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# *A Sub-Optimal Policy for Connection Admission Control Mechanism in Cognitive Radio Sensor Networks*

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*Abstract*— **Satisfying the quality of service (QoS) is a crucial issue in cognitive radio sensor networks (CRSNs) due to the highly variable nature of cognitive radio channels. Connection admission control (CAC) is a beneficial approach to manage the traffic to provide desired QoS. A CAC is proposed in this paper to optimize the packet loss ratio, jitter of packets and end to end delay in CRSNs. The proposed CAC decides based on the priority of data flows, network state and number of available channels. An estimation formula is proposed through a graph coloring approach to evaluate the required number of channels of network states. The proposed CAC is modeled by a semi Markov decision process (SMDP) and a sub-optimal policy is obtained by a value iteration method to achieve the maximum reward in network. Simulation results demonstrate that the proposed mechanism outperforms the recent proposed admission control mechanism in CRSNs.**

***Keywords- Cognitive radio sensor networks; admission control; QoS; semi Markov decision process (SMDP);***



## I. INTRODUCTION

Dynamic spectrum access (DSA) is one of the main solutions to use the spectrum in wireless networks efficiently. The cognitive radio (CR) is a precious technology to provide DSA in order to solve the spectrum scarcity problem. The primary users (PUs) are the licensed users which have higher priority to use channels. The CR-equipped users can use the unlicensed spectrum bands in the absence of PUs according to basic cognitive radio operations: spectrum sensing, spectrum decision and spectrum handoff [1]. A CR user senses the channels periodically (spectrum sensing), if a PU enters into its licensed channel, the CR user leave the channel immediately in order to minimize the interference on the transmission of PUs (spectrum handoff) and decide to select another free channel (spectrum decision) [1].

There are some applications such as industrial control and surveillance in wireless sensor networks which have some specific features such as delay sensitivity and burst traffic. With regard to these features and the requirements of wireless sensor networks, these networks can use the benefits of the CR technology in order to satisfy these requirements and to overcome the spectrum scarcity problem. The wireless sensor networks with CR-equipped nodes are entitled as cognitive radio sensor networks (CRSNs)

[2]. Because of the burst nature of the sensor network traffic and the high dynamicity of the cognitive channels, it is needed to manage the traffic of CRSNs. Admission control is a crucial mechanism for providing QoS when there are many requesting users to access the network with the limited resources simultaneously. The connection admission control (CAC) is a pro-active congestion control which estimates the network resources and then decides about data flows transmission.

There are some studies on CAC in cognitive radio networks (CRNs). The authors of [3] considered a joint admission control and channel allocation using a Markov decision process to support the delay sensitive communications of CR users. In [4], three admission control schemes are proposed using discrete-time Markov chain to minimize the forced termination probability of CR users. A joint admission control, eviction control and bandwidth management framework is proposed in [5] using semi Markov decision process. In [6], a CAC framework is proposed based on channel reservation for CR users and the buffer size of handoff operation in order to analyze the dropping and blocking probabilities. The authors of [7] considered joint admission control, scheduling and spectrum handoff in order to improve the performance of multimedia transmissions using a Markov model. These studies proposed some admission control schemes along with cognitive channel allocation, or scheduling, or spectrum handoff or bandwidth management that are related to admission control in the lower layers of the network. However, the connection admission control mechanisms in higher layer focus on the data flows and prefer to send fewer valuable data flows reliably rather than to send several data flows incompletely. This feature of connection admission control leads to improve the event reliability in CRSNs.

To the best of our knowledge, there is only one study on connection admission control in CRSNs which is [3]. The proposed CAC in [3] is based on the correlations of data flows and the traffic characteristics of CRSNs. In [3], the admission control mechanism decides based on the average capacity of CR channels and defined event reliability metric. The proposed admission control mechanism in [3] estimates the network resources on average and does not decide based on the considering of network state at each decision instance.

The contribution of this study is the propose of a CAC mechanism in CRSNs based on the priority of data flows and the required resources of each data flow and also, the network state which composes of the number of active PUs, the ID and then the number of flowing CR sensors at each decision instance. This mechanism is formulated as a semi Markov decision process (SMDP) in order to reach an optimal decision making framework for each state during network lifetime. In the proposed mechanism, the number of required channels for each data flow is estimated by a graph coloring approach at each decision instance. According to this resource estimation, the network state and the optimal decision at each state are determined. The aim of this admission control is to send the maximum number of valuable data flows by considering the available network resources at each decision instance. On the other hand, when PU activity is high and the network resources are limited, sending a few valuable data flows is desirable in order to inform more valuable information of event toward the sink. The optimal decision policy of the proposed SMDP model is obtained through value iteration method. The simulation results represent the superiority of the proposed CAC mechanism over the last proposed admission control in CRSNs in the terms of packet loss probability, end to end delay and jitter.

