Backup Channel Selection Approach for Spectrum Handoff in Cognitive Radio Networks

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***Abstract---* to overcome the problem of spectrum scarcity a new communication paradigm called Cognitive Radio Network (CRN) has been developed to use the spectrum in an opportunistic manner. The cognitive radio users have to vacate the spectrum band when the primary user reclaims its band. This process named spectrum handoff. This may cause a discontinuity in the secondary user transmission and performance degradation during the selection of a target channel to continue its transmission. The backup channels technique is a solution for the target channel selection problem. This paper proposes M/M/1 queuing model for spectrum handoff in CRN. And also proposes shortest queuing selection model to the backup channel after the handoff process occurs. The obtained results indicate that the proposed model has the minimum values for the queuing time delay and the total system time compares with the random selection. Consequently, the quality of service for the secondary user can be improved.**

Keywords--- Cognitive radio; Spectrum handoff; M/M/1 queuing model; Channel selection.

I. INTRODUCTION.

With the rapid development of wireless applications the fixed spectrum becomes very crowded. The federal communications commission (FCC) allocates spectrum to licensed users known as primary users (PUs) but a large part of the allocated spectrum stays underutilized which necessitates applying of dynamic spectrum access techniques, which allow the unlicensed users known as secondary users (SUs) to use the unused licensed spectrum with special conditions which known as CRN to exploit the spectrum in more efficient and intelligent way [1]. CRNs require new spectrum management functions [2] which can be determined in four major steps: spectrum sensing [2], spectrum decision [3], spectrum sharing [2] and Spectrum mobility.

In spectrum mobility, the SUs must vacate the spectrum band when the PU appears and switch to another channel to resume its unfinished transmission. Therefore, the spectrum handoff procedures are happened for the interrupted secondary user [4]. When the SU takes the decision of spectrum handoff, it wants to resume its transmission on another suitable channel consequently; the target channel selection problem appears.

Target channel selection subject has been discussed in many researches. For instance, [5, 6] indicates that the selection of target channel depends on many factors such as channel capacity, channel availability when the SU makes handoff. To avoid multiple handoffs in the same transmission which cause performance degradation, the target channel should be selected accurately. Therefore, backup channel list solution is common for this issue. SU forms a list of a candidate channels which will be a target channel when the SU take the handoff decision. This approach was adopted by IEEE 802.22 wireless area network standard [7]. An operation mode selection scheme in a CR sensor network depending on backup channel approach for handoff was proposed in [9]. Backup channels used also in [10] with an opportunistic spectrum access model for target channel selection. In [6]-[10] spectrum handoff policies are proposed to let SUs perform spectrum handoff before a PU arrives the channel to avoid interference. In [11] a spectrum handoff strategy was proposed aimed at reduce unnecessary handoffs, delay requirements of the application are considered. [12, 13] considered sensing of the PU may be imperfect and allocated some channels from the unlicensed bands as a backup. The historical information can be used to improve the spectrum sensing process consequently; the target channel selection will be more accurate as in [14]. In [15], a novel graph theoretic matching algorithm has been proposed to solve the problem of dynamic channel allocation which takes into consideration the priorities for both the SUs as well as the channels. Besides the prediction to decide the most suitable target channel, the learning automaton has been used also. As in [16], an algorithm for channel selection has been proposed based on the learning automaton to reduce the handoff. Depending on the feedback information of using the channels, the algorithm selects the optimum channel. This technique supposes that the PU has static appearance. A new technique based on preemptive resume priority (PRP) M/G/1 queuing model has been proposed in [17]. This scheme evaluates the total service time for target channel selections, the shortest waiting time and the longest idle probability. Therefore, the SU selects the most suitable target channel.

In this paper, spectrum handoff model is proposed using M/M/1queuing model to discuss the waiting time for the SU in the queue. Two backup channels are selected as candidate channels for SU handoff from the spectrum sensing stage. After the handoff process, another model is proposed to select the best target backup channel for the SU from the two candidates depending on the shortest queue for the channels. The simulation result indicates that the selection of the channel with short queue gives lower values for the average system time consequently the end to end delay than the traditional random selection as in [8]. The delay is very significant for the quality evaluation for the real-time multimedia services.

