Performance of WiMAX Networks using Horizontal Handover with Channel Reservation Mechanism

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Abstract—**Next generation networks will be characterized by variable and high data rates, QoS, and seamless mobility, within a network and between heterogeneous networks with different technologies and service providers. In this paper, we consider a model of mobility for WiMAX network users introducing horizontal handover mechanism with channel reservation. We take into account several approaches in order to carry out the reservation. We evaluate the performance of the proposed model. The results show, by means of simulation, that channel reservation mechanism improves horizontal handover without reducing the performance of the system.**

Keywords-WiMAX; Channel Reservation; Handover

I. Introduction

Recently, WiMAX networks have been receiving much attention because of the supported high data rate, the QoS capabilities and the wide coverage that enable ubiquitous connectivity. Seamless handover (HO) is one of the important issues in future generation networks. Defining an adapted handover procedure has to be tackled. Besides, we may improve the handover operation through a reservation mechanism. In fact, route reservation is a common topic in ad-hoc context [1] where there is high mobility of nodes. Therefore, next-generation networks will face several challenges such as seamless vertical handover, latency and also channel reservation for mobile nodes. Consequently, an early study of the behavior and the performance of channel reservation mechanism for horizontal HO may be also effective vertical HO between heterogeneous wireless networks. In this paper, we adapt channel reservation (CR) mechanism in WiMAX network and use it to improve horizontal handover. In fact, channel reservation may be carried out in several ways: by neighbor nodes (NNs) (cooperative approach), by the BSs (individual approach) or by both (mixed approach). Therefore, in this paper those three approaches are addressed. In a cooperative approach, we consider a cooperative scheme with CHANNEL RESERVATION performed by neighboring nodes to take into account the mobility. On the contrary, in an individual approach, channel reservation is carried out by WiMAX BSs. Then, we consider a third approach which unifies these two solutions. Finally, these approaches are compared in order to choose the best channel reservation policy.

II. Related work

Recent solutions were proposed to improve handover mechanisms in WiMAX networks. Authors in [2], present an enhanced link-layer handover algorithm where the serving Base Station (BS) forwards downstream data to the neighboring BS being ranged, therefore mobile stations (MS) can receive downstream data as soon as they become synchronized with the neighboring BS. But an obvious inefficiency of this scheme consists in its incapacity to reduce the handover latency in the upstream direction (from MS to BS), which is sensitive for some applications (e.g., Voice over IP). In [3] authors propose an algorithm to determine the best network to handover in an environment that may include IEEE 802.16 and IEEE 802.11 networks. Authors, in [4], suggest to use *Carrier-to-Interference plus Noise Ratio and Arrival Time Difference* to predict the "best" target BS. Therefore, this scheme prunes unnecessary interactions with neighboring BSs other than the target BS. This method is effective in reducing the number of required interactions. However, it also prevents the MS from acquiring more precise information which would normally be obtained from complete ranging and could be decisive for the final BS selection. An architecture for UMTS-WiMAX is proposed in [5] based on 3GPP standards. A seamless inter-system handover scheme is also proposed which enables the service continuity with low handover latency and packet loss. If the MS connects to multiple access points names, the handover preparation phase is more complex in such an architecture. Other authors [6] consider bandwidth reservation in WiMAX and WiFi networks. They proposed a policy-based threshold. The resource allocation is based on two thresholds corresponding to voice/data traffic. The designed policy improves the usage of combined WiFi-WiMAX network, therefore increasing the number of served users which will raise the operator's profits. Authors, in [7], are interested in seamless vertical handover; they introduce a new concept, the takeover, which enables a neighbor node to process requests from other mobile nodes. They developed a protocol and the operation for the takeover and apply it to vertical handover for next-generation heterogeneous networks. The proposed scheme reduces the average handover latency and so enables a fast and seamless vertical handover. A recent paper [8] proposed a new cooperative protocol in the context of IEEE 802.11b to combat radio signal degradation. Authors have shown how much the two cooperative protocols increase throughput, lower delivery latency, and extend transmission span, when compared to conventional IEEE 802.11 protocol. It thus may improve connectivity and network performance in ad-hoc applications.