The rest of this paper is organized as follows. Section 2 states the system model. The problem definition, formulation and solution are explained in Section 3. Simulation results are presented in Section 4, and finally, the paper concludes with some remarks in Section 5.

## II. System Model

This paper considers a cognitive radio sensor network with three types of nodes, CR sensor nodes, CR relay nodes and a sink node that are placed within a certain finite area to provide multiple views. The number of CR sensor users, CR relay nodes and PUs are considered as $N_S$, $N_R$ and $N_{PU}$, respectively. With regard to the occurred event in the event area, some sensors request to send a data flow toward the sink. According to the physical conditions of the event and sensor nodes such as sensors' location, the distance of sensors to occurred event, and also their angle of view to the sensing area, the induced data flows of different sensor nodes have different importance. Therefore, the different weights are assumed for requesting data flows to send that are obtained by the proposed weighting scheme in [3]. It is assumed that these sensors generate constant bit rate (CBR) data flows [8]. The sink node has the knowledge about sensor nodes to decide on the admission of data flows. A CR node has two main operating modes: sensing mode and operating mode. First, a CR node senses the licensed spectrum to decide whether it is idle or occupied by a PU. Sensing time and sensing frequency are denoted by $t_s$ and $f_s$, respectively [9]. After sensing, the CR node enters in operating mode and sends data in a licensed spectrum channel if it is free of PU. The PUs activity is modeled as exponentially distributed inter-arrivals thus their arrival to their related channels is independent. The traffic of a PU can be modeled as a two-state arrival-departure process with arrival rate $r_a$ and departure rate $r_d$. A PU has two states: ON and OFF [10]. The ON state represents the period that PU operates on a channel, and CR node cannot use the channel. The OFF state represents the period that the PU does not operate on a channel, and CR nodes can use the channel. There are CH cognitive channels with the same bandwidth. For each channel, there is a PU ($N_{PU} = CH$) and all of the CR channels have similar PU activity. In each channel, a PU operates based on its arrival rate ($r_a$) and departure rate ($r_d$). When a PU starts to operate on its licensed channel, the operations of each active CR node on the licensed channel in the CRSN will be stopped. In other words, the activity of all CR nodes in the CRSN is affected by the PUs activity.

**Table 1. Notation Table**

| Parameter | Meaning |
|---|---|
| $N_S$, $N_R$, $N_{PU}$ | Number of CR sensor users, primary users (PUs), CR relay nodes |
| $CH$ | Number of CR channels |
| $r_a$, $r_d$ | Average arrival rate of each PU to the channel, average departure rate of PU from the channel |
| $w_i$ | Weight of the $i$'th sensor node |
| $r_i$ | Rate of the $i$'th sensor node |
| $\mathbf{n}(t)$ | Admission condition vector of the flows at decision epoch $t$ |
| $\mathbf{a}(t)$ | Admission decision vector at decision epoch $t$ |
| $q(t)$ | Number of active PUs in the network at decision epoch $t$ |
| $s(t)$ | Network state at decision epoch $t$ |
| $P_{i,d}$ | Probability of using route $d$ related to sensor $i$ |
| $K_i$ | Number of possible routes between the sensor node $i$ and the sink node |
| $\Omega(n)$ | Minimum number of required channels in each possible routes configuration |
| $\gamma(\mathbf{n})$ | Optimal average required number of channels at state $s = (n, q)$ |
| $P_{s,x}(a)$ | Probability of transition from state $s$ to state $x$ by selecting the action $a$ |
| $m_s(a)$ | Decision variable of selection the action $a$ at the state $s$ |
| $\Pi$ | Function of mapping the state space to the acceptable action space |
| $\tau_s(a)$ | Average time after the action $a$ is selected in state $s$ until the next decision epoch (sojourn time) |
| R(s,a) | Earned reward at the state $s$ and selection of the action $a$ |
| $\psi$(CR) | Worthless CR user who is transmitting data packets toward the sink node |

## III. Problem Definition and Formulation

In a cognitive radio sensor network, several sensors are deployed in the event area to provide multiple observations of an event. When an event occurs, depending on the event place and sensing radius, some of the sensor nodes send data flows toward the sink node. Due to the constraints of the cognitive channels, sending all of these flows cannot be reasonable. Furthermore, it is needed to inform the sink node some information about the event. Therefore, a connection admission control is needed to provide the QoS of the cognitive radio sensor network.

