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Editors

Advances in Ubiquitous Networking 2

Proceedings of the UNet'16

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A Welcome Message From the General Chairs

It is our pleasure to welcome you to the 2016 edition of the International Symposium on Ubiquitous Networking, UNet'16. The conference will be held in the city of Casablanca, Morocco, from May 30 to June 1, following the success of last year's first edition. Morocco counts a growing and active community of networking researchers and the choice of Casablanca for UNet'16 allows its attendants, coming from all parts of the globe, to interact in a fascinating environment.

The growth of pervasive and ubiquitous networking in the past few years is unprecedented. Nowadays, a significant portion of the world's population is connected to the Internet most of the time through smart phones, and the Internet of Things promises to broaden the impact of the Internet to encompass devices ranging from electric appliances and medical devices to unmanned vehicles. The goal of UNet is to be a premier forum to discuss technical challenges and solutions related to such a widespread adoption of networking technologies, including broadband multimedia, machine-to-machine applications, Internet of Things, sensor networks, and RFID technologies. To this aim, we count with a main technical track of papers, together with three special sessions on smart cities, big data, and unmanned aerial vehicles.

The UNet'16 program features five special talks addressed by distinguished keynote speakers: Prof. Mohamed-Slim Alouini from KAUST (Saudi Arabia), Prof. Eitan Altman from INRIA (France), Prof. Mehdi Bennis from Oulu University (Finland), Prof. Mohammed Essaaidi from Mohammed V University (Morocco), and Prof. Marwan Krunz from University of Arizona (USA). It also counts with an industrial panel lead by Prof. Latif Ladid, Founder and Chair of the IPv6 Forum and the 5G World Alliance, about new trends and industrial efforts in IPv6, 5G, Internet of Things, and SDN.

With a rich program that reflects on the most recent advances in ubiquitous computing, involving a broad range of theoretical tools (e.g., game theory, mechanism design theory, learning theory, etc.) and practical methodologies (e.g., SDR/SDN platforms, embedded systems, etc.) to study modern technologies (e.g., LTE-A, LTE-B, 5G), we are very pleased to welcome you to this second edition of UNet.

We are very grateful to our technical sponsors, without whom UNet would have not been viable. We thank the IPv6 Forum, 5G World Alliance, IEEE COMSOC 5G Mobile Wireless Internet Emerging Technologies Subcommittee, IEEE COMSOC Internet of Things Emerging Technologies Subcommittee and the IEEE COMSOC Software Defined Networking and Network Functions Virtualization Emerging Technologies Subcommittee. Among our Morocco collaborators, we are especially thankful to the IEEE Morocco Section, the COMSOC Morocco Chapter and the International University of Casablanca.

Enjoy the conference!

Sincerely
UNet'16 General Chairs
Rachid El-Azouzi, Daniel Sadoc Menasché
Essaïd Sabir and Hicham Medromi

A Welcome Message From the TPC Chairs

It is with great pleasure that we welcome you to the 2016 International Symposium on Ubiquitous Networking (UNet 2016) in Casablanca, Morocco. You will find an interesting technical program of three technical sessions reporting on recent advances in context-awareness, autonomy paradigms, mobile edge networking, virtualization, and discussing the enablers, the challenges, and the applications of ubiquitous communications and networking in today's and future contexts. UNet'16 also features five keynote speeches by world-class experts, an industry panel covering the new trends and the industrial efforts in IPv6, 5G, Internet of Things, and software-defined networking, and three special sessions on smart cities and urban informatics for sustainable development, unmanned aerial vehicles theory and applications, and big data applications and solutions.

We have received 144 paper submissions from 15 countries. From those, 44 were accepted as main track papers and 12 were accepted as special session papers, after a careful review process to be included in UNet'16 proceedings. The overall acceptance rate of full papers in the UNet'16 main tracks is 36 %, 38 % including special sessions.

The preparation of this excellent program would not have been possible without the dedication and the hard work of the different chairs, the keynote speakers, and all technical program committee (TPC) members and reviewers. We grasp the opportunity to acknowledge their valuable work, and sincerely thank them for their help in ensuring that UNet 2016 will be remembered as a high-quality event.

We hope that you will enjoy this edition's technical program, and we look forward to meeting you in Casablanca.