III. System Description

Let us consider a WiMAX network with several cells. In some cases, a mesh mode may be assumed (all traffic does not need to go through the BS). Each BS covers a cell. The cell is divided into three zones according to the RSS (Received

Signal Strength) of mobile node (MN) (see figure 1) as follows: *A central zone* (CZ) where the RSS is above a threshold (T1). *A boundary zone* (BZ) (the zone which is near of the overlapping zone) when the RSS is above a threshold (T2) and lower than T1. *An overlapping zone* (OZ) is a zone when the RSS is lower than T2. In addition, we distinguish two types of users according to their locations. MNs are located anywhere else than in the overlapping zone. When a user is located in the overlapping zone, and consequently covered also through the target BS, he is called NN. To perform the channel reservation, we actually consider three different approaches.

A. Proposed Approaches

1) Cooperative Approach (CA): It may be called Ad-hoc mode (see figures 2 and 3). When the RSS of a MN remains lower than T1 and higher than T2 for a predefined duration (D), the MN, which is entering the boundary zone and moving into the target BS, starts the scan process to find a NN (it discuss that another node is NN by: its preset RSS and this NN is covered by only one BS. Indeed, NN is used to reserve a channel in the target BS. It is not then a relay through which the traffic is conveyed). This NN helps it to reserve a channel in the target BS. In the present work, we assume that a user needs one "channel" to communicate. It can be extended to the case where users need a given amount of resource to communicate. The NN asks the target BS for one channel for each MN user. If the target BS has available channels, an acceptance message will be sent from the target BS to NN and then to MN. Then, the target BS starts the handover preparation process for this MN. When it is achieved, the target BS sends a confirmation to the MN through the NN. It frees consequently the channel in the former BS and uses the reserved channel in the target BS. The previous channel can thus be reused by another MN. A simple case enables the target BS to manage its channels without distinguishing between channels reserved to channel reservation requests and channels reserved by a MN. All users are consequently managed in the same way.

2) Individual Approach (IA): This approach may be called infrastructure mode (figure 2). When the RSS of a MN remains lower than T1 and higher than T2 for a predefined duration (D), the MN sends a request to the attached BS. If this BS is not overloaded (load is lower than a threshold τ, in this paper, we consider τ=0.95), the current BS deals with the channel reservation in the target BS. The current BS thus contacts the target BS to reserve a channel. Let us consider in this approach that BSs are able to communicate by either a wireless way (WiMAX mesh mode) or by an infrastructure mode.

3) Mixed Approach (MA): This mode is based on the two previous approaches (see figure 2). The MN has two choices for reserving a channel. If the current BS is overloaded (individual approach (IA) may be not established), the MN starts checking the possibility to reserve with the help of a NN (cooperative approach (CA)). In fact, we found as a result that the order (CA before IA or IA before CA) has no impact on the performance results. The motivation of approach 1 and 3 is that if an obstacle prevents the MN to joint the target BS (causing a weak RSS for preset duration), in this case we can consider a both approaches as a solution of reservation. Moreover, these approaches can be developed so that a NN could be a relay through which data can be sent.

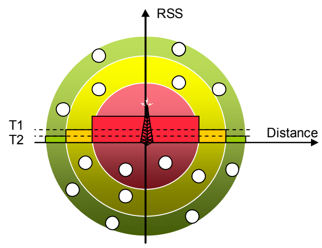

Figure 1: RSS in a WiMAX Cell

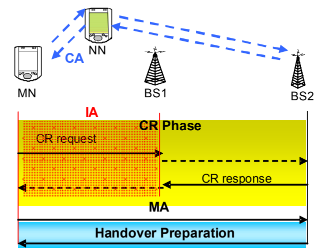

Figure 2: Exchanged messages

B. When do we initialize Handover or Channel Reservation?

1) Handover Conditions: Only the node located in the overlapping zone may initialize a handover. This means that when the RSS of a node passes under the preset threshold T2. The target BS also needs to have available bandwidth to deal with handover requests.