The SMDP is a powerful tool in analyzing stochastic decision control processes satisfying Markov features with random decision epochs. The SMDP has a lot of potential applications in telecommunication, reliability control and maintenance [11]. In an SMDP, the system is in one of the states of a finite state set in each decision epoch. There is a finite action set for each state. The system state evolves in different the decision epochs according to a transition probability matrix which depends on the current system state and selected action from the action set. According to the selected action in each state transition, a cost/reward is obtained. The aim is to optimize the long-term average cost/reward [11].

With regard to SMDP properties, the considered problem and network assumptions, the appropriate theory to model the decision making process for this admission control is SMDP. It is necessary to identify SMDP components related to this problem that are introduced in the next subsections. The notations which are used in this model are listed in Table. 1.

### A. State Space

The system state represents some network information at the beginning of each decision epoch. Define row vector $\mathbf{n}(t) = [n_1(t), n_2(t), \cdots, n_N(t)]$ where $n_i(t) \in \{0,1\}$ denotes the admission condition of the induced data flow from sensor $i$ in the event area at the decision epoch $t$. The $n_i(t) = 1$ represents the sensor node $i$ has been admitted to send and is sending data flow toward the sink node. Also, the $n_i(t) = 0$ represents the sensor node $i$ has not been admitted to send data. Define $q(t)$ as the number of active PUs in the network at the decision epoch $t$. The network state is given by $\mathbf{s}(t) = (\mathbf{n}(t), q(t))$ at the decision epoch $t$ and also, is given by $\mathbf{s} = (\mathbf{n}, q)$ in steady state. The average number of required channels for each network state is considered as function $\gamma(\mathbf{n})$. Thus, the number of used channels by admitted flows plus active PUs should be less than $CH$. Therefore, the state space $S$ can be defined in Equ. 1.

$$S = \left\{ \mathbf{s} = [\mathbf{n}, q] : n_i \in \{0,1\}, 0 \le q \le CH, \gamma(\mathbf{n}) + q \le CH \right\} \tag{1}$$

The details of the function $\gamma(\mathbf{n})$ will be described in the next subsection.

### B. Average Number of Required Channels

The main responsibility of admission control is to estimate the network resources and make decisions based on the needs of users and available network resources. The number of CR free channels is one of the main network resources in CRSNs that should be estimated in order to decide about the admission of data flows.

In order to send sensors' data toward the sink node, some CR channels are required. The number of these required channels depends on the system state, routing protocol and network topology (contending node number). The system state represents which sensors are sending their information toward the sink node. We consider the steady state behavior of routing protocol. In this way, a node selects one of the next hop nodes with a certain probability which does not change rapidly over time [12].

Therefore, for each sensor node, there are several possible routes toward the sink node. In order to decide about the admission of data flows in the network optimally, the optimal number of required channels should be estimated so that minimizing the

data packet collision. Assume there are $K_i$ $(0 \le i \le N_S)$ possible routes between the sensor node $i$ and the sink node. The sensor $i$ uses its possible route $d$ with the probability of $P_{i,d}$. Therefore, there are $\prod_{i=1}^{N_S}(K_i)^{n_i}$ possible combinations of routes for the data flows of admitted sensor nodes at each network state. Each possible combination of routes of the network state forms a network sub-graph. At each considered network sub-graph, the nodes have different number of contending nodes in the transmission of data packets to the sink node. In order to decrease the data packet collision, the optimal number of required channels at each possible combination of routes can be determined according to the maximum number of contending nodes of the nodes in the considered sub-graph. The problem of finding the optimal required number of channels at each possible combination of routes can be modeled by graph coloring approach. According to vertex coloring, different colors are assigned to each two adjacent vertex of the graph [13]. Each color label is equivalent to a CR free channel. The minimum number of required colors at each possible combination of routes can be considered as the minimum number of required channels.