Sincerely
UNet'16 TPC Chairs
Mustapha Benjillali, Francesco De Pellegrini and Mehdi Bennis

Contents

Part I
Main Track 1: Context-Awareness and Autonomy Paradigms

The Allocation in Cognitive Radio Network: Combined Genetic Algorithm and ON/OFF Primary User Activity Models

Yasmina El Morabit, Fatiha Mrabti and El Houssein Abarkan

Abstract Cognitive radio (CR) has appeared as a promising solution to the problem of spectrum underutilization. Cognitive radio user (CU) is an intelligent equipment who scent the spectrum which is licensed to primary radio users (PUs) when it is idle and use it with other CUs for their communication. Thus by modeling PUs activity, CUs can predict the future state ON or OFF (busy or idle) of PUs by learning from the history of their spectrum utilization. In this manner, CUs can select the best available spectrum bands. On this point, many PU ON/OFF activity models have been proposed in the literature. Among this models, Continuous Time Markov chain, Discrete Time Markov chain, Bernoulli and Exponential models. In this paper, we firstly compare these four models in term of better numbers of OFF slots to deduce which model give best performance of available resources. Then, the activity history patterns generated from each model are combined with the genetic algorithm as sensing vectors to select the best available channel in terms of quality and least PU arrivals.

Keywords Cognitive radio · Allocation · Primary user ON/OFF models · Continuous time markov chain · Discrete time markov chain · Bernoulli model · Exponential model · Genetic algorithm · Optimization

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1 Introduction

The rapid development of wireless communication technologies is seriously challenged by the spectrum scarcity and spectrum underutilization problem. According to some studies sponsored by Federal Communications Commission, in certain geographical areas, many frequency bands that are regulated by the traditional fixed spectrum allocation policy are not occupied in most of the time. However, the Cognitive Radio (CR) has appeared as the promising technology to improve the spectrum usage efficiency.

In cognitive radio network (CRN), two types of users exist, one is primary radio user (PU) and the other is cognitive radio user (CU) which is also called secondary user (SU). The CU is considered to be intelligent and self-managing radio user that operate in a decentralized pattern without the need of a central base station. PU has licensed spectrum on which it operates while CU has no licensed spectrum and it operates either on unlicensed spectrum or on PU licensed spectrum when it is idle. If PU arrives on its spectrum band (channel) while CU is utilizing it, then CU has to vacate this spectrum immediately without causing interference to PU and to switch to another available idle channel. Thus, by modeling PU activity with ON/OFF models, In such ON/OFF models a given channel is either occupied (ON state) by the PUs and is unavailable for CUs, or vacant (OFF state) indicates that a channel is free, so it can be utilized by CU. CU can predict the future state (ON or OFF) of the PUs by learning from the history of their spectrum utilization. In this manner, CUs can assign best available channel for their communication. Due to this fact, PU activity modeling is very important for the performance of CRN. In this point of view, many PU ON-OFF activity models have been proposed in the literature [1–3]. Among these models, there are four (4) we're going to study: Continuous Time Markov chain (**CTMC**) [2, 4–6], Discrete Time Markov chain (**DTMC**) [7, 8], Bernoulli (**BN**) process [9–11] and Exponential (**Exp**) model [3]. The lengths of the ON and OFF periods being random variables following some specified distributions.

In **CTMC** model, the time spent is modeled as continuous random variables between transition states. It makes two hypotheses, the first, if the current state is i, the time will be exponentially distributed until the next state transition, the second, if the current state is i, the next state will be j with probability P_{ij} which will be independent of past history of previous state and process until the next transition. In **DTMC**, the state changes at discrete time intervals and they are determined by transition matrix and probability matrix [1]. **Exp** process is a random process which depends on a particular factor called ON-OFF mean time and tells how long ON/OFF time will be. It serves as input to the function in generating random ON-OFF period time in depicting PU behavior [3]. Lastly, **BN** process is a sequence (finite or infinite) of binary random variables which takes only two values, 0 or 1 corresponds to OFF and ON states respectively. These states change according to independent and identically distributed Bernoulli process.

In **CTMC** based modeling it is assumed that CUs observe the system state continuously and can detect randomly arriving PUs. On the contrary, in **DTMC** model, CUs perform the sensing periodically relying in discrete time instants to observe the system state and therefore they cannot instantly detect PUs arriving between sensing instants. Similarly, in the **Exp** and **BN** models, the sensing is done in discrete and probabilistic manner. However, **CTMC** model will not lose the listening of the channel during the sensing process contrary to other models. So, it must yield better results in OFF slots.