2) Channel Reservation Conditions: A MN, which enters the BUNDARY ZONE and which is still covered by an attached BS, can ask a NN or its attached BS, for a channel reservation. In other words, the MN has to find a NN (resp., its attached BS has not to be overloaded in IA). The target BS also has to have enough capacity to deal with channel reservation requests. With the cooperative approach, the user, either MN or NN, holds the reserved resources with his associated BS. However, NN (resp. MN) will be connected to MN (resp. NN) using different channels. Therefore, at a given instant, a MN (resp. NN) which is requesting (resp. serving) the channel reservation, may be connected to its BS and to the NN (resp. MN) simultaneously. We can consider later-on that in the case where there are several NNs, which can serve a MN request, the MN will choose the best NN according to predefined criteria. Other reservations for multi-service usage may be also considered later-on.

C. Channel Reservation and Worst Channel Reservation

We actually assumed that when a MN has a RSS included between T1 and T2 during the duration D, it is located in the BUNDARY ZONE. In this case we start the channel reservation process according the approach (CA, IA or MA). With respect to worst channel reservation (WCR, fully expanded in section IV.B), we distinguish two cases: in the first case, we assume that our system is equipped by GPS. In this case, we can know at each instant the position of a node and consequently cancel or not the reservation when the node changes its direction (when the node leaves the boundary zone and moves towards its attached BS). In the second case, there is no mean to know the node position. We define then the worst channel reservation as follows: we assume that if the MN has a RSS higher than T1 after the channel reservation process (its RSS has been included between T1 and T2 for a duration D), it is that this MN has changed its direction (it did not any more moves towards the target BS). Consequently, the channel request is freezed for a period of time W (W=3D) unless the mobile re-enters the BUNDARY ZONE. This means that we save (delay) the channel reservation request during a period (W).

IV. SIMILATION MODEL

A. *Definition of the Mobility Topology of Proposed Model*

We considered the network depicted in figure 3. A user can move into four directions (D1, D2, D3 and D4). Let us assume a WiMAX network composed of two square macro-cells (MaCs) with overlap. Each BS covers a macro-cell. Each macro-cell is composed of three main areas: a central zone where no handover can quickly occur and in this zone the RSS is high, an up boundary zone (UBZ), a down boundary zone (DBZ) where in these two zones the RSS is medium and the MN is covered through only one BS, and an overlapping zone where the RSS is low and the NN is covered through two BSs. To have consistent results in our model, we do not manage the RSS. However, in our model, the location of user and the direction are considered. For example, a user, located in the overlapping zone and that moves towards his target BS, will experiment a handover. Therefore, a user located in the boundary zones and that moves towards the target BS, can request for a channel reservation. Indeed, in the cooperative approach, we assume that the user, which wants to initialize a channel reservation, has the capacity to scan the neighboring nodes (NNs) in a coverage of five hundreds meters. In the simulation model, we consider that the user achieves a scanning process in the three boundaries micro-cells (MiCs) which are located in front of him and in both sides (cf. fig. 3). Respectively, in the individual approach, we consider that the current BS must not be overloaded (it is loaded less than 95%). Otherwise, channel reservation fails. In order to take into account the inter-BS handover (horizontal handover), we model the boundary zones. The boundary zone is covered by only one BS. However, the overlapping zone models the overlap between macro-cells. Each boundary zone and each overlapping zone has been divided in the model into square MiCs (a band composed of 20 or 8 MiCs). The motivation is that each MiC represents the surface of node scan. In addition, we assume that the MiC is square to simplify the mobility model. Therefore, the CZ in each MaC has been considered as only one big area. The motivation is that we are rather interested in the boundary zones than in the central zones.

The topology of such a system is modeled by a queuing system. The number of servers is equal to the number of BS channels (BS capacity) which are shared between all the users of macro-cell.

B. *Handover, Channel Reservation and Worst Channel Reservation Process*

In the adapted simulation model, we know the location and the direction of MNs. Channel reservation process is carried out in the boundary zones. We distinguish two cases according to the reservation policy: Channel reservation case: if the user has already reserved a channel, it will be freed and then the user transits to neighboring micro-cell. Worst channel reservation case: occurs when a user holds his reservation even if he changed his direction and does not move then into the target BS. The handover process is done in the overlapping zone. We discuss also the two cases: Channel reservation and worst channel reservation when we carry out the handover process.

