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Call Admission Control Algorithms based on Random Waypoint Mobility for IEEE802.16e Networks[1]

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1. Introduction

The next generation network WiMAX (Worldwide Interoperability for Microwave Access), has become synonymous with the IEEE802.16 Wireless Metropolitan Area Network (MAN) air interface standard. In its original release the 802.16 standard addressed applications in licensed bands in the 10 to 66 GHz frequency range. Subsequent amendments have extended the 802.16 air interface standard to cover non-line of sight (NLOS) applications in licensed and unlicensed bands from 2 to 11 GHz bands. These 802.16 networks are able to provide high data rates and are preferably based, for NLOS applications, on Orthogonal Frequency Division Multiple Access (OFDMA) (Piggin, 2004). In OFDMA, modulation and/or coding can be chosen differently for each sub-carrier, and can also change with time. Indeed, in the IEEE802.16 standard, coherent modulation schemes are used starting from low efficiency modulations (BPSK with coding rate 1/2) to very high efficiency ones (64-QAM with coding rate 3/4) depending on the SNR (Signal-to-Noise Ratio). It has been shown that systems using adaptive modulation perform better than systems whose modulation and coding are fixed (Yaghoobi, 2004). Adaptive modulation increases data transmission throughput and the system reliability by using different constellation sizes on different sub-carriers.

The authors in (Peyre et al., 2008) introduce a new Quality of Service (QoS) for real-time calls in IEEE802.16e Multi-class Capacity including AMC scheme and QoS Differentiation for Initial and Bandwidth Request Ranging (Seo et al., 2004). The QoS defined in this work is to maintain a same bit rate for RT calls independently of user position in the cell. The authors use a Discrete Time Markov Chain (DTMC) to model the system over a decomposition of IEEE802.16e cell. The authors took account the mobility of users among

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the regions of the cell. So, the analysis of wireless systems, as IEEE802.16e WiMAX, often requires to model the effect of user mobility. The mobility model is a critical element for any study about the radio communications. Therefore we choose to use the Random Waypoint (RWP) mobility model. This model have been studied largely in Ad-hoc networks (Johnson & Maltz, 1996) and briefly in wireless networks (Hyyti & Virtamo, 2007). In particular we consider (Johnson & Maltz, 1996), wherein the authors introduced the RWP mobility model to find the mean arrival and departure rates into a concentric cell as well as the mean sojourn time in the cellular networks.

Call Admission Control schemes play an important part in radio resource management (Kobbane et al., 2007), (Ibrahimi et al., 2008) and (Ibrahimi et al., 2009). Their aims are to maintain an acceptable QoS to different calls by limiting the number of ongoing calls in the system, minimize the call blocking and dropping probabilities and in the same time efficiently utilize the available resources (Niyato & Hossain, 2005). Our study is motivated by an attempt to find the better CAC in IEEE802.16e WiMAX, for both traffics RT and BE that handles the intra or inter cell mobility issue in the downlink of IEEE802.16e WiMAX with AMC technic. Based on the RWP mobility model for an IEEE802.16e cell, we model the system capacity through a Continuous Time Markov Chain (CTMC). For this reason we propose to study two promising CAC algorithms that guarantee a QoS. Our propositions allow to Internet Service Providers (ISP) to choice a CAC dependently of its purpose to manage their networks.

The rest of this paper is organized as follows: In Section 2, we describe the system and mobility properties as well as both CAC algorithms. In section 3, we develop the system and RWP mobility model. Based on it, the sections 4 and 5, develop the analysis for the first and second CAC schemes respectively. In Section 6 we define the performance metrics used to achieve the performance match. The section 7 provides some numerical results before conclude in section 8.

2. Framework

2.1. IEEE802.16 basis principles

The IEEE802.16e Physical layer uses an OFDMA sub-carrier allocation policy for the data transmission. The uplink and downlink sub-frames divide the time and frequency space into sub-carriers. The minimum frequency-time unit of sub-channelization is one slot, and a frame is constructed by a number of slots. Different sub-carriers are allocated to a mobile transmission in function of the resource requested by the mobile. Moreover, a sub-channel can be used periodically by different mobiles due to theirs classes of traffic. Once a mobile is granted to transmit by a bandwidth response in the DL-MAP, base station assigns one or more subcarriers and hence defines the sub-channels that the mobile will be able to use for its data transmission.

An IEEE802.16e cell is organized in region. Each region use specific modulation and coding technics. Users belongs to a region in function of theirs Signal-to-Noise Ratio SNR. The number of subcarriers allocated to a mobile directly depends on the available modulation, the type of traffic and the requested bandwidth.

2.2 System description

In this paper we consider a continuous time performance model for a single IEEE802.16e cell. The cell is decomposed into several regions. Mobiles are uniformly distributed on the whole cell. The cell population is dispatched between the regions according with theirs area coverages. Each region is characterized by the modulation used for data transmissions. Due to the AMC scheme described in the previous section, the calls use a modulation chosen in function of the receiver SNR. We consider the Adaptive Modulation and Coding (AMC) with pathloss only, consequently, the SNR depends only on the distance between the base station and the calling mobile. The four classes of services defined in the standard are:

• Unsolicited Grant Service (UGS) that caters for real-time, fixed-size data packets with constant bit rate (CBR). This service is granted at regular time intervals without a request or polls.

• Real-Time Polling Service (rtPS) that caters for real time data packets that vary in size generated at periodic intervals, such as MPEG video and VoIP with silence suppression, where packet sizes are variable.

• Non-Real-Time Polling Service (nrtPS), designed for connections that do not have delay requirements. nrtPS is similar to BE. It only differs from BE in that it guarantees a minimum bandwidth, e.g., FTP.

• Best-Effort (BE) that service makes no guarantee of service. To guarantee a minimum bandwidth the connection must subscribe to the nrtPS service, e.g., web browsing data.

We gather these classes of traffic into two types: Real Time (RT), corresponding to UGS or rtPS classes, and Best Effort (BE), corresponding to classes nrtPS and BE. Thus the RT class gathers the non delay-tolerant calls.

The calls can change of roamed region on the basis of the Random Waypoint (RWP) model. We use the RWP model to determine the mobility behavior of a call over a convex area. This area (i.e. the cell) is decomposed into several concentric regions. The RWP model helps us to determine the incoming/migrating rates for each region (intra-mobility). Moreover we extends our theoretical results to obtain the handover rate to/from external cell (inter-mobility).

2.3 Connection Admission Control

In Fig. 1, we describe the first CAC algorithm for a new call of class-c. In this first algorithm, the calls receive the same bit rate depending on its type of traffic (without the priority between RT and BE calls). Consequently, the system allocate a number of subcarriers in function of the location of the call. A new class-c call arriving in region i is accepted if the required resources are available for it. Else, the call is blocked. If a call did not finish its service in the region i and moves to the neighbor region $j = i \pm 1$, the call is accepted in region j if the system accepts its modulation changing. The available resources of the system could be not enough to accept a bandwidth increase. In this case, the migrating call is dropped.

