A Game Theoretic based Call Admission Control Scheme for Competing WiMAX Networks

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Abstract

Call Admission Control (CAC) is one of the most important parts in Radio Resource Management of the wireless networks and it has a huge impact on the quality of service (QoS). Traditional CAC strategies focus on increasing the radio resource utility by decreasing the service blocking probabilities. In this paper, a new CAC scheme based on game theory is introduced to analyze the conflicts and rewards for different network operators. The game theoretic based CAC scheme contains two parts, utility function computation and a non-cooperative game between two networks to maximize their rewards. The proposed framework is preliminary and its objective is investigate the possibility that networks should be able to autonomously define policies for different parts of a coverage area depending on the priority of users and their requirements. In this approach, the two simulated WiMAX networks compete with each other for traffic units in overlapping coverage area and maximize their rewards. The proposed scheme is illustrated with the help of an example in which most of the traffic units lie close to one network as compared to the other network. Future work will present results of simulation studies for more detailed experiments.

Keywords

Game theory, Call admission control, WiMAX, Cooperative control, smart antenna

I. INTRODUCTION

Cellular systems have experienced exponential growth over the last decade and the demand for effective and careful resource allocation is greatly needed. To management of different QoS (Quality of Service) requirements, provide sufficient bandwidth and tolerable delays, and to guarantee a users' service satisfaction, the CAC policies for cellular-system need to consider not only the technical efficiency but also the trade off between this and a network provider's profits [9].

Game theory is a branch of mathematics that provides a suite of analytical tools to analyze the interactions of parties with conflicting interests. Each player has independent decision rights only over its own possible actions, which are confined to its strategy space. Each player's strategy has impact not only on its own payoff, but also on other players' payoffs. For games of pure strategy, which restricts each player to a choice of one strategy or the other, the game may have zero, one, or more Nash equilibriums. Detailed discussions about game theory can be found in [1].

Game theory concepts have been applied to wireless networks on formulations for optimization purposes, namely, in flow and congestion control, network routing, load balancing, resource allocation and quality of service provisioning. Mc Nair and Zhu [2] outlined the decision metrics and decision policy design in the context of vertical handoff for a mobile user running multiple communication sessions. These metrics are also relevant for initial network selection for a mobile user. In [3] and [4] researchers have studied CDMA cellular networks focusing on power control algorithm where Nash equilibrium is used to determine the transmission power of each mobile user. The mobile users compete for the best signal-to-interference ratio, which determines their transmission quality. In [5], various service classes were considered to be players of the game and Nash equilibrium is used to determine the amount of bandwidth offered to a new connection with payoffs calculated as a function of perceived delay and throughput performance. In [6] the formulated game uses service providers as players, each with strategies in terms of amount of offered bandwidth. The Nash equilibrium is then used to maximize the service providers' profits while satisfying the mobile users. In [7] and [8] the considered games are the interactions between the service providers and the mobile users. In [7], a game theoretic framework was developed to analyze the service provider's pricing strategies to attract mobile users, who have the right to decide at a given price whether the connection should be continued or not. In [8], the game was formulated to capture the competitive interactions between the service provider and the mobile users where the service provider can decide whether to admit or reject the mobile users' connection request and the mobile users seeking admission can decide whether to stay with the current provider or to leave.

In [10] H.J.Wang et al. describe a handover policy for heterogeneous wireless networks, which is used to select the best available network and time for handover initiation. The cost of each network is measured in terms of weighted sum of bandwidth, power consumption and cost. The network with lowest cost is selected as the target network.

In [11] Le Bodic et al. look at networks with an auction base pricing scheme and employ two strategies depending on user preference for lower cost and reputation respectively.

Many new pricing schemes are being proposed for RANs [12], the majority focus on network-centric benefit. In [13] Gazis et al. look at the complexity of being "Always Best Connected". The focus is on user-centric benefit. The research involves identifying the network or combination of access networks from the available candidates that will best satisfy the current user requirements in their current circumstance.

The concept of dynamic network selection, in which a user can choose or take active part in the selection of the best available network to serve a connection request and not be fixed to one particular network, is continuing to evolve. Hence, the network selection mechanism in WiMAX networks handles the selection of the best network to satisfy a connection request.

