Performance of WiMAX Networks Integrated in a Segment of Satellite using Channel Reservation Mechanism

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Abstract— **Mobility issue and service continuity represent important challenges for next generation networks. The integration of a satellite segment within a terrestrial network (especially WiMAX) has several advantages in a 4G context. In this paper, we focus on channel reservation mechanisms to ensure quality of service. Primary results show, by means of simulation, the gains and limitations of each mechanism. It is shown that the best results are obtained when the mechanisms are performed by the base stations when the density of users is low. Otherwise, cooperative solutions for which reservations are done by neighboring nodes may improve the performance of the system.**

Keywords-WiMAX, DVB-RCS, Integration, Channel Reservation, Handover, 4G.

I. INTRODUCTION

The integration between terrestrial networks and satellite system may improve service continuity of 4G networks. In [1], authors proposed an architecture for the integration between WiMAX and satellite networks (WiMAX/DVB-RCS). The defined architecture takes into account the MIH (Media Independent Handover) reference model proposed by IEEE 802.21 as integration between a satellite system and terrestrial networks. Two scenarios with a WiMAX/DVB-RCS procedure have been considered. Another architecture of such an integration has also been proposed in [2]. Authors mainly focused on architectural solutions. Moreover, performance of such an integration has also to be carefully evaluated.

In this paper, a model of a WiMAX network integrated in a satellite system is considered. A channel reservation mechanism is implemented in WiMAX network, using three approaches: cooperative, individual and mixed. In addition, we take into account two different mechanisms in order to carry out the down handover (from the satellite system to the WiMAX network). In the first mechanism, the initialization of up handover and down handover is achieved by WiMAX users located in the overlapping zone. In the second mechanism, the network triggers the down handover once there is available resource in WiMAX BS. Consequently, several cases are distinguished and discussed.

II. RELATED WORK

In next-generation context networks, recent researches in [3] propose a new architecture capable of supporting *Always Best Connection* (ABC) service. This architecture, called open wireless architecture, takes into account various radio access technologies, as a 4G mobile system. Authors considered three parts in proposed architecture. A new access discovery mechanism integrates service location protocol and location-based service. A new personalized network selection scheme is proposed. Users can select their personalized "best" network by changing weight factors and constraints in a single objective optimization problem. Finally, a seamless handover mechanism based on Mobile IPv6 has been chosen. This mechanism supports end-to-end quality of service. Through analysis, authors found that this architecture is efficient not only for network operators, but also for users.

In a satellite context, authors in [4] propose and evaluate a handover scheme tailored for LEO satellite systems called: *Dynamic Time-based Channel Reservation.* The proposed algorithm capitalizes on the deterministic topology of this type of system in order to increase channel utilization and reduce both blocking and forced termination probabilities.

However, our aim in this paper is to evaluate the performance of integration between terrestrial network and satellite system.

In terrestrial networks and satellite system convergence context, the integration between the terrestrial network and the satellite system has been proposed in the literature. Authors in [5] proposed a signaling protocol for inter-segment handover (ISHO) in an integrated space/terrestrial-UMTS environment. Simulation results show that, the service interruption time is independent of the signaling protocol and depends only on the satellite round-trip delay and radio interface characteristics.

Other studies have been carried out to develop and evaluate the performance of the ISHO. In [6], authors have shown that the execution delay is in general quite long, especially if high altitude constellations are used. But these works did not address the mobility issues in their proposed system.

III. SYSTEM DESCRIPTION

Let us consider several WiMAX cells covered by a geostationary satellite. Each WiMAX BS covers a cell. WiMAX cells are divided into three zones according to the

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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 close to the overlapping zone) where the RSS is higher than a threshold (T2) and lower than T1. *An overlapping zone* (OZ) where 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 (Neighbor Node).

