Area 1 (it is supposed that it has associated to an AP with excellent coverage), then it can proceed to Area 3, be disconnected (Area W) during sometime, return to Handover Area (Area H) or Area 3 of the same or another AP. In this simple way we capture the handover and wireless disconnection of the MC and also we can memorize the trajectory of the MC. Doing this, we can obtain a profile of movement that can be used to inferred future possible movements, for example, an employee probably defines every day the same trajectory from home to the factory.

A. Previous considerations

MCBM is in charge to measure the different parameters of coverage consulting the WMIC driver: RSSI_Max, CCT and RST. Calculating RSSI_Rel it can discover the current state, and using RST it can discover if it is in the AH state. In order to avoid ping pong between states (e.g. A1→ A2 → A1 → A1 …) it maintains an RSSI_Rel array in which all the old *n* values of RSSI_Rel are stored. If the starting state is *Ai* and a transition like this is evaluated, the next state will be *Ai* again. For security in the decision we can also arrange a band of values centered in the limits of Area of coverage definition (e.g. for Area 1 we can take the band *55 .. 65* for the lower limit of RSSI_Rel).

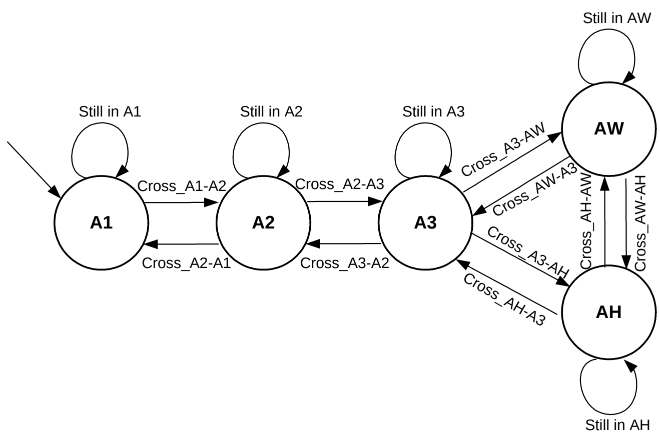

Fig. 3. States and transitions of the cooperative protocol among MCBM, APP and BSBM.

Prediction of transition inter-states is achieved analyzing the RSSI_Rel array. In some cases, it is very simple, e.g. a linear trajectory from Area 1 to Area 2 is easily identified if RSSI_Rel array has the values: 100, 95, 90, 92, 80, 70, 65 and 62 (probably, next value will be less than 55). This means that next MCBM is in state A1 and will be in state A2 activating transition *Cross_A1-A2*. This produces an event that will be processed by MCBM. All other transitions generate the corresponding anticipated event. It is trivial that no relevant actions are associated to the *Still in* transitions: simply the entities remain doing the same actions. The state AW and AH are "disconnected states" (in AW the MC is out of coverage and in AH the MC is deciding to which AP will be connected). That means that MC can experiment loss of video frames. We also must note that when the MC is out of range, it can return to a disconnected state (AH), so it is important to register in APP and BSBM this situation, because it could connect to another AP when it returns to coverage. This situation corresponds with the following events (transitions): *Cross_A3-AW*, *Cross_AW-AH* (indeed a succession of *Cross_AW-AH* and *Cross_AH-AW* can occur: ping-pong).

Another interesting point is to differentiate clearly the situation in which the MC is in A3 of an AP, the event *Cross_A3-AH* occurs, and then the event *Cross_AH-A3* occurs again. In this case we have to differentiate the case in which the MC returns to connect to the original AP or the situation in which a handover occurs and it will be connected to the other AP in state A3 for that AP. The same occurs for *Cross_A3-AW* (A3 for an AP) and *Cross_AW-A3* (A3 for the other AP).

A VoD server can increase or decrease its speed of video transmission till to reach the maximum bandwidth allowed for that connection in the wired network. In the same way, MC can request to the BS that increases or decreases transmission speed in order it to store bigger amount of video frames in its buffer. In this way it can support a wireless disconnection or handover taking frames from its buffer.

Let us note that using the RSSI_Rel array we can predict the speed and trajectory of MC when it is going to reach the AW state. Using this prediction we can ascertain if it will return to a connection state early or on the contrary it will leave the wireless coverage and will not return in several minutes. In the first case we can arrange a buffer in the BS that can be used to support this interval of disconnection. When the MC returns to the wireless connection it can receive from this buffer. And video frames will not be lost. In the second case, simply the APP can send a message to the BSBM telling that do not the buffering of video frames, and stops the VoD server. To do this, the MCBM must communicate a message to the APP telling that before it will be out of coverage.