This paper proposes to model this decision using a game theoretic based CAC scheme, which effectively meets all operational requirements of IEEE 802.16e WiMAX standard. The CAC scheme is formulated as a game between two networks competing in non-cooperative manner as an optimization problem under a certain objective function, which should be chosen to maximize their reward. The outcome of the game is to decide which set of strategies should be selected independently by each network to maximize their reward.

In this paper the network operator has some control over the coverage pattern. Cooperative shaping was initially developed in [15-16]. The concept is that the radiation pattern of adjoining cells should dynamically change shape in coordinated manner to ensure communication is provided where it is needed while removing communication gaps within the coverage.

The approach here assumes some control over the coverage patterns of the cell. The load balancing algorithm assumed is an extension of [14]. The frontier of each cell is defined by maximum outreach of a beam. A base station can only serve the traffic units within the frontier. For convenience, the area within the frontier is divided into locations using polar coordinates. Each location can contain many registered and connected traffic units.

The rest of the paper is outlined as follows: in Section II, the game theoretic based CAC scheme is described. In Section III, we describe the Mobile WiMAX simulator for the scenario where networks are competing with each other. In Section IV, the performance of game theoretic based CAC scheme is evaluated with the help of an example. Finally, Section V concludes the paper.

II. PROPOSED GAME THEORETIC BASED CAC SCHEME

Two competing networks are assumed, and they are referred to as network 1 and network 2. The reward to a network '1' for selecting a particular traffic unit at a certain time is a function of several parameters, including the bandwidth asked for and the cost it can charge the user. For simplicity here, all traffic units are assumed to be assigned the same user grade i.e. each traffic unit require same amount of bandwidth. This means that the bandwidth will have no specific influence on the reward function.

Let p_i^1 and q_i^2 be the prices that network 1 and network 2 can charge respectively. The expected reward to network 1 is made up of (broadly) two parts

i. The utility U_i to be gained *if* the customer awards operator '1' the connection at the price p_i (corresponding to the row in table 1). The utility will go up in as we charge a higher price, and is the same for all columns, i.e. offered prices for operator 2 , as it does not depend on the price operator '2' is offering. If the customer does not award the connection the utility is assumed to be zero.

ii. The probability P[i, j] that the customer will select operator '1' at the price p_i when operator '2' chooses price q_j. The probability P[i, j] will decrease as the row number increases as this corresponds to a higher price from operator '1' and will go up as the column number increases as this corresponds to a higher price from operator '2'.

The reward for operator '1' is given as follows:

$$r_{ij}^1 = U_i \times P[i, j] \qquad \textbf{(1)}$$

The corresponding reward for operator '2' in this cell can be as follows.

$$r_{ij}^2 = U_j \times (1 - P[i, j]) \qquad \textbf{(2)}$$

The probability of selection is based on a user behaviour model. In this case a very simple model is used. The user simply chooses the network offering the lowest price then, i.e.

if $p_i<q_j$ then P[i,j]=1

if $p_i=q_j$ then P[i,j]=0.5

if $p_i > q_j$ then $P[i,j]=0$

The utility in fact depends on the location of the mobile unit as the resource required depends on the location. The dependency on location is modeled in a simple way to test the concept. The utility function must depend on the spare capacity and the price. For example, if the network is idle and the user is near the BS then all the p_i may be regarded as profit.

If we define W_i as a number between 0 and 1 such that it is '1' if the user is near the BS and the cell is idle and '0' when the customer is far from the base station and the cell is very busy. In this case the utility function for Operator 1 and operator 2

$$U_i = W_i \times p_i \qquad \textbf{(3)}$$

$$U_j = W_j \times q_j \qquad \textbf{(4)}$$

So the reward for operator 1 r_{ij}^1 in cell (i, j) from (1) can be modified as shown in (5),

$$r_{ij}^1 = W_i \times p_i \times P[i,j] \qquad \textbf{(5)}$$

So the reward for operator 2 r_{ij}^2 in cell (i, j) from (2) can be modified as shown in (6),

$$r_{ij}^2 = W_i \times q_i \times (1 - P[i,j]) \qquad \textbf{(6)}$$

In the simulation the modified utility value decreases with the distance from the base station.

$$W_i = 1 - \alpha(d - 0.2) \qquad \textbf{(7)}$$

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W is defined for each network to serve the minimum distance between the traffic unit and the base station can be 0.2 km whereas the maximum distance can be 1.5km. From network perspective, the less transmitting power will be needed to serve a traffic unit at d=0.2km as compared to traffic unit at d=1.5km. α is chosen so that W ranges from '1' at d=0.2 km to '0' at d=1.5km. However in the situation where geographic load balancing is considered, it is possible to configure the antenna propagation so that the network operator can affect the value of W. The details of how this can be done are not described here, but are described in [14].