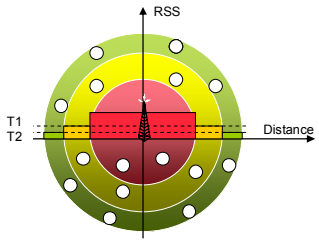

Figure 1: RSS Representation in a WiMAX Cell

The aim of channel reservation (CR) mechanism is to reserve early a channel in the target base station (BS) of a user located in the boundary zones and is moving into his target BS. This reservation may guarantee the horizontal handover (HHO) and improve the performance of the whole system. To perform the channel reservation, we actually consider three different approaches (see figure 2):

1) Cooperative Approach (CA): When the RSS of a MN remains between T1 and T2 for a predefined duration (D), the MN, which is entering the boundary zone and moving towards the target BS, starts the scan process to find a NN so that this NN helps it to reserve a channel in the target WiMAX BS.

2) Individual Approach (IA): When the RSS remains between T1 and T2 for a predefined duration (D), the MN requests its BS for a channel. If this BS is not overloaded, the current BS deals with the channel reservation in the target BS. The current BS thus contacts the target BS to reserve a channel.

3) Mixed Approach (MA): This mode is based on the two previous approaches. The MN has two choices to reserve a channel. In fact, we found as a result that the order (CA before IA or IA before CA) has no impact on the performance results.

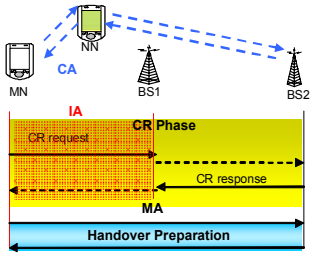

Figure 2: Exchanged messages in the proposed approaches

IV. User and Network Operation

The user starts the horizontal handover in the overlapping zone. If the target BS has a free channel, the user achieves the horizontal handover. Else, he tries a vertical handover (VHO) to join the satellite system. Let us call this process an up handover. Actually, we distinguish two mechanisms: In the first one, the user makes the up handover or down handover (a satellite user - a user which is connecting to the satellite system - switches to the WiMAX network) only in the overlapping zone and he initializes up handover and down handover processes. This mechanism is called user mechanism. In the second mechanism, the user deals with up handover and down handover in the overlapping zone and the network is able to switch a satellite user (any where the user is located) when a WiMAX user leaves the network (close the connection in the WiMAX network). In fact, this mechanism is applied locally, this means that the network looks for a satellite user located in the same zone (to move it to the WiMAX network) when one of the WiMAX users has terminated his connection. Actually, we tried to extend this process in order to find a user among all the zones of the WiMAX cell, but this did not clearly improve the results. Consequently, we consider this local solution as a satisfactory solution. In the other hand, we tried to extend our solution so that the user, which is connected to the satellite, checks, each time he changes his zone (in the WiMAX cell), if it is possible to move to the WiMAX network (do a down handover). But this approach did not lead to interesting results.

In addition, we consider two scenarios: in the first one, we consider a constant data rate: users will receive data at the same rate if they are connected either to the WiMAX network or to the satellite system. In the second scenario, we consider an adaptive data rate (ADR). The data rate of users in the satellite system is divided by a factor *k*.

V. System Evaluation

A. Definition of the Proposed Model

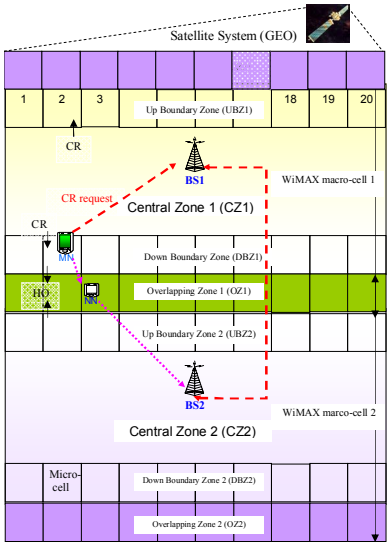

Figure 3: Adapted topology

We consider that a user can move into four directions. Let us assume a WiMAX network composed of two macro-cells

(MaCs) with overlap (figure 3). Each BS represents a macro-cell. Each macro-cell is composed of three main areas: a central zone where no horizontal handover can quickly occur, an up boundary zone (UBZ), a down boundary zone (DBZ), and an overlapping zone.