The Fig. 2 represents our last CAC algorithm for a new call of class-c. In this other CAC algorithm the BE calls have no bandwidth requirement. Since the BE calls tolerate throughput variation, they will use the sub-carriers left by the RT call occupancy. In fact, the BE calls are never blocked and received the same resources according with the Processor

Sharing (PS) (Benameur et al., 2001). Thus, the bit rate of a BE call depends on its region (i.e modulation). For the RT calls only, the CAC algorithm follows the same scheme than previously: a new RT call arriving in region i is accepted if enough resources are available for it. And since a RT call did not terminate its service in region i before migrating to a region j, $j = i \pm 1$, the call will be able to remain in the system if enough resources are available to afford the modulation change.
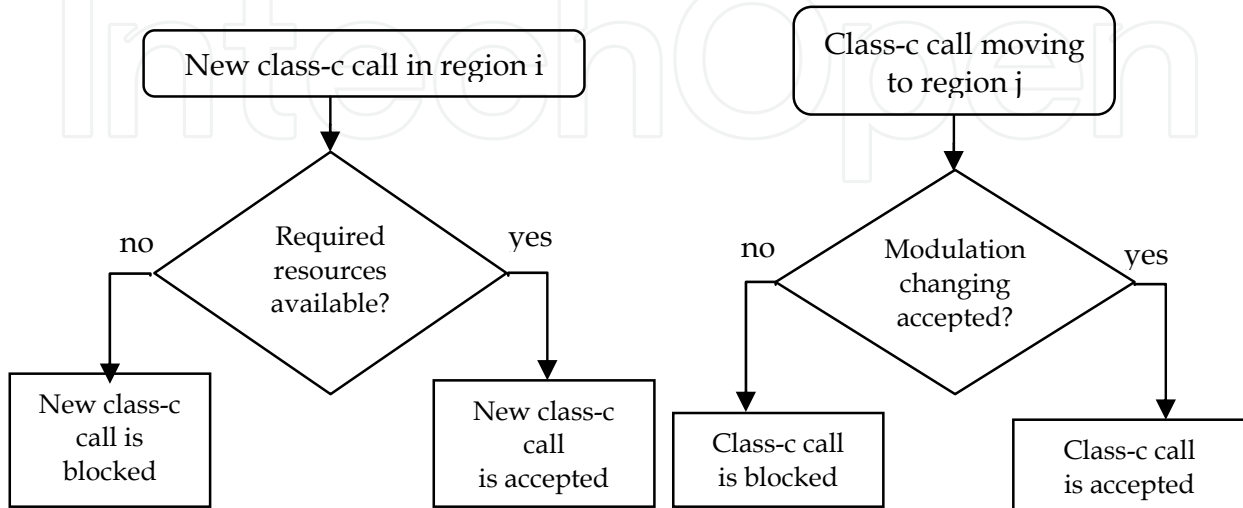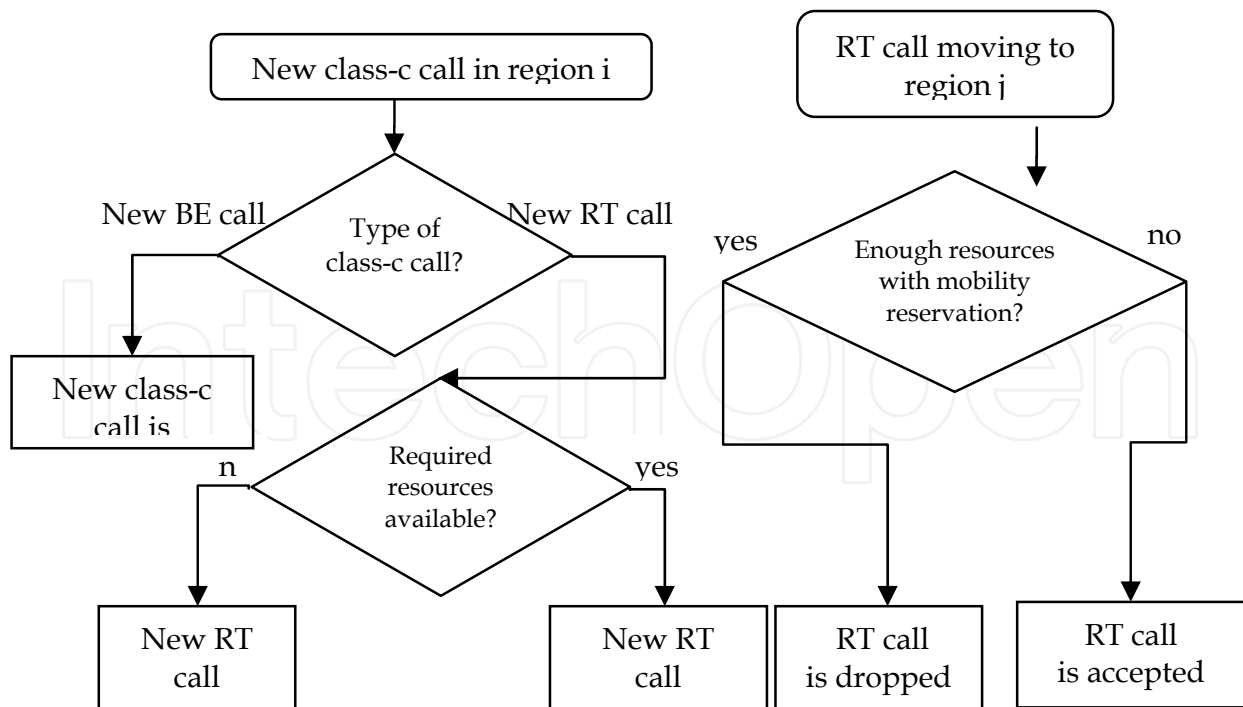
Fig. 1. First CAC Algorithm decision.

Fig. 2. Second CAC Algorithm decision.

Finally, remarks that for both CAC algorithms, the RT calls are independent of the consume resources: the RT-call remaining-time only depends on the behavior of the user. Conversely the BE calls remain in the system in function of the consumed resources: the more sub-carriers a BE call have, the faster it leaves the system.

In addition, our CAC algorithms seek to reduce the dropping probability: the probability that an on-progress service is dropped due to its mobility. As explained above, the call consumes bandwidth in function of the used modulation. By migrating to an outer region, a call may require additional resources. Thus, this call might undergo a drop due to lack of available resources. To prevent from these drops, our CAC algorithms introduce a reserved part of bandwidth. This reservation aims to satisfy the need of additional resources demanded in case of outer migration.

3. Model

3.1 Cell decomposition and instantaneous throughput

We consider without loss of generality, the Adaptive Modulation and Coding (AMC) with pathloss only. Then, the OFDMA cell is decomposed into r regions according to the AMC value corresponding to a certain value of SNR as depected in Fig. 3. Let R_i (i=1, …,r) be the radius of the i-th region and S_i represents the corresponding surface. Each region corresponds to a specific modulation order (see Table 1). In OFDMA scheme, the total number N of sub-carriers is divided into L sub-channels (or groups) each containing k sub-carriers, such $k=N/L$.