Assume the minimum number of required channels at each possible routes configuration is considered as $\Omega(i_1 n_1, i_2 n_2, \cdots, i_{N_S} n_{N_S})$ where the $i_1, i_2, \cdots, i_{N_S}$ are the selected route indexes of sensor 1, sensor 2, ... , sensor $N_s$, respectively and also the $n_i \in \{0,1\}, i = 1, 2, \cdots, N_S$ is the admission state of the sensor $i$ which is described before. The value of the product $i_b n_b$ will be zero when sensor $b$ is not admitted and will be $i_b$ when sensor $b$ is admitted. The notation of $I_b$ is considered for the product $i_b n_b$.

According to these definitions, the optimal average required number of channels at each state $(\gamma(\mathbf{n}))$ can be calculated by Equ. 2.

$$\gamma(\mathbf{n}) = \sum_{i_1=1}^{K_1}\sum_{i_2=1}^{K_2}\cdots\sum_{i_{N_S}}^{K_{N_S}}\left\{\left(P_{1,i_1}\right)^{n_1}\left(P_{2,i_2}\right)^{n_2}\cdots\left(P_{N_S,i_{N_S}}\right)^{n_{N_S}} \times \Omega(I_1, I_2, \cdots, I_{N_S})\right\} \quad (2)$$

The value of $\Omega(I_1, I_2, \cdots, I_{N_S})$ is calculated by the minimum number of colors required for the network graph when the sensors $1, 2, \cdots, N_S$ are sending data packets in their $i_1, i_2, \cdots, i_{N_S}$ routes toward the sink. Therefore, the $\gamma()$ is the function of network state.

### C. Action Space

At each decision epoch, an action $a$ is selected as the result of the admission control decision for the next epoch. The action $a$ at decision epoch $t$ can be defined as $\mathbf{a}(t) = [a_1(t), a_2(t), \cdots, a_N(t)]$. The $a_i(t) = 1$ represents the sensor $i$ is admitted for sending data flow at decision epoch $t$ and the $a_i(t) = 0$ represents the rejection decision about this flow. Hence, the action space $A$ can be defined as

$$A = \left\{\mathbf{a}: a_i \in \{0,1\}, 0 \le i \le N_S, \sum_{i=1}^{N_S} a_i \le 1\right\} \quad (3)$$

The $\boldsymbol{a} = [0, 0, \ldots, 0]$ means that no data flow is admitted. At each decision epoch, the admission control mechanism decides about the admission of the sensors' sending request and at most admits one of the requesting sensors' data flow. For each state, a subset of the action set $A$ is valid; thus an action space for each state $s \in S$ can be defined as

$$A_s = \left\{\mathbf{a} \in A: \mathbf{s} = [\mathbf{n}, q], [\mathbf{n} + \mathbf{a}, q] \in S\right\} \quad (4)$$

### D. State Transition

Assuming the states $\mathbf{s} = [\mathbf{n}_s, q_s]$ and $\mathbf{x} = [\mathbf{n}_x, q_x]$, the transition probability $P_{sx}(a)$ is the probability of transition from state $s$ to state $x$ by selecting the action $a$. There are some kinds of events in this admission control mechanism; (I) PU arrival to a channel that is free of CR user, (II) PU arrival to a channel that is using by a CR user and the CR user leaves the channel, (III) PU departure from a channel, and (IV) CR user arrival. When a PU departs from related channel, there is at least a CR user request in the queue to use this free channel. The event rates of the mentioned events are $\sum_{i=1}^{N_S} r_a \delta\left(CH - \gamma(n_x) - q_x\right)$, $\sum_{i=1}^{N_S} r_a\left(1 - \delta\left(CH - \gamma(n_x) - q_x\right)\right)$, $\sum_{i=1}^{N_S} q_s r_d$, $\sum_{i=1}^{N_S} a_i r_d\left(1 - \delta\left(CH - \gamma(n_x) - q_x\right)\right)$, respectively, where the function $\delta(i)$ can be defined as follows

$$\delta(i) = \begin{cases} 1 & i \ge 0 \\ 0 & i < 0 \end{cases}$$

These events are independent Poisson processes, thus sum of these events follows the Poisson process too [14]. The total event rate of this system is the sum of event rates of the events (I), (II), (III) and (IV). Therefore, the inter-event time of this model is the reverse of total event rate. This inter-event time can be defined as the expected sojourn time of the SMDP. The sojourn time is the average time after action $a$ is selected in current state $s$ until the next decision epoch $(\tau_s(a))$.