In order to take into account the channel reservation we model precisely the boundary zones. The boundary zone is the zone close to the overlapping zone and 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 into eight or twenty square micro-cells (MiCs). However, the central zone in each macro-cell has been considered as only one simple large area. The motivation is that we are rather interested in the boundary zones and the overlapping zones than in the central zones. Finally, the WiMAX network is covered by the geostationary satellite system (GEO).

VI. Performance Analysis

To evaluate the performance of the proposed model, we consider the following criteria: New Calls Blocking Rate (NCBR) and Handovers Blocking Rates (HOBR) in the WiMAX network and in the satellite system. Horizontal Handover Blocking Rate (HHOBR), up handover Blocking Rate (up HOBR), down Handover Blocking Rate (DHOBR) and Channel Reservation Blocking Rate (CRBR). The Numbers of handovers were studied: Numbers of accepted horizontal handover (NBHHO), of up handover (NB up HO), of down handover (NBDHO) and of channel reservation (NBCR). We also studied the number of attempts of horizontal handover attempts, of up handover, of down handover and of channel reservation.

Several scenarios are distinguished. Each BS has 45 channels. In the following figures, WiMAX stands for blocking rates in the case of pure WiMAX network. Net (resp. user) refers to the blocking rate in the case where we take into account the network mechanism (resp. the user mechanism). ADR means that the adaptive rate mechanism is activated ($k=4$). CA, IA or MA corresponds to the utilization of the three adopted approaches. Finally, channel reservation corresponds to the case taking into account the channel reservation mechanism.

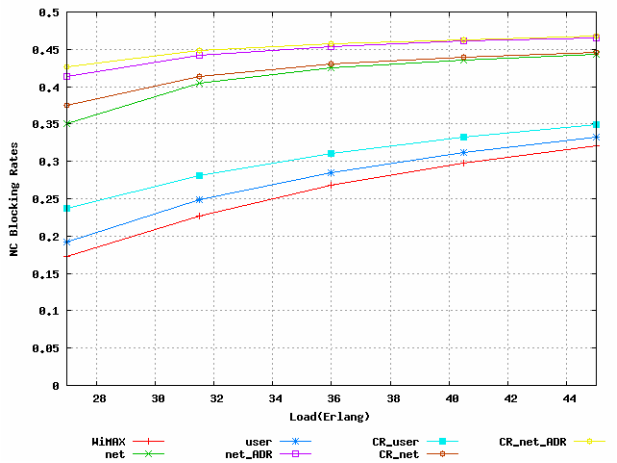

Figure 4: NCBR in the pure WiMax

A *New Calls Blocking Rate in the pure WiMAX*

In order to avoid the complexity of figures, let us represent the main curves.

In figure 4, it is shown that the new calls blocking rates in the WiMAX network is higher when we integrate the WiMAX network in a satellite system. This is due to the fact that the satellite system decreases the load of WiMAX network (increase the capacity of system to accept more new calls which are switched later-on to the WiMAX network). This increase is higher in the case of network mechanism (net) rather than with the user mechanism (user). Because with the network mechanism, the network switches many satellite users to the WiMAX network.

It is also shown that ADR increases the blocking rate mainly in the net-ADR since satellite users remain longer in the system. However, when we apply the channel reservation mechanism, we observe that the (net) case shows the higher blocking rate both because of the lack of channel availability and of the effect of the network mechanism. Consequently, the CR-net-ADR leads to the maximum new call blocking rate.