This paper is organized as follows: in section II, spectrum handoff mechanism is illustrated. In section III, M/M/1 queuing model is indicated. Section IV presents the 1st proposed system model. Section V discusses the 2nd proposed system model. Section VI introduces the simulation results. Finally, the conclusion of the paper is done in section VII.

II. SPECTRUM HANDOFF MECHANISM.

The spectrum handoff process has two phases. The first one is the evaluation phase in this phase, SU observes and analyzes the environment and decides if handoff triggering occur or not. Once SU takes the decision of performing spectrum handoff, it transforms to the second phase, link maintenance phase. In this phase, the SU pauses its transmission and leaves the channel for the PU and switches to another free channel to resume its transmission [4]. The first proposed model illustrates the spectrum handoff process using M/M/1 queuing model.

III. M/M/1 QUEUING MODEL:

M/M/1 means that the system has a Poisson arrival process, an exponential service time distribution and only one channel. For an M/M/1 queue with an arrival rate of λ and a service rate of μ, queuing theory provides the following theoretical results [18]:

- The mean waiting time in the queue =

$$\frac{1}{\mu-\lambda}-\frac{1}{\mu} \tag{1}$$

- The total system time for user =

$$\frac{1}{\mu-\lambda} \tag{2}$$

IV. THE 1st PROPOSED MODEL: SPECTRUM HANDOFF PROPOSED SYSTEM MODEL.

The block diagrams of the proposed models in this paper are constructed using Simulink Matlab version 10.

The spectrum handoff proposed model block diagram, shown in Fig.1, consists of:

- Two entities generator: responsible for generation entities for the PU and SU.
- Entity priority: it for setting the priority of the two users. The first priority for the PU and the second priority for the SU.
- Path combiner: it merges the two input ports.
- Start timer: define the beginning of a timer for each entity.
- Priority queue: it stores the coming entities in sorted sequence according to ascending order.
- Channel: the server that serves user's entity for a period of time. The t port is for setting the service time distribution to be exponential. P port is for SU preemption when the PU appears.
- Output switch: it selects one entity port for departure.
- Read timer: defines the end of the timer.
- Signal scope: to scope the output.
- Entity sink: terminates the port.
- Display: to show the values for the average system time for the two users.
- Arrival rate block: constant value block which here equal to 0.5.
- Discrete event subsystem: subsystem for calculating the theoretical value for the average waiting time for M/M/1 queuing model.
- Multiplexer: to multiplex the signals.

A. These assumptions are made in the proposed model:

- The proposed model consists of one PU and one SU.
- The model is overlay mode i.e only one user uses the channel simultaneously.