In our study, we consider the multi-services WiMAX/OFDMA system with two types of traffics real-time (RT) and best-effort (BE). Also, we define the instantaneous bit rate (radio interface rate) for a call of class-c located in the region $_i$ as follows:

$$d_c^i = L_c^i \times k \times B \times e_i, \tag{1}$$

where K is the number of sub-carriers assigned to each sub-channel; B is the baud rate (symbol/sec); e_i is the modulation efficiency (bits/symbol) and L_c^i is the sub-channels allowed for class-c call in region i. The above bit rate can be degraded by the error channel due to collision, shadow fading effect, as defined in (Tarhini & Chahid, 2007),

$$R_c^i = d_c^i \times (1 - BLER_i), \tag{2}$$

where $BLER_i$ is the BLock Error Rate in region i. The Table 1 indicates the modulations and codings used in a IEEE802.16e cell as function of the user SNR. The SNR requirement for a BLER less than 10^{-6} depends on the modulation type as specified in the standard (Standard IEEE802.16, 2004). Then, we have γ_1= 24.4 dB, γ_2= 18.2 dB, γ_3= 9.4 dB, γ_4= 6.4 dB and γ_0 =∞.

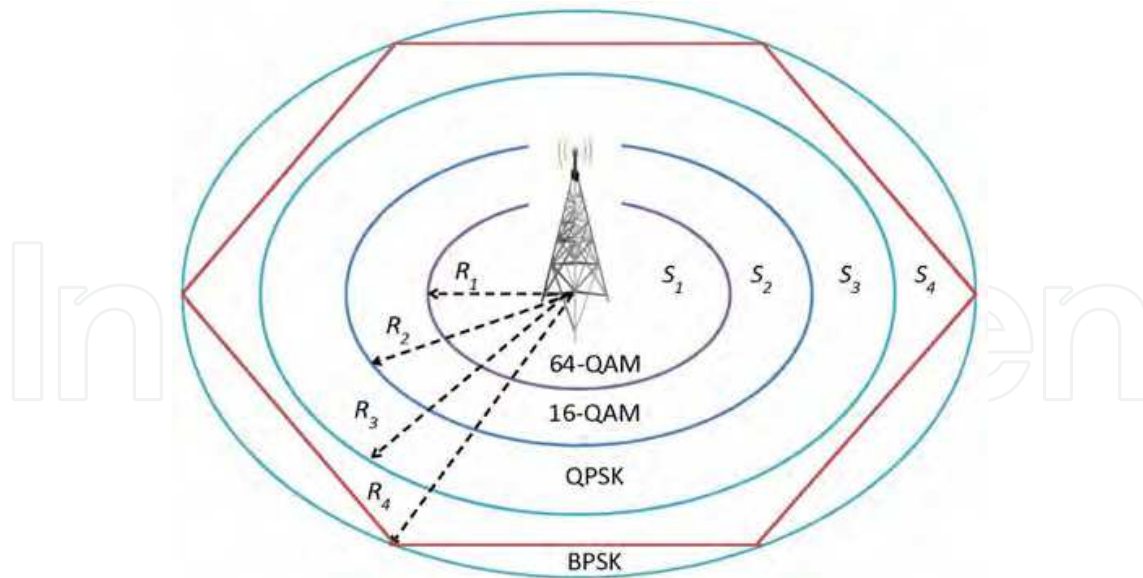| Modulation	Coding rate	Received SNR (dB)	Cell ratio (%)
64-QAM	3/4	$[\gamma_1, \gamma_0)$	1.74
16-QAM	3/4	$[\gamma_2, \gamma_1)$	5.14
QPSK	1/2	$[\gamma_3, \gamma_2)$	20.75
BPSK	1/2	$[\gamma_4, \gamma_3)$	39.4

Table 1. IEEE802.16e AMC settings.

Fig. 3. OFDMA Cell decomposed into concentric regions.

3.2 System state and transitions

Our model of the system is based on the Continuous Time Markov chain (CTMC) technic. The different transition rates within the space of feasible states defined in the next sections are caused by one of the following events: arrival of a new call of class-c to region i; migration of an ongoing call of class-c from region i to j; termination of an ongoing call of class-c in the region i. Furthermore, we consider in our analysis the following assumptions:

1. The arrival process of new calls of class-c in region i is Poisson with rate $\lambda_{c,i}^0$;

2. The service time of a class-c call is exponentially distributed with mean $1/\mu_c$;

3. The mean dwell time or sojourn time in region i is exponentially distributed with mean $1/\Gamma_c^i$;

4. The mean arrival rate of migrating call of class-c from the region i to region j is $\lambda_c^{i,j}$.

Let $n_c^i(t)$ be the number of calls of class-c in progress at time t in region i. The state of the system at time t is defined by: $\vec{n}(t) = (n_{RT}^1(t),\ldots,n_{RT}^r(t),n_{BE}^1(t),\ldots,n_{BE}^r(t))$. Then, we model the process $\{\vec{n}(t), t>0\}$ as 2r-dimension quasi-birth and death Markov chain. In the steady-state it has an unique stationary distribution, with:

$$\vec{n} = (n_{RT}^1,\ldots,n_{RT}^r,n_{BE}^1,\ldots,n_{BE}^r).$$

3.3 User mobility behaviour

We compute the arrival migration rates using RWP model. In the RWP model a node moves in a convex domain $\Omega \subset R^2$ along a straight line segment from one waypoint to another. The waypoint, denoted by P_i, are uniformly distributed in Ω, $P_i \sim U(\Omega)$. Transition from P_{i-1} to P_i is referred to as the i-th leg, and the velocity of the node on i-th leg is given by random

variable v_i. In particular in the RWP model, it is assumed that P_i and v_i are all independent and v_i are uniformly distributed. Here, the domain Ω corresponds to one cell and leg to path between both waypoints P_i and P_{i-1}. Also, the node corresponds to a mobile or user moving in the cell. With this notation the RWP process (for a single node) is defined by an infinite sequence of triples (Bettstetter et al., 2004),

$$\{(P_0, P_1, v_1), (P_1, P_2, v_2), ...\}.$$

We note that the process RWP is time reversible. This means that the arrival rates across any line segment or border are equal in both directions. In other words, the average rates of calls moving from region i to region j per time unit is equal to the number of calls moving from region j to region i per time unit, i. e., $\lambda_c^{i,j} = \lambda_c^{j,i}$ as proved in (Norris, 1999).