B *New Calls Blocking Rate in the Satellite system*

First, we notice that the new call blocking rate in the satellite system is lower than the one of the WiMAX system because in our model we gave the priority to new calls to join the WiMAX network rather than the satellite system. We observe in figure (5), in the case of the network mechanism especially with channel reservation (net_CR) that the system is overloaded. Indeed, the new calls blocking rate in the satellite system is considerable. In addition, the channel reservation mechanism does not increase the blocking rate since this mechanism is only applied at WiMAX network level. Therefore, in the case of user mechanism with ADR, we notice that the blocking rate is lower than with the network mechanism with ADR and also lower than with the user mechanism. It is due to the fact that there is not a lot of up handover requests in this case (the up handover requests are only in the overlapping zone).

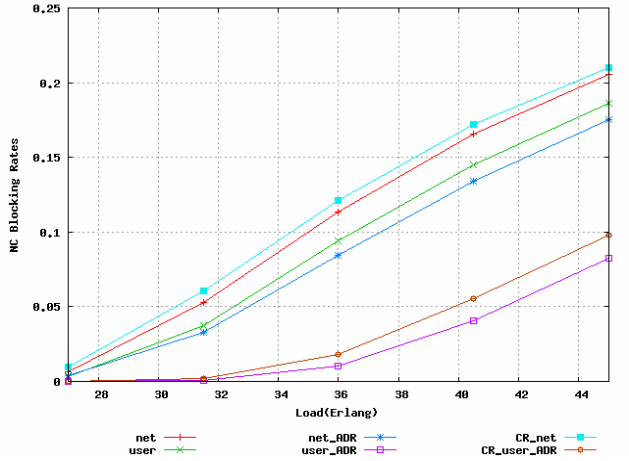

Figure 5: New Calls Blocking Rate in the Satellite System

C *Horizontal Handover Blocking Rate*

As shown in figure 6, the horizontal handover blocking rate is considerable in the case of the network mechanism as the network mechanism switches more satellite users to WiMAX network. In addition, the channel reservation mechanism, based on the cooperative approach especially with the user mechanism, decreases the horizontal handover blocking rate in the two cases: fixed and ADR. This result has been obtained when 4x4 km^2 macro-cells are considered. For larger macro-cells (10x10 km^2), the density of users is low and thus the individual approach leads to the better results.

In the other hand, when the ADR is taken into account and *k* varies from 0.25 to 4, it is shown that the blocking rate increases especially with the network mechanism. When the packet delay is high, it will increase the blocking rate as the user remains longer in the system. Consequently, it is better for the user to be connected to terrestrial network.

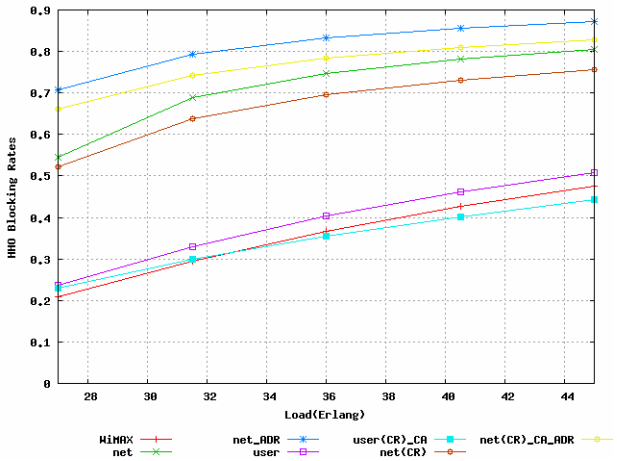

Figure 6: HHO Blocking Rate

D *Up Handover Blocking Rate*

We notice in figure 7 that the up handover blocking rate in the case of network mechanism is low. This is due to the fact that the network mechanism switches the satellite users to WiMAX network and consequently it frees channels to accept new users. Indeed, ADR also decreases the blocking rate. This increases the connection duration of satellite users and thus decreases the up handover requests.

E *Channel Reservation Blocking Rate*

In the case of user mechanism, as shown in figure 8, the channel reservation blocking rate depending on the IA is much lower than the one depending on the CA. In this last case, the CRBR in the pure WiMAX network is very similar to the one when we get the WiMAX network is integrated in a satellite system. That means that the channel reservation does not affect the WiMAX/Satellite system (when we use the user mechanism). The ADR has no influence.

