Analysis of a WiMAX Cell with Two AMC Modes and Elastic Data Traffic

Tatiana Efimushkina
Peoples Friendship University of Russia
Moscow, Russia
tvefimushkina@gmail.com

Dmitri Moltchanov, Yevgeni Koucheryavy
Tampere University of Technology
Tampere, Finland
{moltchan, yk}@cs.tut.fi

Abstract

We consider a WiMAX cell model that uses adaptive modulation and coding (AMC) as well as call admission control strategy (CAC) providing quality of service (QoS) on a desired level. The schemes allow mobile users to change AMC mode dynamically in order to minimize losses and maximize transmission rate. In this paper, a WiMAX cell model is divided into two zones with different average signal to noise ratio where each zone uses its own AMC transmission mode. We assume two types of traffic services: voice calls and elastic data sessions.

To evaluate the role of elastic traffic an analytical model is presented with elastic data sessions. The Markov model is analyzed and the blocking probability as well as other performance characteristics is calculated.

INDEX TERMS: ADAPTIVE MODULATION AND CODING, CALL ADMISSION CONTROL, ELASTIC TRAFFIC, ANALYTICAL MODEL, PERFORMANCE EVALUATION.

I. INTRODUCTION

Since the demand for high data rates and QoS is growing rapidly, spectral efficiency is a stringent requirement in present and future wireless communications. On the other hand, random fluctuations in the wireless channel do not allow the continuous use of highly bandwidth-efficient modulation, and therefore AMC has become a standard approach in WiMAX [1-3]. The idea behind AMC is to dynamically adapt the modulation and coding scheme to the channel conditions to achieve the highest spectral efficiency.

We propose here a scheme, under which bandwidth allocated for elastic data traffic can be used for voice traffic, if the ongoing data sessions have a minimum bandwidth required to continue the transmission. Consequently, the scheme can improve the bandwidth utilization without violating the QoS of elastic data traffic.

An analytical model to investigate the performance under the joint scheme of AMC and CAC is developed in [1], where three types of calls, new, handoff, modulation-changed calls, are considered. The reservation scheme applied is used by handoff as well as modulation-changed calls. Numerical results show that the proposed scheme reduces the blocking probability of modulation-changed calls. However, only voice traffic service is assumed. In contrast to study [1], here we envisage an integrated case where voice and elastic data flows share the same channels and AMC scheme applies to both of them.

II. DESCRIPTION OF THE ANALYTICAL Model

A. Basic assumptions

The overall cell's frequency interval is divided into M basic frequency channels (Bfc). Each Bfc means the channel with the minimum frequency bandwidth. In order to establish a connection with the AMC mode i, each of the voice calls requires s_i Bfcs, whereas any data session needs t_i Bfcs, $i=\overline{1,2}$.

The network state can be denoted as $(\vec{v},\vec{d})=(v_1,v_2,d_1,d_2)$, where v_i is the number of ongoing voice calls, while d_i presents the number of ongoing data sessions with AMC mode i, $i=\overline{1,2}$.

To achieve the most efficient bandwidth usage, all idle Bfcs are allocated to ongoing data sessions. Let us denote the number of Bfcs that can be used by data sessions as $M'=M-s_{\cdot}v_{\cdot}$, where $s_{\cdot}v_{\cdot}=\sum_{i=1}^{2}s_iv_i$. Besides, the ongoing data sessions occupy M' in proportion to the part of minimum bandwidth usage for each of the AMC mode: $\left\lfloor M'\frac{t_id_i}{t_{\cdot}d_{\cdot}}\right\rfloor$, $i=\overline{1,2}$, where $t_{\cdot}d_{\cdot}=\sum_{i=1}^{2}t_id_i$. To simplify the writing we will also use the notation $v_{\cdot}d_{\cdot}=s_{\cdot}v_{\cdot}+t_{\cdot}d_{\cdot}$. Thus, each of the data sessions with AMC mode i occupies not necessarily integer $n_i(\vec{v},\vec{d})=\left\lfloor M'\frac{t_id_i}{t_{\cdot}d_{\cdot}}\right\rfloor\Big/ d_i$, $i=\overline{1,2}$, Bfcs.