Our aim is to compute the migration rates $\lambda_c^{i,j}$. As the velocity of the user (node) is assumed to have an uniform distribution from v_{min}, ($v_{min}>0$) to v_{max}, denoted by $f_v(v)$, where

$$f_v(v) = \begin{cases} \dfrac{1}{v_{max} - v_{min}}, & if\ v \in \left[v_{min}, v_{max}\right]; \\ 0, & otherwise. \end{cases}$$

Let T_i denote the transition time on i-th leg (path) defined as $T_i = \dfrac{l_i}{v_i}$, where $l_i = |P_i - P_{i-1}|$. The variables l_i and v_i are independent random variables. The average time from one waypoint to another is given by:

$$E[T] = \bar{l}\int_v \frac{1}{v} f_v(v)dv = \bar{l}\frac{\ln(v_{max}/v_{min})}{v_{max} - v_{min}} = \bar{l}.E[1/v]. \quad (3)$$

We consider the area A_i of each concentric cell of radius R_i as a convex disk of same radius in which the mobiles move according to the RWP model. Our aim is to compute the arrival rate into a cell of radius R_{i-1}. As introduced in (Hyyti & Virtamo, 2007), let $a_1 = a_1(R_{i-1}, \varphi)$ denote the distance from point $R_{i-1} = |(0, R_{i-1})| \in A_i$ to the border of A_i in direction φ (angle anti-clockwise away from the tangent at point $R_{i-1} = |(0, R_{i-1})|$). $a_2 = a_1(R_{i-1}, \varphi + \pi)$ denotes the distance to the border in the opposite direction (see Fig. 4). Also, we note the specific flux at R_{i-1} in direction φ by

$$\psi(R_{i-1},\phi) = \frac{1}{2C_v}.a_1 a_2 (a_1 + a_2),$$

(4)

where $C_v = \bar{l} A_i^2.E[1/v]$. We recall that the $i-th$ disk surface is $A_i = \pi R_i^2$ and the mean length of a leg in this disk is

$$\bar{l} = \frac{1}{\pi R_i^2} \int_0^\pi a_1 a_2 (a_1 + a_2) d\phi.$$

(5)

According with the RWP model developed in cellular network context (Hyyti & Virtamo, 2007) , the arrival rate for one user to region $i-1$ over all contour of disk of the radius R_{i-1} is given by

$$\lambda(R_{i-1}) = 2\pi R_{i-1} \int_0^\pi \sin(\phi)\psi(R_{i-1},\phi)d\phi.$$

(6)
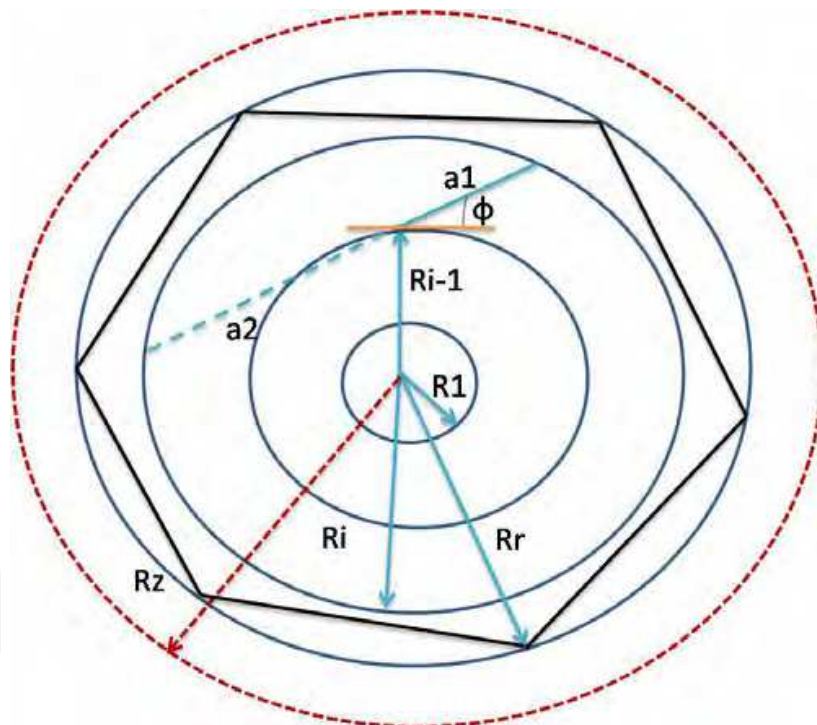
Fig. 4. RWP domains (disk of radius Ri) and Rz=2Rr-Rr-1.

From the Fig. 6, we deduce easily the distances a_1 and a_2 as follow:

$$a_1(R_{i-1},\phi) = \sqrt{R_i^2 - R_{i-1}^2 \cos^2(\phi)} - R_{i-1}\sin(\phi),$$

$$a_2(R_{i-1}, \phi) = \sqrt{R_i^2 - R_{i-1}^2 \cos^2(\phi)} + R_{i-1}\cos(\phi).$$

As the user mobility behaviors are independent, the total migration rate from region i ($i = 1, \ldots, r$) to region j ($j = i \pm 1$) of class-c is given by

$$\lambda_c^{i,j} = \lambda(R_j).n_c^i. \tag{7}$$

Finally, the handover arrival rate is given by

$$\lambda_c^{ho} = \lambda_c^{r+1,r} = \lambda(R_r).n_c^r. \tag{8}$$

Now we can compute the mean sojourn time Γ_c^i of one mobile that proceed to class-c call in region i. This mobile can arrives from region j with rate $\lambda_c^{j,i}$ ($i = j \pm 1$) or from outside as new call with rate $\lambda_{c,i}^0$. Let p_c^i be the probability of finding a call of class-c in region i ($i = 1, \ldots, r$). Then the mean sojourn time is given by (Hyyti & Virtamo, 2007):

$$\Gamma_c^i = \frac{p_c^i}{\lambda_c^{i+1,i} + \lambda_c^{i-1,i} + \lambda_{c,i}^0}, \quad with \quad \lambda_c^{0,1} = 0, \tag{9}$$

where

$$p_c^i = P(n_c^i(t) \geq 1) = \sum_{\vec{n}, n_c^i \geq 1} \pi_k(\vec{n}). \tag{10}$$

where π_k is the probability distribution computed in the next system analysis and *k=1, 2*.

4. System analysis for the first CAC algorithm

4.1 Bandwidth occupancy
As described above in the Fig. 1, the interest QoS is to guarantee for a call of class-c a same bit rate independently of its position in the cell. In fact, we allocate to it the needed sub-channels by using equation (2) as

$$L_c^i = \frac{R_c}{k \times B \times e_i \times (1 - BLER_i)}. \tag{11}$$

We recall that the mean call duration of BE calls in the system depends on the transmitting payload in bits, i.e., $\mu_{BE} = \dfrac{R_{BE}}{E(Pay)}$, where $E(Pay)$ is the mean file size (Downey, 2001). Thus, we define the space of the admissible states as follows

$$E = \{\vec{n} \in N^{2r} \mid \sum_{i=1}^{r} \{n_{RT}^{i} L_{RT}^{i} + n_{BE}^{i} L_{BE}^{i}\} \leq L\}.\tag{12}$$

Let L_m be the reserved capacity for migrating or handoff calls of class-c and L_0 denotes the remaining capacity given by $L_0 = L - L_m$. Let $B_1(\vec{n})$ be the occupancy bandwidth when system state is $\vec{n}$, with

$$B_1(\vec{n}) = \sum_{i=1}^{r} \{n_{RT}^{i} L_{RT}^{i} + n_{BE}^{i} L_{BE}^{i}\}.\tag{13}$$

4.2 Equilibrium distribution

The call of class-c can come as new call or migrating/handoff call in region i of the cell. For $\vec{n}$ the current system state, we define the arrival rate of call in region i, as

$$\lambda_c^i(\vec{n}) = \begin{cases} \lambda_{c,i}^0 + \lambda_c^{i-1,i} + \lambda_c^{i+1,i}, & if\ B_1(\vec{n}) < L_0; \\[2mm] \lambda_c^{i-1,i} + \lambda_c^{i+1,i}, & if\ L_0 \leq B_1(\vec{n}) < L. \end{cases}\tag{14}$$