$$\tau_s(a) = \left\{\sum_{i=1}^{N_S} r_a + \sum_{i=1}^{N_S} q r_d + \sum_{i=1}^{N_S} a_i r_d\right\}^{-1} \quad (4)$$

The transition probabilities can be derived using the decomposition property of the Poisson process. The transition probabilities between the states of this system can be determined as

$$P_{sx}(a) = \begin{cases} r_a \delta(CH - \gamma(n_x) - q_x)\tau_s(a), & x = s + PU \\ q_s r_d \tau_s(a), & x = s - PU \\ r_a(1 - \delta(CH - \gamma(n_x) - q_x))\tau_s(a), & x = s + PU - \psi(CR) \\ a\, r_d \delta(CH - \gamma(n_x) - q_x)\tau_s(a), & x = s + CR \\ 0, & otherwise \end{cases}$$

The $s + PU$ and $s - PU$ are the arrival and departure of a PU, respectively that are equivalent to $s + [0,1]$ and $s - [0,1]$, respectively. Also the $s + CR$ and $s - CR$ are equivalent to $s + [1,0]$ and $s - [1,0]$, respectively. The $\psi(CR)$ is the representative of the worthless CR user who is transmitting data packets toward the sink node. The worth of CR users is determined based on their weight. According to this admission control mechanism, when a PU starts using its related channel while there is no free channel for

CR users, the most worthless CR user leaves using CR channel and stops sending data.

### E. Policy and Reward Function

A policy $\pi$ is a function that maps state space to acceptable action space. For each state $s \in S$, an action is chosen according to policy $\pi$. The $\Pi$ is the acceptable policy space. The reward function $R(s,a)$ is the average reward obtained from the network in current state $s$ after the action $a$ is selected until the next decision epoch. The reward function is the reward earned by the weight of new admitted CR user at each decision epoch. This function is defined as the sum of the weights of admitted flows to send to the sink node that can be defined as:

$$R(s,a) = \sum_{i=1}^{N_S} a_i \omega_i. \tag{6}$$

The average reward is considered as a performance measure. Inspiring from [14], the average reward function for $\forall \pi \in \Pi$ is defined as

$$J_\pi(s_0) = \lim_{T\to\infty} \frac{1}{T} E\left\{\int_0^T R(s(t),a(t))dt\right\} \tag{7}$$

where the $s_0$ is the first state that SMDP is started from and $E\{.\}$ is the expectation function. The purpose is to find the optimal policy $\pi^* \in \Pi$ that maximizes the average reward for all initial states. On the other hand, the aim is to find the best policy that maximizes the average value of sent information via the admitted sensors.

### F. Value Iteration Algorithm as a Solution of the SMDP

The suboptimal policy $\pi$ can be obtained by the value iteration algorithm. The steps of the value iteration algorithm are as follows [12]:

1. Initialization: $n = 1$, choose a number $\theta$ in the range of $[0, \max_{a,s} \tau_s(a)]$ and $\forall s \in S$ choose $V_0(s)$ in the range of $[0, \max_a R(s,a)]$.
2. $\forall s \in S$ compute the function $V_n(s)$ from Equ. 8 and obtain the stationary policy $\pi(n)$ which is maximize the right hand side of Equ. 8. The $V_n(s)$ function is the maximum obtained reward per time resulted by selection of an action $a$ from action space in n'th step of algorithm that is the function of $V_{n-1}(s)$.

$$V_n(s) = \max_{a\in A(s)} \left[\frac{R(s,a)}{\tau_s(a)} + \frac{\theta}{\tau_s(a)} \sum_{x\in S} P_{sx}(a) V_{n-1}(x) + \left(1 - \frac{\theta}{\tau_s(a)}\right) V_{n-1}(s)\right] \tag{8}$$

3. The algorithm is stopped with stationary policy $\pi(n)$ when $0 \le \frac{M_n - m_n}{m_n} \le \varepsilon$, otherwise go to next step. The $\varepsilon$ is the specified accuracy number and the values of $M_n$ and $m_n$ are computed as follows

$$M_n = \max_{s\in S}\{V_n(s) - V_{n-1}(s)\} \tag{9}$$

$$m_n = \min_{s\in S}\{V_n(s) - V_{n-1}(s)\} \tag{10}$$

4. $n = n + 1$ and go to step 2.

The steps of this algorithm are iterated for finitely much number of iterations. The value of $\delta$ is recommended to set as $\max_{a,s} \tau_s(a)$.