B. Primitives of the protocol

The entities of the protocol exchange a number of messages that regulates their actions. These messages are exchanged using a compact set of primitives:

- *Increase Speed of Video Frames Transmission*. It has a parameter indicating the server to which the message is sent. The syntax of this primitive is: *entity*:*ISVF* (*server*), where *entity* can be [BSBM | MCBM], *ISVF* is the abbreviated name of this primitive and *server* can be [VoD | BSBM] where VoD indicates the name of the video streaming server. The entity sends this primitive to the server.

- *Decrease Speed of Video Frames Transmission*. It is the contrary of ISVF, that we abbreviate as *DSVF*.
- *Start Buffering Additional Frames* which syntaxis: *entity*:*StBAF*(). The *entity* starts buffering forward video frames. Where *entity* can be [BSBM | MCBM].
- *Stop Buffering Additional Frames* which syntaxis: *entity*:*SpBAF*(). The *entity* stops seeking and buffering forward video frames to be buffered. Where *entity* can be [BSBM | MCBM].
- *Consume Video Frames* which syntax is: *MCBM*:*CVF*(). The MCBM simply consumes frames of video allocated in its buffer.
- *Send* which syntax is: *MCBM*:*Send*(*BSBM*, *par*) where *par* is: a) *hc* for *handover cancelled* (for this case the MCBM consumes its buffer and in parallel it receives video frames from the BSBM), b) *hd* for *handover done* (for this case the MC realizes the dessasociation from the original AP and association to the new AP and then the same actions as for *hc*), c) *rc* for *return to coverage* (when the MC is in AW and returns to A3 it will be able to send this message).
- *Predict Disconnection Time* which syntax is: *MCBM*:*PDT*(*dt*) where *dt* is an output parameter that represents the amount of future disconnection time for MC.

C. Actions of the protocol associated to transitions

We suppose that the APP entity simply forwards the messages associated to the above primitives. For that reason we do not include explicitly their actions. When the MCBM detects a transition sends a message to the BSBM. The main actions associated to transitions are:

- *Cross_A1-A2*. The BSBM buffers forward video frames: *BSBM*:*ISVF* (*VoD*), *BSBM*:*StBAF*().
- *Cross_A2-A1*. The BSBM stops buffering forward video frames: *BSBM*:*DSVF* (*VoD*), *BSBM*: *SpBAF*().
- *Cross_A2-A3*. The MCBM buffers forward video frames: MC*BM*:*ISVF* (*BSBM*), *MCBM*:*StBAF*().
- *Cross_A3-A2*. The MCBM stops buffering forward video frames: MC*BM*:*DSVF* (*BSBM*), MC*BM*: *SpBAF*().
- *Cross_A3-AH*. *MCBM*:*CVF*().
- *Cross_AH-A3*. a) A3 of original AP: *MCBM*:*Send*(*BSBM*, *hc*), b) A3 of new AP: *MCBM*:*Send*(*BSBM*, *hd*).
- *Cross_A3-AW*. MCBM predicts the amount of buffer (depending on dt), in order to support the disconnection (it is inefficient to allocate more buffer if the MC will not return to A3). This is done invoking to *MCBM*:*PDT*(*dt*), MCBM:*BSBM*:*StBAF*(), *MCBM*:*CVF*().
- *Cross_AW-A3*. *MCBM*:*Send*(*BSBM*, *rc*). Let us note that it is sent independently to which AP it will be associated again.
- *Cross_AH-AW*. It must also predict the amount of time for it will be disconnected: *MCBM*:*PDT*(*dt*), MCBM:*BSBM*:*StBAF*(), *MCBM*:*Send*(*BSBM*, *hc*), *MCBM*:*CVF*().
- *Cross_AW-AH*. *MCBM*:*CVF*().

D. Additional considerations for Real Time video

Real time video is a more complex task to support because MC or BS can not request its peer to increase or to decrease the video frame transmission speed. The speed of transmission (variable or constant is fixed and we can not consumed future frames that have not been produced till now).

We apply the ideas expressed in [19] to support wireless disconnections for real time video, but we base our solution taking into accounts the diagram state of Fig. 3.