We have two classes of services RT and BE. Each class-c call in region i $(i = 1, 2, \ldots, r)$ requires the effective bandwidth L_c^i. Then, we have $2r$ classes in the cell and the equilibrium distribution is given by BCMP theorem (Chao et al., 2001) for multiple classes with possible class changes, with $\rho_c^i = \dfrac{\lambda_c^i(\vec{n})}{\Gamma_c^i + \mu_c}$ as

$$\pi_1(\vec{n}) = \frac{1}{G} \prod_{i=1}^{r} \frac{(\rho_{RT}^i)^{n_{RT}^i}}{n_{RT}^i!} \frac{(\rho_{BE}^i)^{n_{BE}^i}}{n_{BE}^i!},\tag{15}$$

where $\vec{n} \in E$ and G is the normalizing constant given by

$$G = \sum_{\vec{n} \in E} \prod_{i=1}^{r} \frac{(\rho_{RT}^i)^{n_{RT}^i}}{n_{RT}^i!} \frac{(\rho_{BE}^i)^{n_{BE}^i}}{n_{BE}^i!}.$$

So, this probability depends of the mean sojourn time Γ_c^i which depends itself on the probability p_c^i in equation (10). Also the latter depends of the above distribution and vice versa. We can use the fixed point theorem to resolve this problem as follow:

Algorithm :   Probability convergence algorithm

1: Initialize the probability in (9): $p_{c,old}^i = p_c^i = 0.1$.

2: Compute the mean sojourn time in (9).

3: Calculate the steady-state probability $\pi_1(\vec{n})$ from (15).

4: Derive the new value of probability from (10), denoted by $p_{c,new}^i$.

5:   Check the convergence of the probability between the old and the new values. if $| p_{c,new}^i - p_{c,old}^i |< \xi$, where ξ is a very small positive number, then the new probability is used to compute the performance metrics. Otherwise, go to step 2 with new value as initial value. The iterations are continued until to reach the convergence of probability.

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5. System analysis for the second CAC algorithm

5.1 Bit rates per class and feasible system states

Here, we consider the CAC algorithm follows the scheme described in the Fig. 2. Consider there is a minimum capacity reserved for BE calls denoted by L_{BE} and reserved L_{RT}^m sub-channels for RT calls mobility. We denote by L_{RT} the remaining capacity for RT calls given by:

$$L_{RT} = L - L_{BE} - L_{RT}^m. \tag{16}$$

Let $B_2(\vec{n})$ be the bandwidth occupied by RT calls when system sate is $\vec{n}$, with

$$B_2(\vec{n}) = \sum_{i=1}^{r} n_{RT}^i L_{RT}^i, \tag{17}$$

where

$$L_{RT}^i = \frac{R_{RT}}{k \times B \times e_i \times (1 - BLER_i)}.$$

In this section, we guarantee for RT calls a QoS in terms to maintain a same bit rate everywhere in the covered area by the cell. Whereas a BE call receives the instantaneous bit rate denoted by R_{BE}^i in region i. The dynamic capacity $C(\vec{n})$ shared fairly among all BE calls simultaneously in progress in the system is

$$C(\vec{n}) = \begin{cases} L - B_2(\vec{n}) - L_{RT}^m, & if \ B_2(\vec{n}) < L_{RT}; \\ L_{BE}, & otherwise. \end{cases} \tag{18}$$

The BE calls share the reserved capacity with PS manner. The number of sub-channels L_{BE}^i allocated to a BE call in region i with PS policy is

$$L_{BE}^i(\vec{n}) = | \frac{C(\vec{n})}{\sum_{i=1}^r n_{BE}^i} |, \tag{19}$$

where $|x|$ indicates the largest integer that is less than or equal to x. Then the BE call receives in region i the bit rate $R_{BE}^i(\vec{n}) = L_{BE}^i(\vec{n}) \times k \times B \times e_i \times (1 - BLER_i)$. Therefore, the mean BE call duration is given by $\mu_{BE}^i = \dfrac{R_{BE}^i(\vec{n})}{E(Pay)}$. Since the system accept without limit the BE calls, the space of admissible states is

$$F = \{ \vec{n} \in N^{2r} \mid \sum_{i=1}^r n_{RT}^i L_{RT}^i \leq L_{RT} \}. \tag{20}$$

We define the indication function as

$$\delta(X) = \begin{cases} 1, & if \ X \ is \ true; \\ 0, & otherwise. \end{cases}$$

5.2 Transition rates

The transition rates from the state $\vec{n}$ to other ones are introduced as described in the sequel. Let $\vec{n}_{i+}^c$ be the state when a new class-c call is arrived and we denote this transition by $q_{(\vec{n}, \vec{n}_{i+}^c)}$. Let $\vec{n}_{i-}^c$ be the state when a class-c call in region i terminates its service or changes

its modulation order and we denote this transition by $q_{(\vec{n},\vec{n}^c_-)}$. Let $\vec{n}^c_{i,j}$ ($j = i \pm 1$) be the state when a class-c call in region i moves to the neighbor region j and we denote this transition by $q_{(\vec{n},\vec{n}^c_{i,j})}$. Then, we have

$$q_{(\vec{n},\vec{n}^{RT}_{i+})} = \delta(B_2(\vec{n}) + L^i_{RT} \leq L_{RT})\lambda^0_{RT,i},$$

$$q_{(\vec{n},\vec{n}^{BE}_{i+})} = \lambda^0_{BE,i},$$

$$q_{(\vec{n},\vec{n}^{RT}_{i,j})} = \delta(B_2(\vec{n}) + \Delta^{i,j}_{RT} \leq L_{RT} + L^m_{RT})\lambda^{i,j}_{RT},$$

$$q_{(\vec{n},\vec{n}^{BE}_{i,j})} = \lambda^{i,j}_{BE},$$

$$q_{(\vec{n},\vec{n}^{RT}_{i-})} = n^i_{RT}(\mu_{RT} + \Gamma^i_{RT}),$$

$$q_{(\vec{n},\vec{n}^{BE}_{i-})} = n^i_{BE}(\mu^i_{BE}(\vec{n}) + \Gamma^i_{BE}),$$

where Γ^i_c is computed in Algorithm 1 by replacing the the probability π_1 by π_2, and $\Delta^{i,j}_{RT} = L^i_{RT} - L^j_{RT}$.

Let Q be the matrix of the possible transitions, where $Q = (q_{(\vec{n},\vec{n}')})$ for $\vec{n} \in F$ and $\vec{n}' \in F$. The transition rate from state $\vec{n}$ to $\vec{n}'$ is denoted by $q_{(\vec{n},\vec{n}')}$. Its value must be obtained as the sum of all terms in each line in matrix Q is equal to zero for RT call and BE one as well as $i = 1, \ldots, r$.