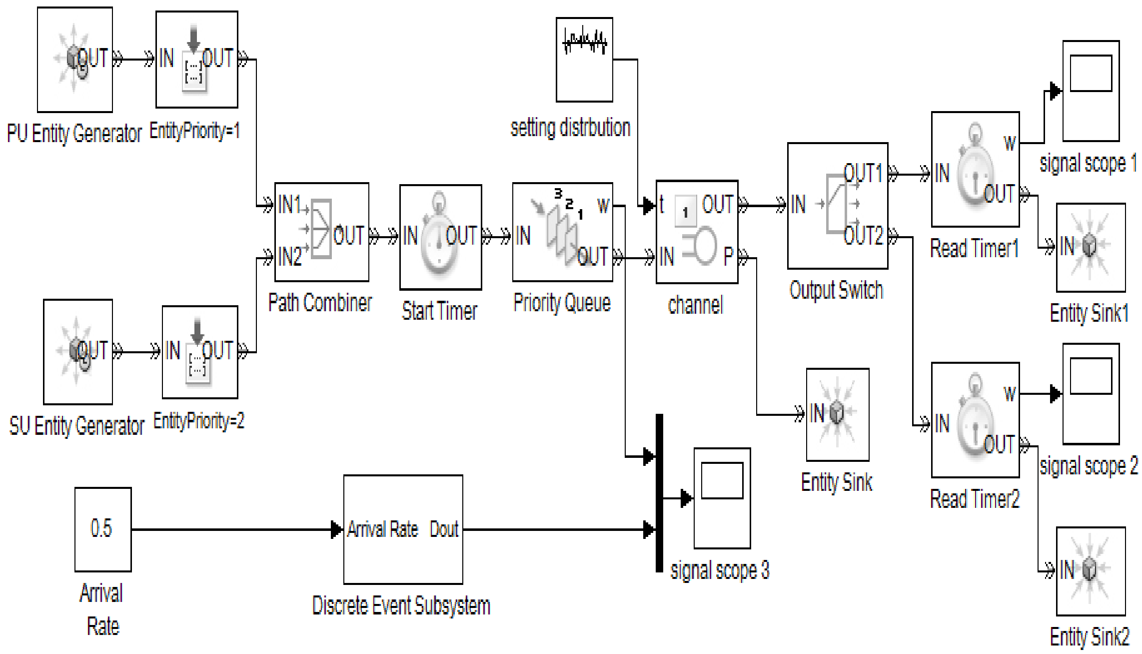

Fig.1 spectrum handoff proposed system model

- When the PU appears and reclaims its channel, the SU makes spectrum handoff process and changes the channel to one of two backup channels.

B. The steps of the spectrum handoff proposed model:

- The entities for the two users are generated from the entity generator blocks with Poisson arrival rate.
- The priority is determined in the entity priority block. The first priority is for the PU and the second priority is for the SU.
- The entities for the two users combine in the path combiner then the timer starts.
- In the priority queue block, the entities of the two users sorted according to its priority. W port in this block indicates to the simulation value of the average waiting time.
- The theoretical value of the average waiting time is calculated in discrete event subsystem to compare with the simulation value in the average waiting time scope.
- The users have been served in the channel. If the SU uses the channel and the PU appears and reclaims its channel, the SU vacates the channel through P port and the spectrum handoff process occurs. The SU changes the channel to one of backup channels.
- The output switch selects one output and departs it. The SU total system time measured at reading timer block.

When the SU makes spectrum handoff process, target channel selection problem appears. In this paper, two backup channels are determined for preempted entities of the SU. The delay is an important factor for SU to resume its transmission. In this paper, a model for shortest queue selection technique is proposed.

V. THE 2nd PROPOSED MODEL: THE SHORTEST QUEUE SELECTION PROPOSED MODEL.

This model indicates the difference in average system time in the random selection technique and the shortest queue selection proposed model.

The block diagram of the proposed model shown in Fig.2 consists of:

- Arrival process block: for determination the SU arrival rate Poisson distribution.
- Replicate block: it outputs a two copy of the input.
- Start timer: to begin the time determination.
- Read timer: to read the determined time.
- Average system time scope: to scope the two output signals.

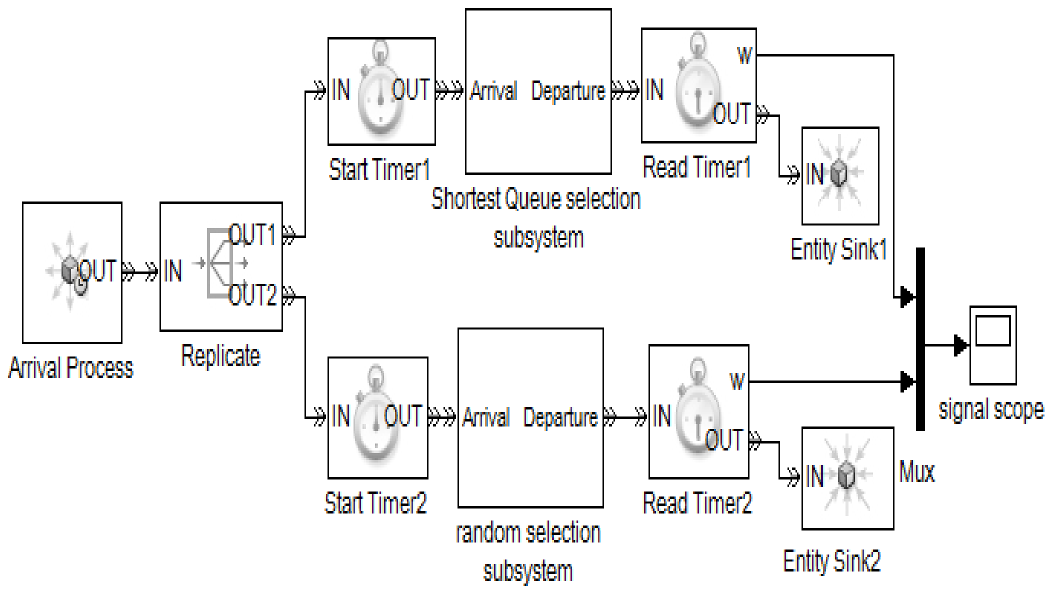

Fig.2 shortest queue selection proposed model.