## IV. Experimental Results

In this section, the performance of the proposed mechanism is evaluated through CogNS that is a simulation framework based on NS-2 [15] for cognitive radio networks [16]. A CR sensor network is placed in a $50m \times 50m$ field. The number of the PUs and frequency channels is taken as 6. It is assumed each PU individually has the license of using related frequency channel. The values of $N_S$, $N_R$ and $N_{CR}$ are set as 8, 3 and 7, respectively. The sensing time and operating time are considered as 0.01 and 0.6 sec, respectively. The default values of PUs' arrival and departure rates are considered as 1; these two rates are changed for different experiments. The packet size is considered 100 bytes. The simulation time is 200 second. The value of termination parameter in value iteration method (ε) is considered as 0.02. Each experiment is run five times, and the results are averaged.

The proposed admission control mechanism is evaluated in this section by several experiments in different PU activity settings. The PU activity ($r_d$,$r_a$) is determined based on the length of ON and OFF periods of PU transmissions. When the PU arrival rate ($r_a$) is greater than the PU departure rate ($r_d$), this state is considered as a "high PU activity" state. Furthermore, when the PU arrival rate is smaller than the PU departure rate, this state is considered as a "low PU activity" state. Also, when the PU arrival rate is equal to PU departure rate, this state is considered as a "medium PU activity" state [6]. According to these definitions, the PU activities (3,1) and (5,1) belong to the low PU activity state, the PU activities (1,1), (3,3) and (5,5) belong to the medium PU activity state, and the PU activities (1,2), (1,3), (1,4), (1,5) and (1,6) belong to the high PU activity state.

In this section, the performance of the introduced mechanism (referred as SMDP-based) is evaluated and compared with the proposed mechanism in [3] (referred as Threshold-based) and the network without applying the admission control (referred as complete sharing). The Fig. 1, Fig. 2 and Fig. 3 illustrate the packet loss probability, jitter and end to end delay, respectively, for three scenarios, i.e., complete sharing, the network with SMDP-based admission control mechanism and the network with Threshold-based admission control mechanism, with regard to different PU activities. This admission control estimates the average required channels of the flows. According to this estimation, more valuable flows are admitted to send data toward the sink. As depicted in these figures, the packet loss ratio of the network is reduced with the proposed SMDP-based admission control, especially in high PU activities, i.e., (1,3) and (1,5). As depicted in these figures, the SMDP-based admission control overcomes the Threshold-based admission control and the complete sharing.

The jitter is considered as a metric of packet end-to-end delay variance, in the literature. Sending data flows according to the decisions of the proposed

admission control leads to reduce the average jitter of data packets as depicted in Fig. 2. Furthermore, this mechanism reduces the packet end to end delay as illustrated in Fig. 3.

Fig. 4 represents the average reward earned by the optimal policy that is a decision maker, in the different states of the network. This figure illustrates the average reward per second in the networks with different channel numbers with regard to different PU activities. The channel numbers varies from 3 to 7. The existence of the more channels in the network leads to admit the more number of data flows and earn more reward. In the low PU activities the network earns highest reward and also in the high PU activities the network earns lowest reward due to the more active PUs. The highest reward is earned in PU activity (5,1) and channel number 7.

Fig. 5 depicts the throughput of the networks with different channel numbers for different PU activities. The numbers of channel varies from 3 to 7. As illustrated in this figure, network throughput decreases with the increase of the PU entrance rate or the decrease in the number of channels. The highest throughput is obtained in PU activity (1,1) and channel number 7.

## V. Conclusion

In this study, a suboptimal optimal connection admission control (CAC) mechanism is proposed in order to provide QoS of the CR users in cognitive radio sensor networks. This mechanism is modeled as a semi Markov decision process (SMDP) and a suboptimal policy is obtained by a value iteration method. This proposed mechanism decreases the jitter, end to end delay and packet loss ratio of the packets in the network. The performance of the CAC is evaluated by NS-2 based simulation. The simulation results represent that the proposed mechanism outperforms the previous proposed admission control mechanism in CRSNs. Due to the requirements of CRSNs, the end to end delay and power constraints can be added to this SMDP model as future work.