On the contrary, with the network mechanism, there is a considerable and constant blocking rate of channel reservation when we carry out the channel reservation based on individual approach (on the cooperative approach in the case of 10x10 km^2). This is due to the fact that the MN, which needs to perform the horizontal handover procedure, does not find free channel to reserve in the WiMAX BS. Otherwise, there are enough neighboring users to help him to perform this reservation.

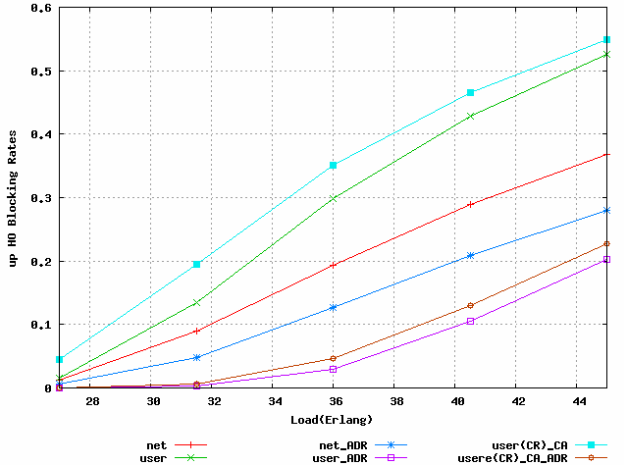

Figure 7: Up Handover Blocking Rate

With respect to the ADR, the CA without ADR (using network mechanism) is better than in the case with ADR. Otherwise, the ADR does not affect the results when we use the IA with the network mechanism.

To summarize, when we use the user mechanism, the blocking rate is lower than the one of the network mechanism.

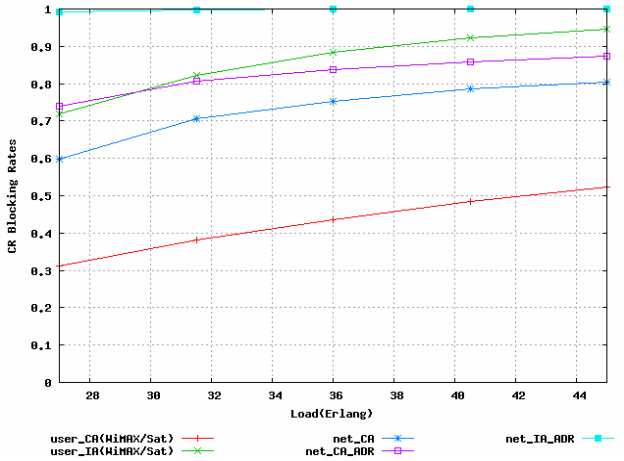

Figure 8: Channel Reservation Blocking Rate

F *Number of different Handovers and Channel Reservation*

- Number of horizontal handover

This number decreases as a function of the load since the new calls blocking rate increases. The number of horizontal handover is more interesting in the case of the network mechanism especially with ADR because the system reaches quickly its saturation and it has more new calls blocking.

- Number of up handover

This number increases as a function of the load in the case of the network mechanism where system is overloaded. Therefore this number decreases in the case of user network.

- Number of down handover

This number is low in the case of user mechanism (see figure 9) as we only switch satellite users in the overlapping zone. However, it is important in the case of network mechanism. With respect to the network mechanism with ADR, the number of down handover is low as the satellite users remain longer in the system and consequently the number of down handover becomes low. When we take into account the channel reservation mechanism in the case of network mechanism, the number of down handover is considerable.