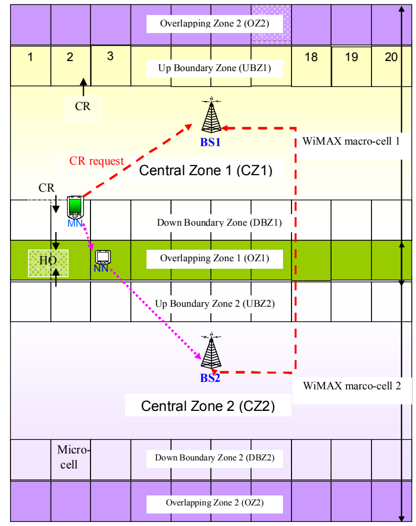

Figure 3: Adapted topology

C. *Proposed Model Parameters*

Let us detail the simulation parameters: The BS capacity (C) varies from C=5 to 45 channels. The simulation time is 10^{+6}sec. The following table shows the considered parameters:

TABLE I. MODEL PARAMETERS

	Case 1	*Case 2*
MaC dimensions (km^2)	10x10	4x4
CZ dimension (km^2)	10x8	4x2
Number of MiCs in the BZs	20	8
Speed of mobile (km/h)	36	36
Tcz (sec)	900	300

Where, T_{CZ} is the average time to cross the CZ. In the other hand, we assumed that call duration is exponentially distributed. Finally, the arrival rates are variable in order to vary the normalized load from 60% to 100%.

V. PERFORMANCE ANALYSIS

We first present the performance of a system with classical handover procedure and then handover with channel reservation mechanism. In fact, we consider the following performance criteria: *New Calls Blocking Rate (NCBR)* is the rate of new calls (users) rejected per unit of time, *Handover Blocking Rate (HOBR), Channel Reservation Blocking Rate (CRBR).* We study the two cases: Channel reservation and worst channel reservation. Instead of studying the blocking rates, we would also consider the channel utilisation rate (channel occupancy).

A. *Handover and Channel Reservation Mechanism*

We will present the results for case 1 when C=15 channels per BS. As shown in figure 4, *New Call Blocking Rate*

(NCBR) increases as a function of the input load (Erlang). It is the same case for *HO Blocking Rate (HOBR*). Handover individual approach (HOBR-CA) does not increase the HOBR. In figure 5, we compare HO without channel reservation and the one of cooperative approach *(HOBR-CA),* we notice that the cooperative approach improves slightly the *HOBR* and reduces *NCBR.*