Initially for every new connection request, the network rewards will be calculated from equations (5) and (6).
Then for every price we get the success probabilities of these strategies to get the reward for each network and at last we attain the Nash equilibrium point by using these rewards as payoffs of the game. For network '1' the prices are p_1, p_2, p_3 and for network '2' they are q_j, q_2, q_3. Each cell has two numbers, the reward for network '1' and the reward for the network '2'. For a price 'p_i' and 'q_j' the corresponding rewards for each network is calculated and filled in the corresponding cell of Table I.

Table I: Rewards for the networks at corresponding offered prices

Network-2 Network-1	q_1	q_2	q_3
p_i	r_{11}^1, r_{11}^2	r_{12}^1, r_{12}^2	r_{13}^1, r_{13}^2
p_2	r_{21}^1, r_{21}^2	r_{22}^1, r_{22}^2	r_{23}^1, r_{23}^2
p_3	r_{31}^1, r_{31}^2	r_{32}^1, r_{32}^2	r_{33}^1, r_{33}^2

Consider a game of two networks which has a finite number of pure strategies. Let us denote the strategy sets of respective networks by $P_1 = \{p_1, p_2, p_3\}$ and $P_2 = \{q_1, q_2, q_3\}$. The outcome associated with (p_i, q_i) is denoted by r_{ij}^1, r_{ij}^2 In non-cooperative game, no preplay communication is permitted between the networks.

III. THE SIMULATION MODEL

In order to test the performance of the game theory based CAC scheme where the objective is to maximize the revenue for network operators a simulation test was performed. A comprehensive system level WiMAX network simulator [15] has been extended to two WiMAX networks including same features such as power control and soft handover. In this simulator, the WiMAX networks are based on IEEE 802.16e standard with traditional hexagonal cellular model used as the underlying framework.

Simulations are based on two 6×6 cellular WiMAX networks where cells have the same area. All BSs are in the centre of the belonging cell and each has six sectors. Each BS has a maximum service capacity. There are 18000 MSs within the 72 cell area i.e. 36 base stations for each network. The arrival rate and holding time make sure that total number of talking subscribers does not exceed the total system's maximum service capacity.

In the experiments, all 18000 MSs are uniformly distributed over the area of the network. The simulators work by processing events in a sequence of snapshots in a pre-prepared scenario. Each snapshot is 60 seconds long. At each snapshot, uplink and downlink power control and uplink and downlink revenue based CAC are performed for each event. The MS can only be admitted to a cell if it passes both uplink and downlink game theoretic based

CAC scheme. The main simulation parameters are listed in Table II:

Table II: Simulation parameters

Parameter Name	*Symbol*	*Value*
Cell radius	r	1km
Circular radius	R	1.05km
Forbid distance	d_{forbid}	0.02km
Minimum distance	d_{min}	0.1km
Maximum distance	d_{max}	1.5km
BS Bandwidth	BS_{BW}	5MHz
Antenna Altitude	h_b	30m
Mobile Altitude	h_m	1.5m
Max DL transmission power	$P_{MAX\text{-}DL}$	43dBm
Max UL transmission power	$P_{MAX\text{-}UL}$	23dBm
Soft-handover threshold	P_{SHO}	-74dBm
Pilot threshold	P_{MIN}	-80dBm

IV. ILLUSTRATIVE EXAMPLE

For simplicity purpose we will discuss the proposed game theoretic CAC model with a simple scenario. We consider two overlay WiMAX networks with uniform traffic distribution.

Therefore we have a game of two players and four possible pure strategies for each player; each strategy is to select one of the four prices to charge. For every new connection request, the game is played between the two networks.

Therefore,

$N = \{1, 2\}$

$P1 = \{p_1, p_2, p_3, p_4\}$

$P2 = \{q_1, q_2, q_3, q_4\}$

The payoff function associated with these set of strategies for each network are represented by R_i.