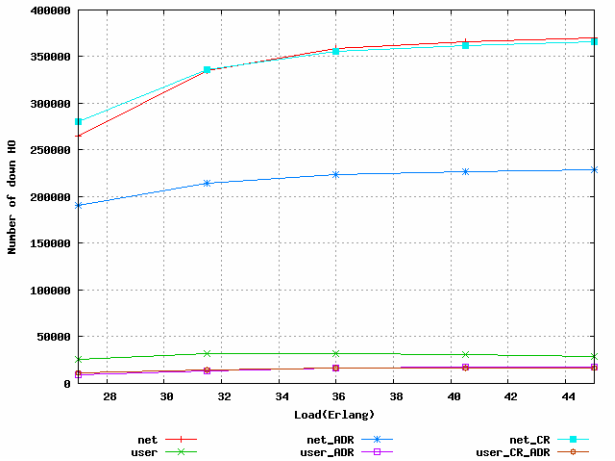

Figure 9: Number of down handover

- Number of channel reservation

This number is more interesting in the case of the cooperative approach (figure 10) especially in the case of the user mechanism (with CA) as in the case where there are enough NNs to carry out the channel reservation. In the network mechanism, the number of channel reservation is low. With respect to the ADR, the number of channel reservation becomes slightly low as the system is overloaded and then it accepts less new calls.

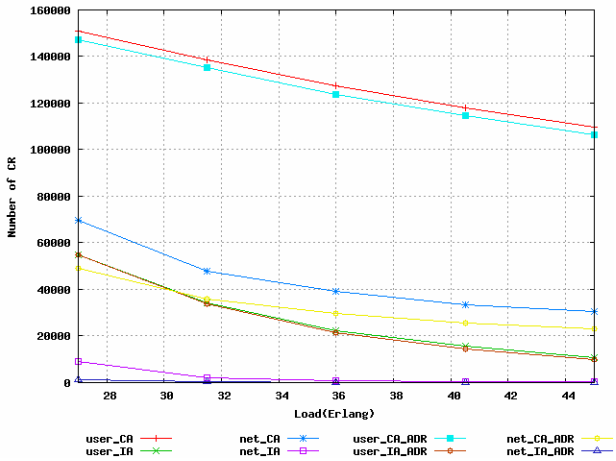

Figure 10: Number of channel reservation

- Number of HO and CR Attempts

The curves of the attempts of different handover and channel reservation are in general similar to those of the number of handovers. This means that the attempts are more important when the system is overloaded. The solutions can be classified in the following order: network mechanism with ADR, without ADR and then user mechanism. When the system is overload (especially WiMAX network), the attempts of handover or channel reservation requests are higher (figure 11). Consequently, when we apply the network mechanism, we are faced to signaling issues.

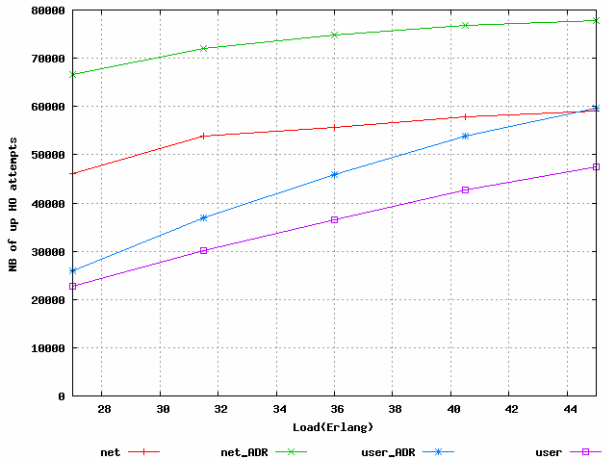

Figure 11: Up HO Attempts

VII. Conclusion

We adopted a model of interconnection of a WiMAX network and a satellite system as a definition of 4G. The results show that the channel reservation mechanism does not degrade the performance of 4G system and improves it in some cases. Reservation mechanism can be carried out and be improved depending on cooperative or individual approach according to the dimension of the cells (density of users). Moreover, the network mechanism lightly increases the load of the system but this mechanism allows the users to benefit from the characteristics of WiMAX network. Prospective works aim to improve the performance of system by considering with the optimization of resource reservation according to both the available channels taking into account users with dynamic resources.

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