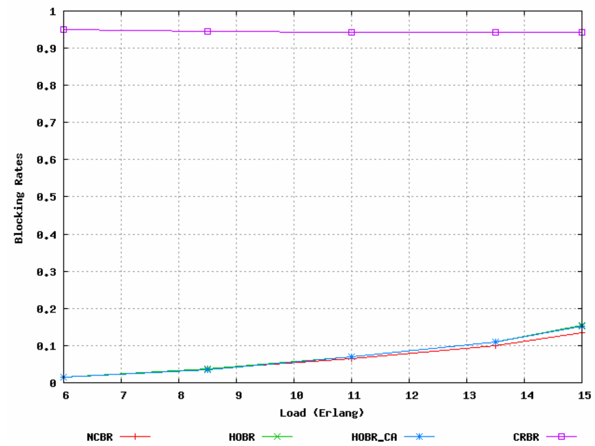

Figure 4: Blocking Rates in cooperative approach

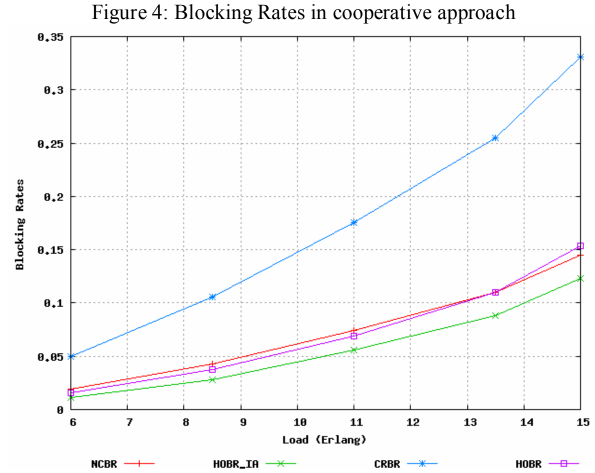

Figure 5: Blocking Rates in individual approach

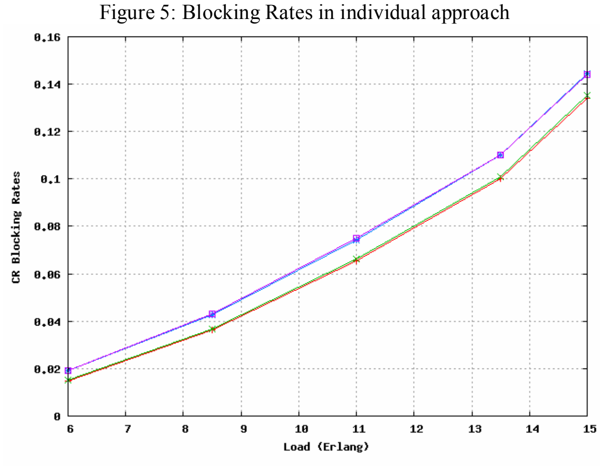

Figure 6: New Calls Blocking Rates

Besides, the *CRBR* in the cooperative approach (figure 4) is interesting and nearly constant. It is due to the fact that MNs do not find a neighboring node (the density of NNs is not satisfactory). In fact, in case 2 if we fix the arrival rate of users (this means we increase the density of users and reduce the dimensions of MaCs), we notice that the cooperative approach becomes efficient. Consequently, the cooperative approach is mainly based on the density of users as this approach takes into account the NNs to carry out reservations. Anyway, the channel reservation mechanism proposed in the cooperative approach does not degrade the performance of the system. In the other hand, we observe in figure 4 that the individual approach reduces clearly the HOBR and leads to a CRBR lower than the one of the cooperative approach. Indeed, the third approach nearly leads to the same results as the one obtained in the individual approach since the cooperative approach with these parameters is not efficient. Actually the channel reservation mechanism leads to good results when we have few channels. Consequently, the reservation mechanism may be more useful when the system is congested.

B. *Comparison*:

We compare then the three approaches. Actually, we notice the following differences: Channel reservation mechanism does not increase clearly new calls blocking rate (figure 6) compared to handover without channel reservation and in the three approaches. Indeed, the cooperative approach leads to the best results with respect to the NCBR as it is not efficient at low density. Besides, in the case of the last two approaches, this increase is weak. In fact, when we apply a channel reservation mechanism this means that we only reserve early a channel.

In the other hand, the channel reservation mechanism reduces handover blocking rate especially in the last two approaches (figure 7). Moreover, the individual approach minimizes the HOBR. Therefore, the cooperative approach leads to the worst HOBR. But this rate is not so far from to the one without reservation. With respect to the CRBR, the third approach clarifies the minimum rate (see figure 8). The cooperative approach leads again to the worst CRBR. Let us now observe the results in the case of worst channel reservation. Actually, the cooperative approach shows the lower NCBR (as well as in the case of channel reservation).

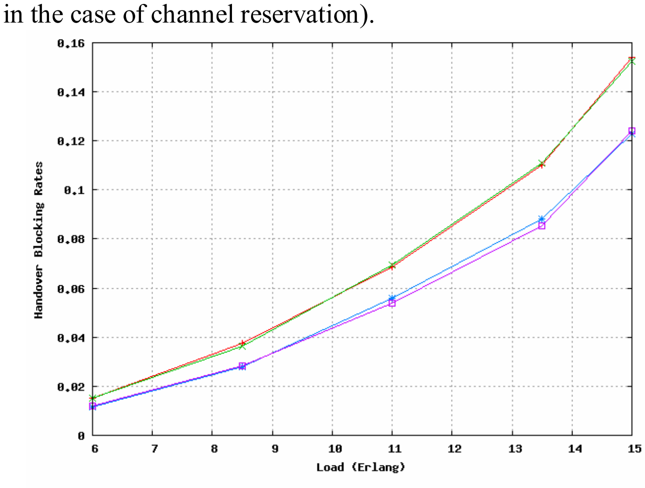

Figure 7: Handover Blocking Rates

Therefore, the individual approach shows the worst rate. Indeed, the cooperative approach points out the minimum

HOBR, therefore, the individual approach leads to the worst results. With respect to the CRBR, the individual approach is the best solution. However, the cooperative approach leads to the worst rate. Moreover, we noticed that the worst channel reservation shows the worst results. This is due to the fact that there are not enough available channels in the target BS to serve channel reservation or handover requests as a user can keep his reservation even if he changes his direction towards the target BS and perhaps for a long duration. Of course, this will later-on causes the reduction of available channels and increases the number of reserved channels at a given instant. In this context, the third approach is the best with respect to the CRBR and the worst approach is the first where the CRBR is nearly constant with the load. It is due to the fact that, with respect to these parameters, the MN can not find a NN to help it to carry out the channel reservation.