We divide the buffers BSM and MCB into several parts defining a serie of limits: $LimA_i$, $i=1, 2, 3$ and *W or H*, With $LimA_i < LimA_{i+1}$. $LimA_2$, $LimA_3$ and $LimA_W$ are the limits associated to transitions: Cross_A1-A2, Cross_A2-A3, Cross_A3-AW (the same is applied for AH). $LimA_1$ is associated to transition *Still_A1*. When the transition *Cross_Ai-Ai+1* occur, the last $LimA_{i+1}$ video frames (from 0 to $LimA_{i+1}$) are stored in these buffers simultaneously. When the transition *Cross_Ai+1-Ai* occur, the last $LimA_i$ are stored.

We can support a wireless disconnection or handover because in the BSM is stored a set of the last video frames sent by the real time video server. When the MC is in AW or in AH it can repeat the consumption of the last video frames stored in the MCB (from 0 .. $LimA_3$). When the MC returns to A3 it can request the BSBM the last $LimA_W$ video frames. Then it can receive that frames and the real time frames. In this very simple way the MC is always showing video frames to the user, but also no video frames area lost if the disconnection period is not high (probably in this case the video session must be finished because it is not practical to show the last video frames sent a long time ago).

IV. The Prediction of States

Predicting the next state is crucial for our mechanism. Discovering with relative anticipation the next state allow us to generate the corresponding transition before the MC changes of state permitting it to take actions in advance.

We use two RSSI_Rel arrays (the immediately last: *RSSI_Rel_l* and the current: *RSSI_Rel_c*), each of them has a fixed number of elements, for example 5, named as *RSSI_Rel[i]*, *i=1, .., n*. We can measure these values each 5 ms (for example, at present it depends on the concrete network and multimedia application). Using these two arrays, we apply the following metrics to anticipate the next state:

- *Ordering of values*. We seek an increasing, decreasing or varying pattern in the RSSI_Rel_c. If the pattern is increasing probably indicates that MC is changing from Area i to Area i+1, and the contrary if it is decreasing. If the pattern is varying then the MC probably will remain in the same Area.

- *Take into account the Areas defined by RSSI_Rel_c[1] and RSSI_Rel_c[n]*. We can obtain a same area or a different area defined by these two values. This metric indicates us in which Area the MC Starts and in Which Area it arrives.
- *Range of RSSI_Rel_c*. This value is measured as *RSSI_Rel_c[n] – RSSI_Rel_c[1]*. This value can be small, large or very large. With this value we obtain the total amount of walk done from the beginning to the end. The walk can be small, large or very large.
- *RSSI_Real_c jitter*. We compute the maximum and the minimum of the operation: *RSSI_Rel_c[i]-RSSI_Rel_c[i+1]*, for *i=1, .., n-1*. Subtracting these two values we obtain a small, large or very large classification. With this value we obtain the same as the last metrics but now for each step the MC does. Combining this and the last metrics we can study the movement of the MC from it beginning to the end and in every step.

Combining these 4 values in an appropriate way and comparing with the corresponding ones for *RSSI_Rel_l* we can anticipate an approximation of the next state.

V. Conclusions and Future Work

In this paper we present initial ideas about efficient management of VoD and real time video in wireless networks that combine WiFi and WiMax technology. While in recent papers several authors center their work in efficient handover mechanism, we study a more complex problem that arises when disconnection areas are also studied in combination with handover areas. We base our solution on an anticipated calculation of the RSSI values that can be used to discover when the MC will change of Area. A simple graph definition shows us in a simple way the different areas in which the MC can be and also the possible solutions using a simple protocol based on very simple primitives.

We plan to simulate this algorithm using a well known simulator. For example the speed of MC can be simulated in order to obtain accurately the limits of the buffers in MC and BS.

We have supposed a simple scenario in which terminals can experiment a gradual transition of coverage (no jumps). In real situations it is not the case. So a new extension of this work will be to contemplate complex situations in which the transitions between coverage states automaton could be any. The same study can be done for strong chaotic wireless channels in which although MC is static, it could experiment disconnections.

We also will study a more complex situations in which more than one AP overlap their coverage areas. We must define new kind of parts of area in which three or more AP overlap their coverage areas. Also the automaton must be extended to consider the new areas; this implies that the protocol also must be extended.

Finally a more complete study must be done in order to predict accurately the next state state and transitions.

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