5.3 Steady-state distribution

Now, we recall that $\pi_2(\vec{n})$ denotes the steady-state probability when system is in the state $\vec{n}$ ($\vec{n} \in F$) and by $\vec{\pi}$ the steady-state distribution vector, where $\vec{\pi} = \{\pi_2(\vec{n}) \mid \vec{n} \in F\}$. The steady-state probability vector is solution of the following system of equations:

$$\vec{\pi}Q = \overline{0}, \tag{21}$$

$$\vec{\pi}\,\overline{1} = 1. \tag{22}$$

where $\overline{1}$ is a column vector of ones and $\overline{0}$ is a row vector of zeros.

6. Performances metric

Once the equilibrium distribution probabilities 4.2 and 5.3 are calculated, we compute many interesting metrics of the system. In this section, we provide explicit expressions for various metrics like dropping probabilities, blocking probabilities, average sojourn time and average throughput.

6.1 First scheme

6.1.1 Blocking probabilities

A new call of class-c in region i is blocked with probability:

$$B_c^i = \sum_{\vec{n} \in E_c^i} \pi_1(\vec{n}), i = 1,\dots,r,$$

(23)

where $E_c^i = \{\vec{n} \in E \mid B_1(\vec{n}) + L_c^i > L_0\}$.

6.1.2 Dropping probabilities

Migrating call dropping probability in region i. The migrating call of class-c from region i to region j is dropped with probability

$$D_c^i = \sum_{\vec{n} \in E_c^{i,j}} \pi_1(\vec{n}), i = 2,\dots,r,$$

(24)

where $E_c^{i,j} = \{\vec{n} \in E \mid B_1(\vec{n}) + L_c^j - L_c^i > L\}$.

6.1.3 Average throughput

The average throughput in the system is

$$Th_1 = \sum_{\vec{n} \in E} \pi_1(\vec{n}) \sum_{i=1}^{r} (n_{RT}^i R_{RT} + n_{BE}^i R_{BE}).$$

(25)

6.2 Second scheme

6.2.1 Blocking probabilities

A new call of class-RT in region i is blocked with probability

$$B_{RT}^i = \sum_{\vec{n} \in F_{RT}^i} \pi_2(\vec{n}), i = 1,\dots,r,$$

(26)

where $F_{RT}^i = \{\vec{n} \in F \mid B_2(\vec{n}) + L_{RT}^i > L_{RT}\}$.

6.2.2 Dropping probabilities

Migrating call dropping probability in region i. The migrating call of class-RT from region i to region j is dropped with probability

$$D_{RT}^i = \sum_{\vec{n} \in F_{RT}^{i,j}} \pi_2(\vec{n}), \, i = 2, \ldots, r, \qquad (27)$$

where $F_{RT}^{i,j} = \{\vec{n} \in F \mid B_2(\vec{n}) + \Delta_{RT}^{j,i} > L_{RT} + L_{RT}^m \}$.

6.2.3 Average throughput

The average throughput in the system is

$$Th_2 = \sum_{\vec{n} \in F} \pi_2(\vec{n}) \sum_{i=1}^{r} (n_{RT}^i R_{RT} + n_{BE}^i R_{BE}^i(\vec{n})). \qquad (28)$$

7. Numerical applications

The following parameters and assumptions are used in our numerical applications. Considering OFDMA cell system with an FFT (*fast Fourier transform*) size of 2048 sub-carriers. The cell is decomposed into two regions ($r = 2$), R_1 = 300 m and R_2 = 600 m with AMC scheme: 16-QAM 3/4 (e_1 = 3 bits/symbol) and QPSK 1/2 (e_2 = 1 bit/symbol). The baud value B = 2666 symbols/sec, $BLER_i$ = 0, and K = 48. These parameters correspond to the transmission modes with conventionally coded modulation (Liu & Zhou, 2005); The bit rate R_{RT} is equal to 128 Kbps and R_{BE} is 384 Kbps (Tarhini & Chahed, 2007); The total bandwidth L is 10 sub-channels; The mean call duration for RT calls is equal to 120 sec and the download of files with mean size for BE calls is equal to $E(Pay)$ = 5 Mbits. We assume a mobile moves according to the RWP model on a convex disk of radius R_z = 900 m. It randomly chooses a new speed in each waypoint from an uniform distribution between [v_{min}, v_{max}], where v_{min}=3km/h (low mobility) or v_{min} = 20km/h (high mobility), v_{max} = 90 km/h.

7.1 Impact of first scheme

The Fig. 5 presents the blocking probabilities for each burst profile (i.e. modulation) in terms of reserved resources for mobility. As expected, the probabilities increase as the reserved threshold L_m increases and the modulation efficiency decreases. Moreover, an appreciable difference exists between class RT and class BE blocking probability. This is due to the required capacity per class type, the BE class call in our numerical environment requires more bandwidth than the RT class call. So, when threshold increases, the blocking probability increases due to the CAC mechanism which gives the priority to migrating/handoff call than the new call. So the blocking probability mainly depends on the required bandwidth associated with the call modulation efficiency. We also observe that as

the reserved bandwidth L_m increases, the calls are more blocked as the incoming region is away from the base station and as the calls demand an high bandwidth. In particular, we observe on the figure the blocking probabilities for two type of arrivals : BE calls in 16QAM and RT calls in QPSK. The blocking probabilities are exactly the same because the product between the required bandwidth and the modulation efficiency are the same for both.
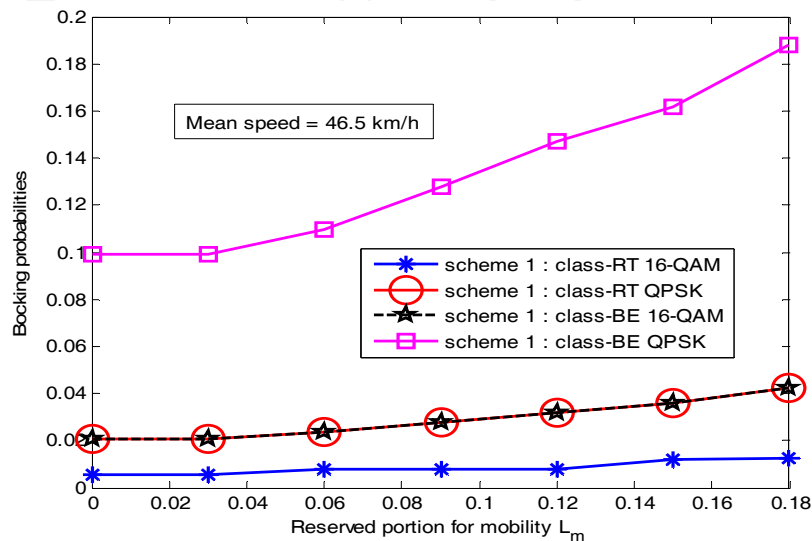

Fig. 5. Blocking probabilities versus threshold L_m and mean speed for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.