For each selected strategy pair (p_1,q_1) the payoff for each network is given as follows:

$$R_1 = \{r_{11}^{1}\}$$
$$R_2 = \{r_{11}^{2}\}$$

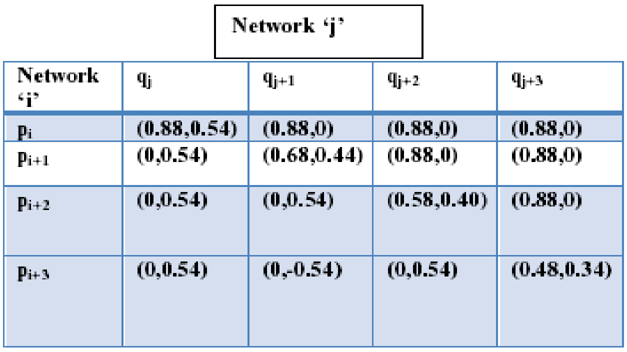
In order to validate the proposed scheme the simple scenario is assumed such that two third of the traffic units are closely located to network ‘1’ as compared to network ‘2’.

In order to test the performance of proposed scheme, the snapshot is considered of around 2500 users uniformly distributed between the overlapping coverage areas of two networks.

The simulation was run on more than 2000 traffic units and the respective network payoffs of each traffic unit for a particular strategy pair were calculated according to the proposed scheme mentioned in Section II. For discussion purpose, the payoff table for the 500th traffic unit is shown below in Figure 1:

If the network ‘1’ selects the strategy p_1 and network ‘2’ selects the strategy q_2 then the payoffs for each network will be as follows:

$$R_1 = \{0.88\}$$
$$R_2 = \{0\}$$



	Network ‘j’			
Network ‘i’	q_j	q_{j+1}	q_{j+2}	q_{j+3}
p_i	**(0.88,0.54)**	**(0.88,0)**	**(0.88,0)**	**(0.88,0)**
p_{i+1}	**(0,0.54)**	**(0.68,0.44)**	**(0.88,0)**	**(0.88,0)**
p_{i+2}	**(0,0.54)**	**(0,0.54)**	**(0.58,0.40)**	**(0.88,0)**
p_{i+3}	**(0,0.54)**	**(0,-0.54)**	**(0,0.54)**	**(0.48,0.34)**

Figure 1: Payoff table for 500th Traffic unit

This strategy pair maximizes the payoff for network ‘1’ but the network ‘2’ can select other strategy to maximize their payoff so this does not satisfy the Nash Equilibrium condition. The Nash Equilibrium solution will exist for the strategy pair (p_1,q_1). The payoff values for each network will be as follows:

$$R_1 = \{0.88\}$$
$$R_2 = \{0.54\}$$

The net reward for serving traffic units of both networks for the simple scenario are calculated and shown below in Figure 2:

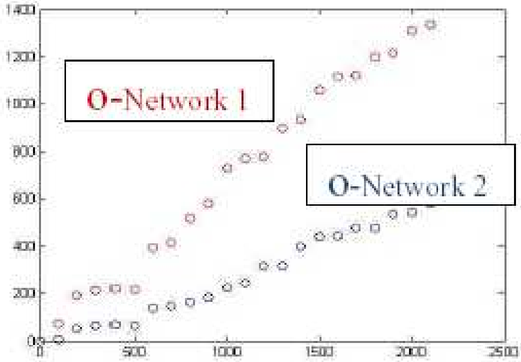


Figure 2: Net Reward for each network during the Simulation

The x-axis represents the number of traffic units within the snapshot and y-axis represents the net reward generated for serving theses traffic units. The results show that reward for Network ‘1’ is always more than the reward for Network’2’ which clearly satisfies the working of the simulator in accordance with illustrated simple scenario.

V. CONCLUSION

In this paper, we have presented a modeling approach for network selection in WiMAX networks. The approach is based on game theory and the scheme is modeled as a game between non-cooperative players, the WiMAX networks. The players compete for connection requests by traffic units in order to gain reward by means of utility functions.

We have presented a game theoretic model and with the help of an illustrative example demonstrated the defined concepts. Studying the example we observe that networks maximize their rewards by accepting the connection requests with higher network utility. This is indeed because of the consideration of the power consumed to serve a connection request in the payoffs each network receives in this game.

Future work will investigate the strategies selected for all traffic units served by a particular base station of a network to dynamically define strategies for future connection requests within that specific coverage area to maximize the reward for the networks.

Simulation experiments for complicated scenarios are currently being conducted to assess the potential of the approach outlined here and will be reported in future work. In the paper, a model for network competition with economic reward scheme is described and the key parameters of the multi-network WiMAX simulator that is being used to validate the work.

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