The purpose of these models is to provide a realistic model of PU activity pattern which is considered in the network by CUs in taking decisions about spectrum by selecting the best available channel in terms of quality (such as transmission power (POW), bit error rate (BER), etc.), and least PU arrivals. These diverse factors with contradictory objectives bring the channel selection problem inside the domain of multi-objective optimization problem. The most popular approach to solve such problems is the genetic algorithm (GA). The GA optimizes the multiple parameters of a problem in parallel and provides the optimal solution for a given problem.

The GA is a search algorithm based on the principles of natural selection and genetics. It relies upon evolving a set of solutions, represented by the so-called chromosomes, over a period of time. Eventually, through the GA operators (selection, crossover and mutation) a good solution will be found by combining different possible solutions [12].

In this paper, we have firstly performed a comparative study of these four ON/OFF PU activity models in term of the average of ON and OFF state durations of each model, to deduce which model gives better resources of idle slots to give the CU the leverage to utilize them. The history channel patterns maintained from each model is used as a sensing vector to calculate the Cognitive User Opportunity Index (CUOI), and we used it as the new information gene to the same structure of chromosome used in our previous work [13]. Thus, our proposal takes into account the behavior of PU in the channel to find the optimal channel with least PU activities and with the quality required by the CU. The comparison of the performance of each model combined with the GA is showed in Matlab. The simulation results show that a combined allocation model based CTMC and GA outperforms other models in term of the average fitness value.

2 Problem Formulation

We consider a system with M channels; each channel is divided into N slots. Let $Z^k(t)$ denote the state ON or OFF of a channel k at time t and a sample ON/OFF period correspond to the value 0/1. The sensing produces a binary random sequence for each channel (Fig. 1).

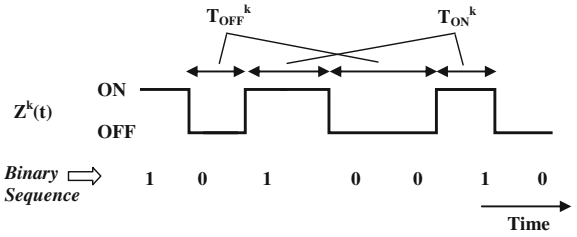

Fig. 1 ON/OFF PU activity

2.1 PU ON-OFF Models

The ON/OFF channel usage model specifies a time slot in which the PU signal is occupying or not occupying a channel. Source alternating between states ON (busy) and OFF (idle).

ON-OFF DTMC Model. The DTMC is a stochastic process $\{X_t, t = 0, 1, 2\ldots\}$ takes a finite number of possible values, represented by a transition matrix P. If $X_t = i$, then the process is said to be in state i at time t, and the probability P_{ij} that it will next be in state j is $P_{ij} = P(X_1 = j \mid X_0 = i)$. So we have that $P_{ij} = P(X_1 = j \mid X_0 = i) = P(X_{t+1}=j \mid X_t = i)$ for all $t \geq 0$ [14, 15].

The transition probability matrix P of this channel is assumed to be known and does not change, which can be represented by a 2×2 matrix as shown in Eq. (1) for the case of a single channel [7].

$$P = \begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix} \tag{1}$$

Where P_{00} is the probability of the channel to remain in the busy state, P_{01} is the probability of the channel to change from busy state to idle state, P_{11} is the probability that the channel remain in the idle state and P_{10} is the probability that the channel change from idle to busy state (Fig. 2).

The cumulative distribution function (CDF) of the ON and OFF durations adopted from the Ref. [3] and expressed by Eqs. (2) and (3) respectively:

$$T_{ON}(n) = \lim_{n \to N} \sum_{i=n}^{N} P_{01} P_{00}^{i} \tag{2}$$

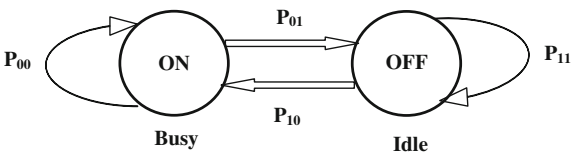

Fig. 2 ON-OFF two states discrete Markov model for a single channel

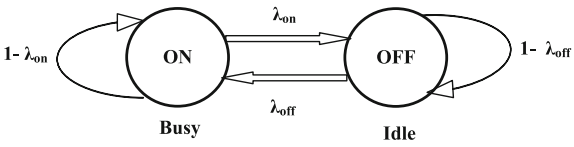

Fig. 3 ON-OFF two states continuous Markov model

$$T_{OFF}(n) = \lim_{n \to N} \sum_{j=n}^{N} P_{10} P_{11}^{j} \tag{3}$$

With $n = \{1, 2 \ldots N\}$.