The Fig. 6 shows the average throughput of the whole cell versus the reserved threshold mobility. On this figure two singular behaviors have to be studied. The first main observation deals with the throughput increasing because of an higher mobility. As a mobile moves faster, it increases its probability to change region (and thus modulation) per unit of time. This fact implies also more calls dropped due to lack of resources. In fact the system will implicitly coerce the system calls to use better modulations. This last deduction explains how an higher mobility allows to reach a better throughput. Note that this remark is confirmed in (Peyre & Elazouzi, 2009) and also observed for the ad-hoc networks (Grossglause & Tse, 2002). Moreover, we can criticize on the Fig. 6, the impact of resource reservation to ease the call mobility. For any mobility behavior, the average cell throughput decreases as the reservation share increases. But the throughput fall depends on the mobility behavior. In fact, by introducing a resource reservation, we helps more and more migrating calls to remain in the border regions. Theses calls use more subchannels to reach the same bit rate than previously. Consequently, the system reaches a lower throughput by prioritizing the user mobility management.
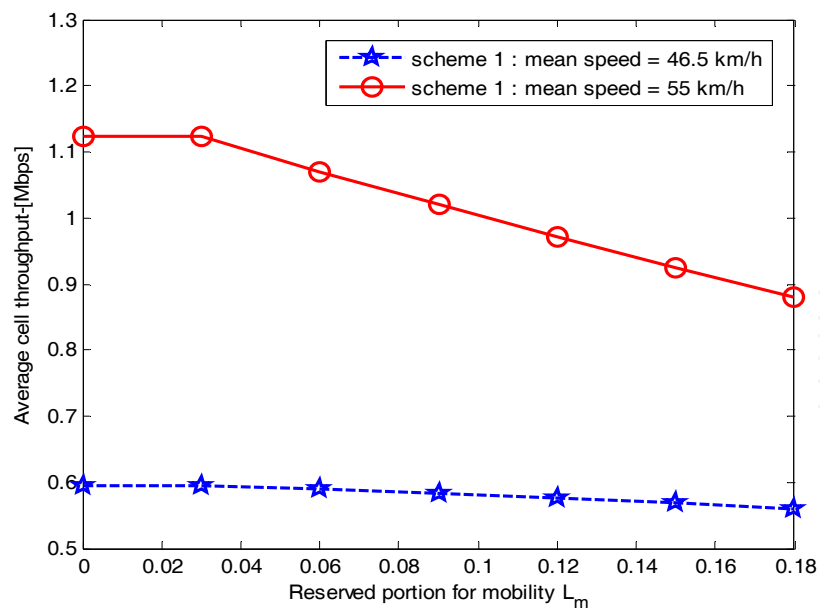
Fig. 6. Average throughput versus threshold L_m and mean speed for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.

The Fig. 7 represents the dropping probabilities versus reserved threshold L_m. We plot the results for both types of traffic in the border region (i.e. QPSK modulation), and for two mobility behaviors. The figure helps to appreciate the great impact of the resource reservation on the mobility management efficiency. Concerning the real-time traffics, we observe that an higher mobility causes an twenty-times dropping increase. To fight against this effect, our CAC algorithm permits to tune the resource reservation in order to decreases the call drops under a desired value. For examples, a reservation lower than ten percents of the total bandwidth decreases the number of dropped calls under a one-percent probability. For the Best Effort traffic, we observe exactly the same behavior. Nevertheless, the dropping probability for the BE traffic remains higher than for the RT because the BE calls require an higher bit rate. As they ask for more bandwidth, they undergo more drops. For this type of traffic, our CAC allows also to greatly reduce the dropping probability of the BE calls by increasing the resources reservation L_m.

7.2 Impact of second scheme
The Fig. 8 shows the blocking probabilities for the RT traffics in both regions versus the bandwidth reservation for the Best Effort call. We plot the results obtained for two resource reservation profiles for the user mobility management. This figure clearly shows the impact
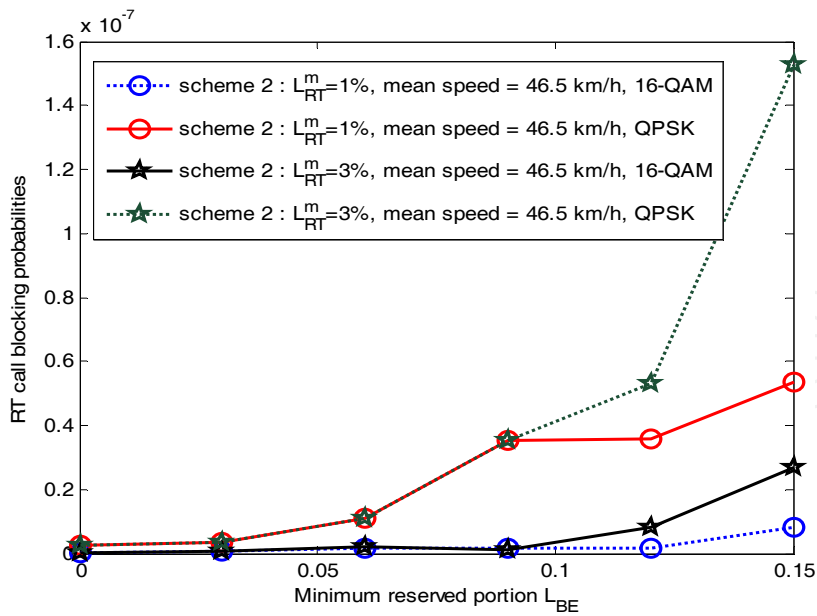
Fig. 7. Blocking probabilities versus threshold L_m and mean speed for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.
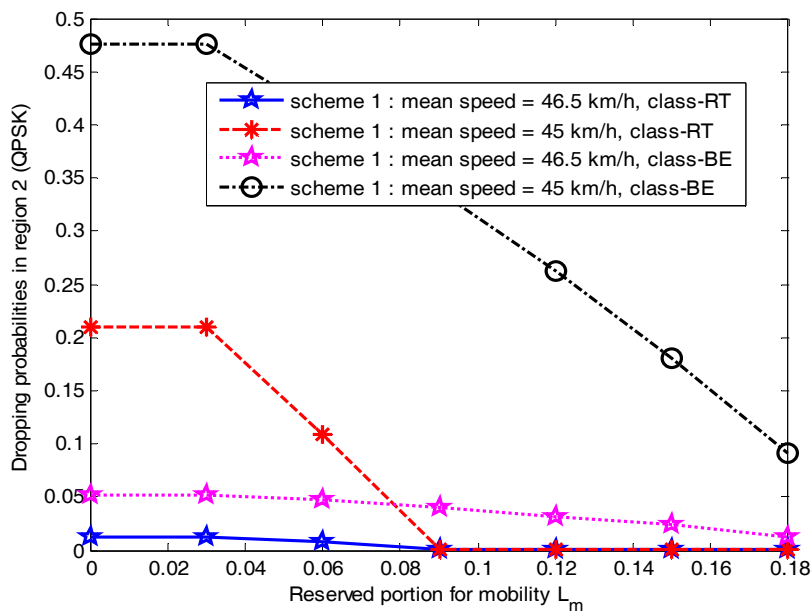

Fig. 8. Dropping probabilities versus threshold L_{BE} and L_{RT}^m for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.

of L_{BE} and L_{RT}^m on the blocking probabilities experienced in each region. In general, the blocking probabilities are heavily increased by the BE bandwidth reservation. In addition, this drawback is amplify by the increase of the mobility management resource reservation.

From this statement, we could compute the the value ranges for L_{BE} and L_{RT}^m which satisfy a maximum blocking probability threshold.