B. CAC scheme's acceptance of the arriving calls

There are three types of calls: handoff call, new call, and AMC changing call, which are modeled as independent Poisson processes.

In this paper we consider a reservation scheme, so an AMC changing call as well as a handoff call takes precedence over a new call. Let g represent the number of reserved Bfcs, $0<g<M$.

A new voice call with AMC mode i will be accepted into the system when current bandwidth usage is less than $M-g$ and the ongoing data sessions will have minimum of Bfcs available to continue transmission after de-allocating s_i of Bfcs to a new voice call: $M-g-v_{\cdot}d_{\cdot}\geq s_i$, $i=\overline{1,2}$.

A handoff voice call with AMC mode i will be accepted if the bandwidth usage of the system is less than M and the ongoing data sessions will have minimum of Bfcs available to continue transmission after de-allocating s_i of Bfcs to a handoff voice call: $M-v_{\cdot}d_{\cdot}\geq s_i$, $i=\overline{1,2}$.

An AMC changing voice call from mode 1 to mode 2 will be accepted into the system if there are enough Bfcs for modulation change $M-v_{\cdot}d_{\cdot}\geq\Delta s$, where $\Delta s=s_2-s_1$, $s_2\geq s_1$, taking in mind possible de-allocation of some Bfcs from ongoing data sessions.

A new, handoff and an AMC changing from mode 1 to mode 2 request for a data session will be accepted if $M-g-v_{\cdot}d_{\cdot}\geq t_i$, $M-v_{\cdot}d_{\cdot}\geq t_i$ and $M-v_{\cdot}d_{\cdot}\geq\Delta t$, where $i=\overline{1,2}$, $\Delta t=t_2-t_1$, $t_2\geq t_1$, respectively.

All the idle Bfcs after changing AMC mode from 2 to 1 are allocated to the ongoing data sessions.

Otherwise, the mentioned voice calls and data sessions in the system will be blocked. After any voice call's service termination all the idle Bfcs are allocated at once to data sessions proportionally and hence data transmission of the sessions continues with higher rate.

C. Load parameters

The arrival voice calls, requests for data session and AMC changing processes are Poisson and the service times assumed to be exponentially distributed with μ_i, presenting the service intensity of one Bfc with AMC mode i. Then, for $i=\overline{1,2}$

- λ_i^{vn} is the arrival rate of a new voice call with AMC mode i
- λ_i^{vh} is the arrival rate of a handoff voice call with AMC mode i

- λ_i^{dn} is the arrival rate of a new request for data session with AMC mode i
- λ_i^{dh} is the arrival rate of a handoff request for data session with AMC mode i
- $\mu_i^{\mathrm{v}} = s_i \mu_i$ is the service intensity of a voice call with AMC mode i
- $\mu_i^{\mathrm{d}}(\vec{v},\vec{d}) = n_i(\vec{v},\vec{d})\mu_i$ is the service intensity of a session with AMC mode i at the state $(\vec{v},\vec{d})$
- μ_i^{vm} is the intensity of a voice call changing AMC from mode i to $|i-2|+1$
- μ_i^{dm} is the intensity of a data session changing AMC from mode i to $|i-2|+1$.

The functioning of the network system is described by Markov process with the state space

$$S = \left\{ (\vec{v},\vec{d}) \mid v_i = \overline{0, \left\lfloor \frac{M}{s_i} \right\rfloor}, d_i = \overline{0, \left\lfloor \frac{M}{t_i} \right\rfloor}, 0 \le v_{\cdot} d_{\cdot} \le M, i = \overline{1,2} \right\}.$$

According to the made assumptions for the Markov process there is a unique steady-state probability distribution $p(\vec{v},\vec{d})$.