ON-OFF CTMC Model. CTMC behave much like DTMC, with the key difference that the jumps between states take place at random times rather than at fixed steps. Characterized by:

- The amount of time spent in state i is an exponential distribution with mean λ.
- When the process leaves state i, it next enters state j with transition rate q_{ij} (Fig. 3).

Let λ_{on} be the flow rate from zero to one and λ_{off} be the flow rate from one to zero. The transition rate matrix is given by:

$$Q = \begin{bmatrix} -\lambda_{on} & \lambda_{on} \\ \lambda_{off} & -\lambda_{off} \end{bmatrix} \tag{4}$$

Mathematically, the durations for PU to stay in ON state and in the OFF state follow two independent random variables which are given to be exponentially distributed, with probability distribution functions [16]:

$$f_{on}\left(T_{on}^{k}\right) = \lambda_{on} e^{-\lambda_{on} T_{on}^{k}} \tag{5}$$

$$f_{off}\left(T_{off}^{k}\right) = \lambda_{off} e^{-\lambda_{off} T_{off}^{k}} \tag{6}$$

where (λ_{on}, λ_{off}) are the mean parameters for the exponential distributions.

ON-OFF Bernoulli Model. The probability density function for Bernoulli process given by:

$$f(x) = p^{x}(1-p)^{(1-x)} \tag{7}$$

where $x \in \{0,1\}$, p is the probability of channel in ON state and $(1 - p)$ is the probability of channel in OFF state.

ON-OFF Exponential Model. Mathematically the ON and OFF durations are represented as [3]:

$$f_{on}\left(T_{on}^{k}\right) = \lambda_{on} e^{-\lambda_{on} T_{on}^{k}} \tag{8}$$

$$f_{off}\left(T_{off}^{k}\right) = \lambda_{off} e^{-\lambda_{off} T_{off}^{k}} \tag{9}$$

2.2 Genetic Algorithm

The structure chromosome of our scheme consists of 5 genes with different size and characteristics. We utilize the same genes from our previous work [13]: FB (frequency band), PWR (power), BER (bite error rate) and MOD (modulation). In this study we added a new gene CUOI (Table 1). The CUOI is represented between 0 to 1 considering 4 bits and 16 possible levels ranging from 0000 to 1111.

Table 1 Structure of the chromosome

FB	PW	BER	MOD	CUOI
5bits	4bits	4bits	2bits	4bits

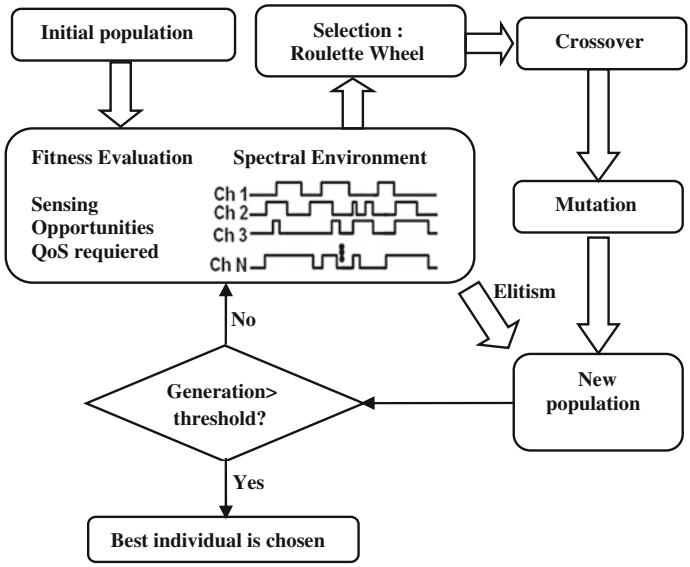

Fig. 4 Flowchart of GA scheme

The Fig. 4, show the flowchart of the proposed genetic algorithm (GA) formulation.