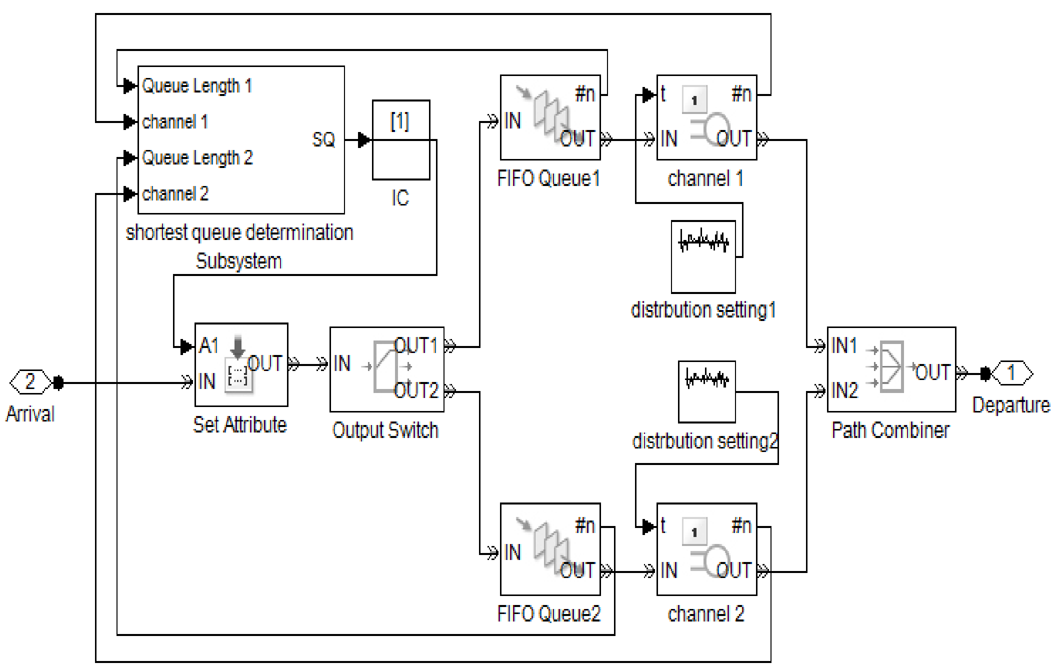

Fig. 3. Shortest queue selection subsystem

The block diagram of shortest queue selection subsystem shown in Fig.3 consists of:

- The shortest queue determination subsystem: combines the entities in the queue length and the entities in the channel for each channel. Then the shortest queue has determined.
- IC block: initial condition for selection channel.
- Set attribute: to set and define the condition of the channel selection which is the shortest queue.
- Output switch: select the entity port for departure.
- FIFO queue block: this block stores the entities according to first in first out sequence.
- Distribution setting block: setting the service time distribution to exponential distribution.
- Path combiner: combines the entities and merges paths of the two channels.

A. The steps of proposed model:

- The preempted entities of the SU from the spectrum handoff proposed model vacate the channel when the PU appears. There are two backup channels for the SU to resume its transmission. The SU selects the best channel to use according to the shortest queue. The arrival process indicates to SU's entities arrival.
- The entities of the SU are copied by the replicate block to input the two system models: the shortest queue selection model and the random system. The timer is switched to calculate the beginning of the total system time.

B. In the shortest queue selection subsystem:

- The shortest queue parameter has calculated in the shortest queue time determination block. By combining the entities in the FIFO queue and entities in the channel for the two backup channels. To start the simulation, initial condition (IC) for channel selection has used. The channel 1 has selected to be the first channel in the simulation by setting the IC = 1.
- The channel which has the shortest queue is selected by the output switch.
- The SU's entities queued in FIFO queue to be served in the channel. Then the entities have been combined in the path combiner to enter the read timer and be shown in the average system time scope.