The Fig. 9 shows the dropping probabilities for the RT traffics in the border region versus the bandwidth reservation for the Best Effort call. We plot the results obtained for two resource reservation profiles for the user mobility management. The figure shows how the resource reservation L_{RT}^m fights against the dropping due to the BE bandwidth reservation. On this figure, the dropping probability is reduced as the BE reservation is greater than ten percents. So we can determine the possible values for L_{RT}^m from a desired maximum dropping probability.

The Fig. 10 shows the total cell throughput. This figure presents the impact of the different bandwidth reservation to increase the BE call throughput and to ease the call mobility. On the Fig. 10 we can appreciate the great impact of the BE bandwidth reservation L_{BE}. Indeed, by reservation 15% of the total bandwidth, we double the total cell throughput. In addition, to increase the mobility-purpose reservation slightly decrease the total throughput. This observation leads to think that a small quantity of subchannels for Best effort calls allows to reach very higher throughput. In fact, this by reserving few subchannels to the BE calls, we also increase the blocking and dropping probabilities for the RT calls. Therefore, these amount of resources freed by the dropped call or let free by the blocking one allow to the BE calls to use even more resources.
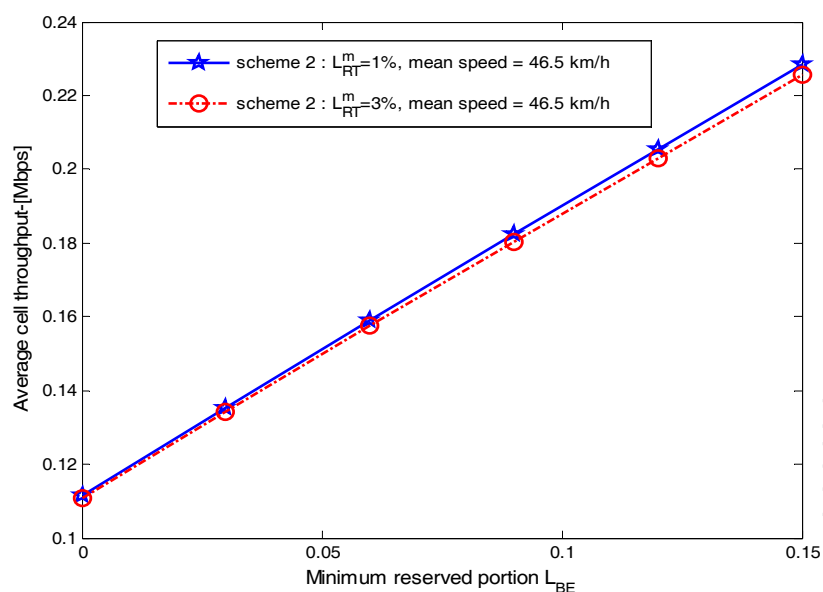

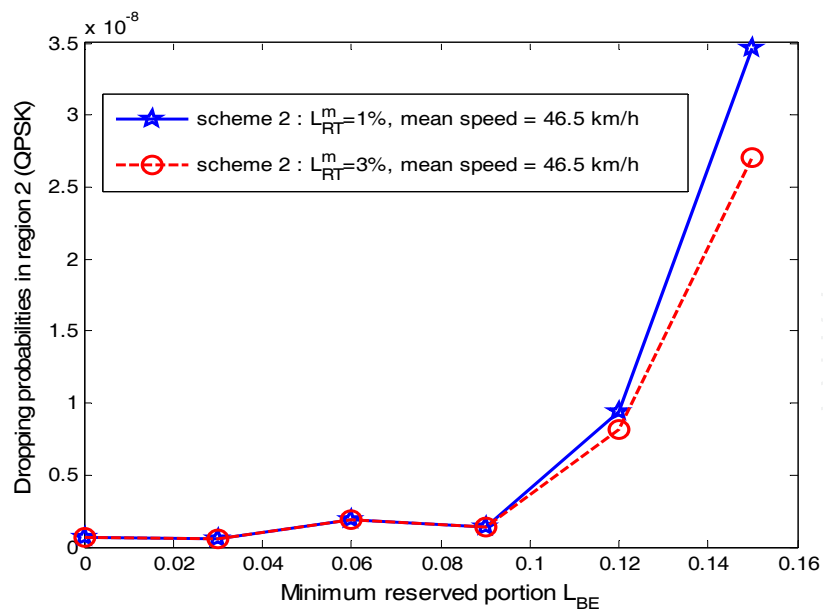Fig. 9. Mean throughput versus L_{BE} and L_m for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.

Fig. 10. RT dropping probabilities versus threshold L_{BE} and L_{RT}^m for $\lambda_{RT,i}^0 = \lambda_{BE,i}^0 = 0.3$ call/sec.

8. Conclusion

Recently many works have been introduced to study the WiMAX performances in order to improve some QoS for users. In this sense our work contributes in order to improve the QoS of users. In fact, by considering both traffics RT and BE, we proposed two strategies of QoS management. The first defines constant bit rates (CBR) for RT and BE calls. We also introduce a resource reservation to ease the mobility of the users. The second scheme replaces the CBR policy of the BE calls by a Processor Sharing (PS), and we add an other bandwidth reservation to improve the minimum Best Effort call throughput. Moreover, we define a realistic mobility model through the accurate Random Waypoint model. Based on these propositions we develop a continuous time Markov chain which determines the steady state of the system. From the model, we provide a large range of performance metrics. We conclude our analysis by criticize the impact of each CAC algorithm parameters on the system performances. By gathering all our results, we can easily choose one of the two proposed CAC algorithms to meet with the desired traffic prioritization policy. In addition, we analyzed the possible ways to tune the parameters of each CAC algorithms in order to specify the main thresholds (average throughput, blocking and dropping probabilities). As future works we seek to introduce thinking times in our RWP model. Our main objective is also to improve the CAC algorithms by determining the best way to roam the mobile user to a region, in function of its speed and the expected time spend in the next region.

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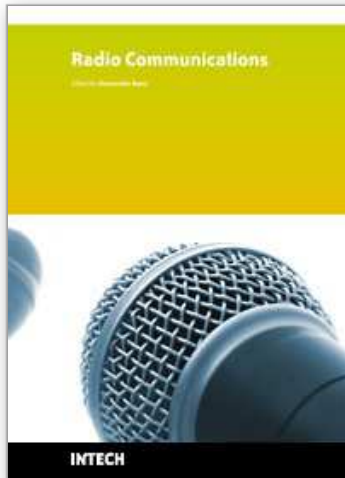
Radio Communications

Edited by Alessandro Bazzi

In the last decades the restless evolution of information and communication technologies (ICT) brought to a deep transformation of our habits. The growth of the Internet and the advances in hardware and software implementations modified our way to communicate and to share information. In this book, an overview of the major issues faced today by researchers in the field of radio communications is given through 35 high quality chapters written by specialists working in universities and research centers all over the world. Various aspects will be deeply discussed: channel modeling, beamforming, multiple antennas, cooperative networks, opportunistic scheduling, advanced admission control, handover management, systems performance assessment, routing issues in mobility conditions, localization, web security. Advanced techniques for the radio resource management will be discussed both in single and multiple radio technologies; either in infrastructure, mesh or ad hoc networks.

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