Let us define the indicator function

$$u(x) = \begin{cases} 1, x \ge 0, \\ 0, x < 0; \end{cases}$$

and $u^{\mathrm{n}}(\vec{v},\vec{d}) = u(M - g - v_{\cdot} d_{\cdot})$, $u^{\mathrm{n}}(\vec{v},\vec{d}) = u(M - v_{\cdot} d_{\cdot})$.

III. PERFORMANCE MEASURES

The blocking probability of each arrival type of voice calls as well the data session requests and other performance characteristics can be obtained from the steady-state probability distribution.

Let π be the probability that an arriving voice call or data session request is blocked, then $\pi = \sum\limits_{B} p(\vec{v},\vec{d})$, where B is the bounded area, in which the call or request is blocked. In this paper the bounded area is specified for each of the voice call or request for data session.

Let us denote the mean number of voice calls as well as the data sessions in the system as $\overline{N}$. Then,

$$\overline{N} = \sum_{S} (v_1 + v_2 + d_1 + d_2) p(\vec{v},\vec{d}).$$

The mean transmission time of voice calls with AMC mode i, $i = \overline{1,2}$, W_i^{v} is represented by the equation

$$W_i^{\mathrm{v}} = \frac{\sum\limits_{S} v_i p(\vec{v},\vec{d})}{\lambda_i^{\mathrm{vn}}(1 - P^{B_i^{\mathrm{vn}}}) + \lambda_i^{\mathrm{vh}}(1 - P^{B_i^{\mathrm{vh}}}) + \mu_{|i-2|+1}^{\mathrm{vm}} \sum\limits_{S} u^{\mathrm{h}}(\vec{v} + \vec{e}_i - \vec{e}_{|i-2|+1}, \vec{d}) v_{|i-2|+1} p(\vec{v},\vec{d})},$$

while the mean transmission time of the data requests with AMC mode i, $i = \overline{1,2}$, W_i^{d} is derived by

$$W_i^{\mathrm{d}} = \frac{\sum\limits_{S} d_i p(\vec{v},\vec{d})}{\lambda_i^{\mathrm{dn}}(1 - P^{B_i^{\mathrm{dn}}}) + \lambda_i^{\mathrm{dh}}(1 - P^{B_i^{\mathrm{dh}}}) + \mu_{|i-2|+1}^{\mathrm{dm}} \sum\limits_{S} u^{\mathrm{h}}(\vec{v}, \vec{d} + \vec{e}_i - \vec{e}_{|i-2|+1}) d_{|i-2|+1} p(\vec{v},\vec{d})}.$$

Utility with elastic data sessions is calculated by the following equation

$$U^{\mathrm{e}} = \frac{1}{M} \sum_{S'''} s_{\cdot} v_{\cdot} p(\vec{v},\vec{d}) + \sum_{S''} p(\vec{v},\vec{d}),$$

where $S'' = \left\{ (\vec{v}, \vec{d}) \in S \mid t_{\cdot} d_{\cdot} > 0 \right\}$, $S''' = S - S''$.

IV. CONCLUSION

AMC-based CAC scheme for mobile cellular systems was evaluated by means of teletraffic analysis. Markov model for case with elastic data sessions was described.

The main performance characteristics were obtained. Topics of future research are the consideration of general case, extending the number of AMC modes from more than two, buffer for elastic data sessions and a threshold for elastic data sessions.

REFERENCES

[1] Kwon E., Lee J., Jung K., Ryu S. A Performance Model for Admission Control in IEEE 802.16 // WWIC, 2005, pp. 159-168.

[2] Chen W.-Y., Wu C., Lu L.-L. Performance Comparisons of Dynamic Resource Allocation With/Without Channel De-Allocation in GSM/GPRS Networks // IEEE Communications Letters, 2008, vol.7, no.1.

[3] Hong D., Rappaport S. Traffic Model and Performance Analysis for Cellular Mobile Radio Telephone Systems with Prioritized and Nonprioritized Handoff Procedures // IEEE Transaction on Vehicular Technology,1986, vol.35.