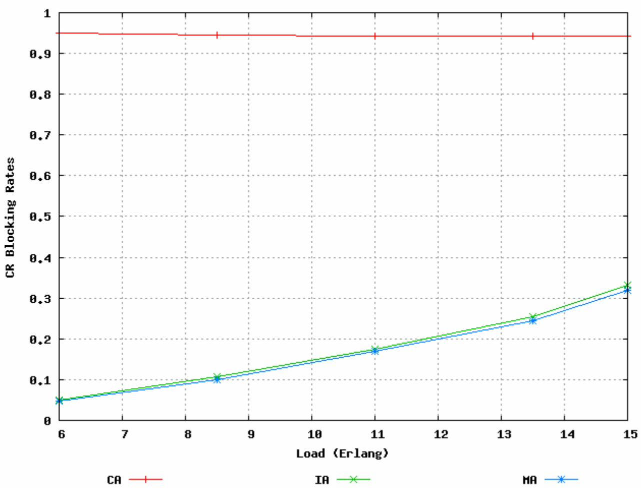

Figure 8: Channel Reservation Blocking Rates

Finally, in figure 9, we present the handover blocking rates as a function of the BS capacity. We notice that the rates decrease when the BS capacity increases. In the other hand, we observe that the cooperative approach is efficient at a high density of users (8 MiCs case). The efficiency of the channel reservation mechanism is clear when the capacity is low (5 and 15 channels). In general, the results obtained with the individual approach are clearly near to those of the third approach. This is due to the fact that in these two approaches, there is a BS as an intermediary means to carry out the channel reservation. Therefore, the cooperative approach depends on NNs. As result of our paper, we may say that the performance is better when the mechanism is based on the BSs to reserve a channel rather than when it depends on NNs when the density of users is low.

VI. Conclusion

In this paper, we evaluated channel reservation mechanisms to improve the WiMAX horizontal handover. It is shown that the channel reservation mechanism reduces clearly the handover blocking rate and it does not degrade the performance of the system. Therefore, the worst channel reservation mechanism degrades all the performance criteria. Indeed, we compared between three approaches. It has been shown that when there is a light density of users the best performance results are obtained when the reservation is achieved by a BS rather than when MNs send their requests through a NN. Moreover, the efficiency of channel reservation mechanism is considerable when there are a low number of channels. Besides, the cooperative approach indicates good results when the density of users increases. This density is related to the system dimensions. Perspective works deal with the interconnection between a WiMAX network and a satellite system with and without channel reservation. We will focus on overhead signalling, delay and power consumption. The idea of NN may be also later-on considered in a VANET context.

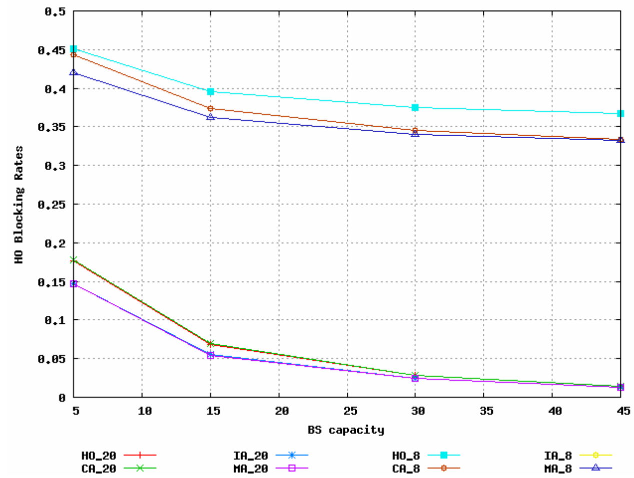

Figure 9: HO Blocking Rates as a function of the BS Capacity

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