The fitness function of the new added gene can be represented using Eq. (10) as given in [17]:

$$f_\gamma = \frac{\gamma}{\gamma_{max}} \tag{10}$$

Where:

- γ is future channel usage opportunity for the CU, is presented by the following equation:

$$\gamma(t) = e^{-Z_k^t} \tag{11}$$

- Z_k^t The history channel vector of K_{th} channel at the instant t, which maintain the idle/busy state of a channel k. It can be represented as follows:

$$\mathrm{Z_k^t} = \left\{\mathrm{Z_k^1}, \mathrm{Z_k^2}, \ldots, \mathrm{Z_k^t}\right\} \tag{12}$$

- γ_{max} Indicates the maximum value of the CUOI.

The overall fitness function value of chromosome F can be calculated as cumulative sum of individual fitness value f_i of all the genes. This value is obtained by:

$$F = \sum_{i=1}^{5} w_i f_i \tag{13}$$

where, $w = [w_{FB}\, w_{PWR}\, w_{BER}\, w_{MOD}\, w_{CUOI}]$ is a weight vector. In current article, we utilize the following weights, $w_{CUOI} = 0.5$ and remaining 0.5 is equally divided among other four objective functions.

3 Simulation Results

In order to analyze the performance of the ON/OFF behavioral pattern of primary users (PUs) in the investigated models: CTMC, DTMC, Exponential (Exp) and Bernoulli (BN) models, five simulation scenarios was carried out using Matlab software. These simulations show the availability of resources in terms of unused slots.

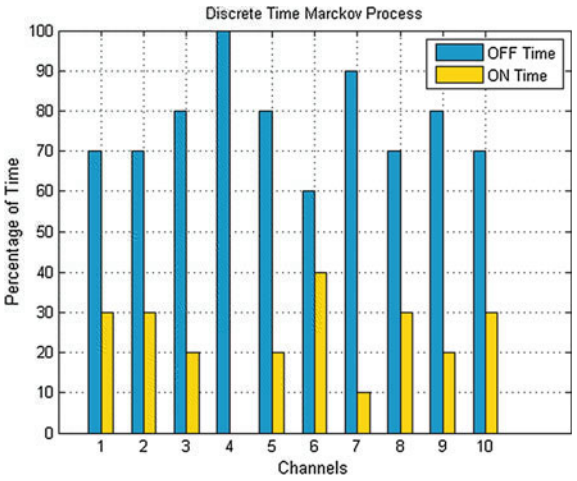

Fig. 5 PUs ON-OFF DTMC behavior

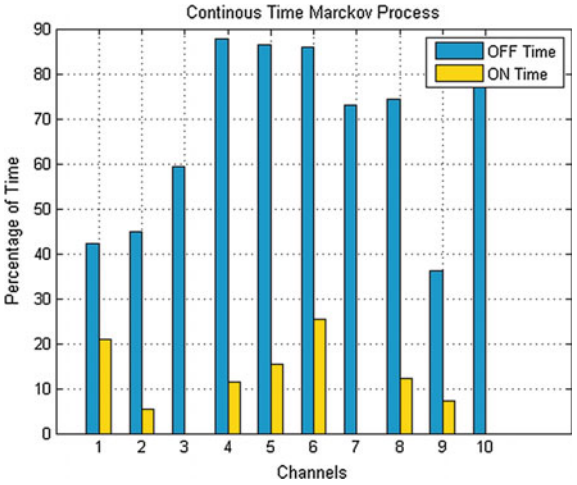

Fig. 6 PUs ON-OFF CTMC behavior

In the simulation we consider the parameters: $M = 10$ channels, $N = 10$ slots, the transition matrix P for the Markov models was chosen from [3], $P = [0.8866, 0.1134; 0.5309, 0.4691]$, exponential parameters rate $\lambda_{ON} = 0.2$ and $\lambda_{OFF} = 0.5$ and the probability $p = 0.5$ for the Bernoulli model. The Figs. 5, 6, 7 and 8 gave a percentage usage of ON/OFF time for each of the PUs slots in CTMC, DTMC, Exponential and Bernoulli models respectively.