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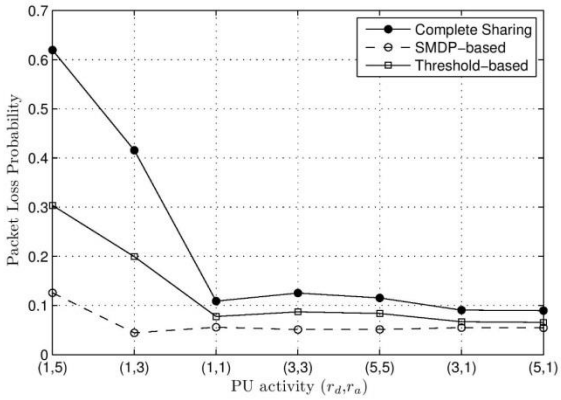


Fig 1: Average packet loss probability in different PU activities in the network with complete sharing, the networks with SMDP-based and Threshold-based admission control mechanisms

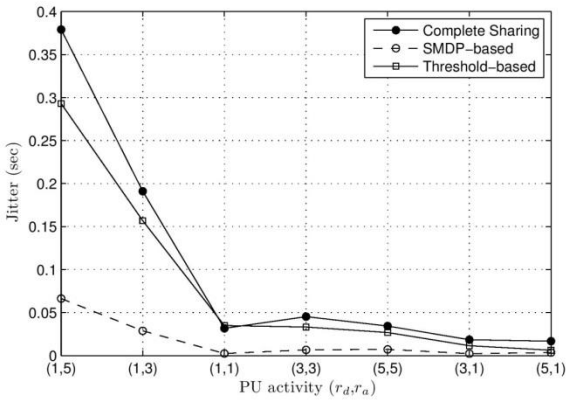


Fig 2: Average jitter in different PU activities in the network with complete sharing, the networks with SMDP-based and Threshold-based admission control mechanisms

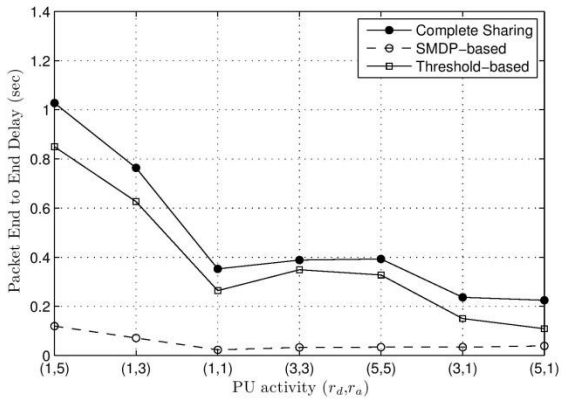


Fig 3. Average packet end-to-end Delay in different PU activities in the network with complete sharing, the networks with SMDP-based and Threshold-based admission control mechanisms

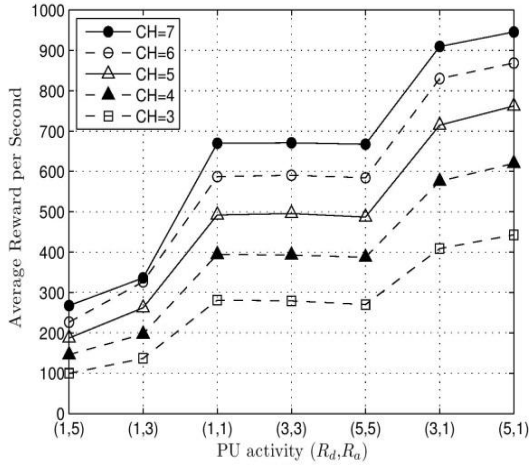


Fig 4: Average reward per second in different channel numbers and different PU activities

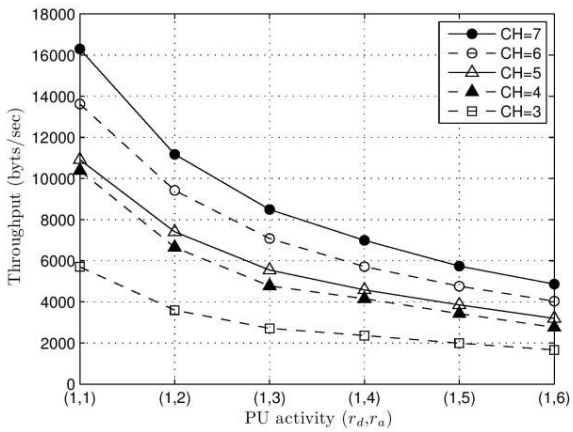


Fig 5: Average throughput in different channel numbers and different PU activities

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