The simulation results show that the percentage usage of the channels revolves between 10 and 40 % in DTMC. While in CTMC model it revolves around 0 and

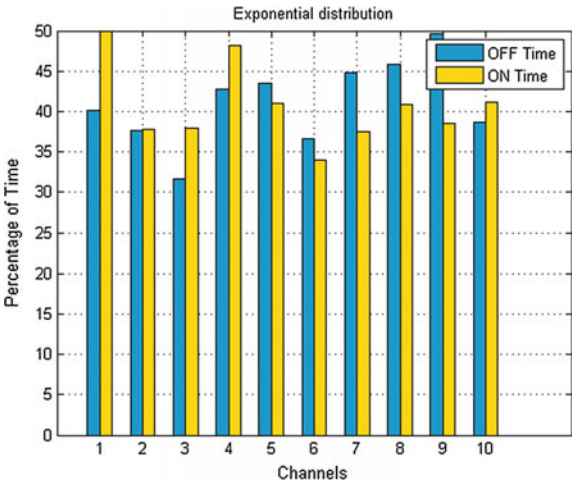

Fig. 7 PUs ON-OFF exponetial behavior

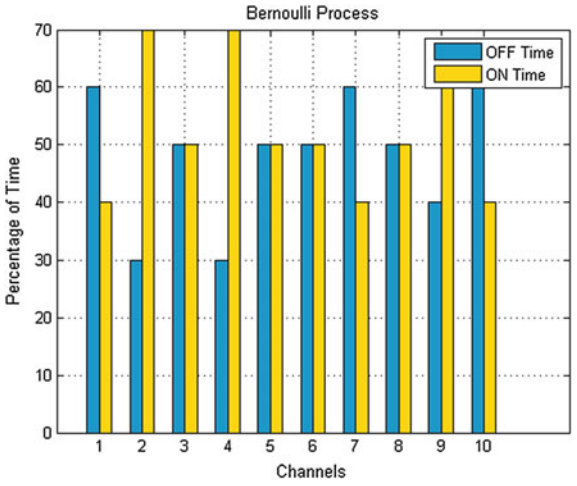

Fig. 8 PUs ON-OFF Bernoulli behavior

25 %. Contrariwise in Exp and BN models, the usage exceeds 40 %. However CTMC and DTMC are relatively reliable in terms of OFF slots than Exp and BN models with some difference between the Markov models, which is explained by the continuous sensing in the case of CTMC model (Fig. 6).

Figure 9 shows an average time for each model: an average of 85 % of available resources found in CTMC model, and 80 % in DTMC model, which agrees with [3] views about DTMC behavior. However, for both models, Exponential and Bernoulli there is no stable average of available resources.

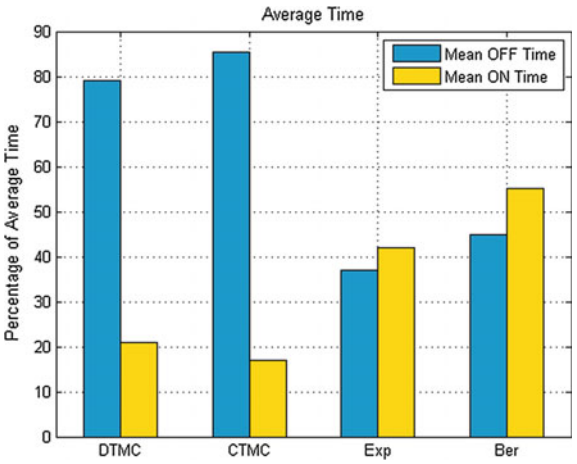

Fig. 9 Average PUs ON-OFF time for four behaviors

Table 2 Simulation parameters

Parameter	Value
Population size	20
Crossover rate	0.8
Mutation rate	0.003
Iterations	300

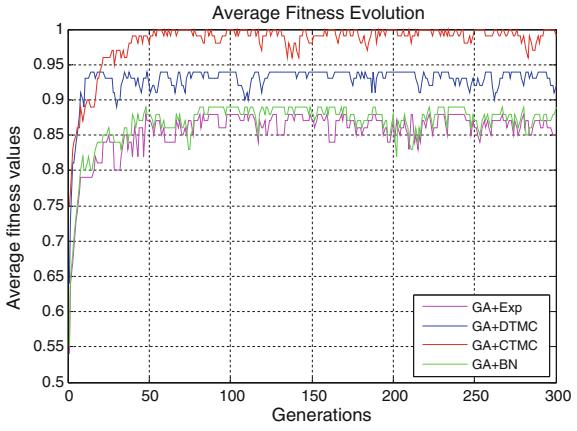

Fig. 10 The compare of average fitness value evolution between the four combined models

These results show that Markov models based on CTMC yielding potentially better results in OFF slots. Because in CTMC based modeling it is assumed that CUs observe the system state continuously and can detect randomly arriving PUs without lose of the listening contrary to other models. So, CTMC can be used for the prediction of the activities of PUs.