C. In the random selection subsystem:

- As shown in Fig. 4, the output switch outputs the entity to any channel from the two. The two backup

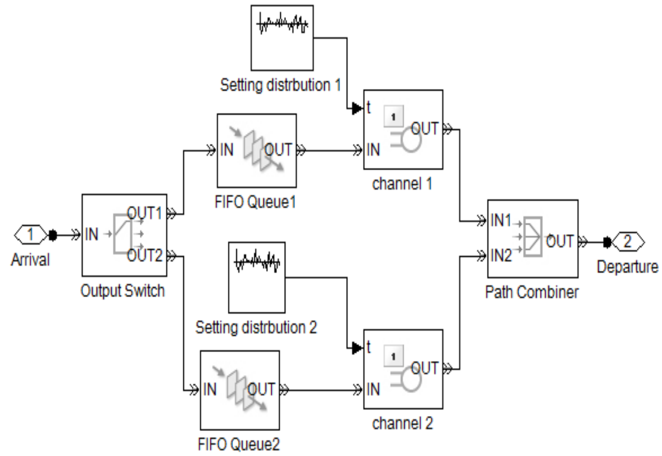

Fig. 4. Random selection subsystem.

channels have the same probability of using by the SU.

- The coming entities enter FIFO queue to be served in the channel. The exponential distribution is selected for the service time.
- The path combiner combines the two outputs from the two channels.
- The average system time for the random selection subsystem has been shown in the scope with the one for the shortest queue subsystem.

VI. SIMULATION RESULTS.

The simulation parameters for the proposed models are shown in table 1.

Table.1 the simulation parameters.

Number of PU	1
Number of SU	1
Distribution of PU signal	Exponential
λ_{PU}	0.1
Distribution of SU signal	Exponential
λ_{SU}	0.5
Capacity of priority queue	Infinity
Simulation time	2500 sec
μ_{PU} , μ_{SU}	1

A. For the 1st proposed model.

In M/M/1 queuing model, the average waiting time in the queue calculated from (1).

For μ=1, λ_{SU}= 0.5.

The average waiting time for SU = 1 sec. in Fig.5, the theoretical value for the average waiting time = 1 sec. the simulation results move around 1 sec.

In M/M/1, the average system time for the user can be calculated from (2):

For PU, μ=1, λ=0.1. The average system time for the PU= 1.1111 sec. Fig. 6 indicates the average system time for the PU in the simulation. It equals to 1.18 sec as it appears in the display in Fig.1.

For SU, μ=1, λ=0.5

According to (2), the average system time for the SU= 2 sec. Figure 7 indicates the simulation values for the average system time for the SU. It equals to 1.987 as indicates in the display in Fig.1.

B. For the 2nd proposed model.

When the PU arrive the channel in the 1st proposed model, the SU leaves the channel. Two backup channels are reserved for the SU when the spectrum handoff process occurs.

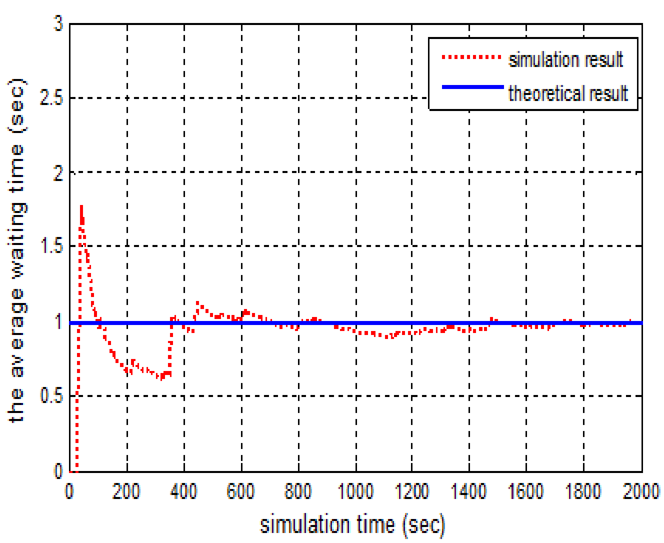

Fig. 5.Comparsion between the theoretical and simulation result for the average waiting time for SU

In the traditional case, the SU selects any of them randomly to resume its transmission. In the 2nd proposed model, the SU selects depend on the shortest queue which decreases the average system time. Figure 8 indicates the difference in the average total system time for the SU between the shortest queue selection model and the random model. It is obvious that the proposed model has lower values for the total system time than the random model. Consequently, the end to end delay decreased and the SU performance improved.

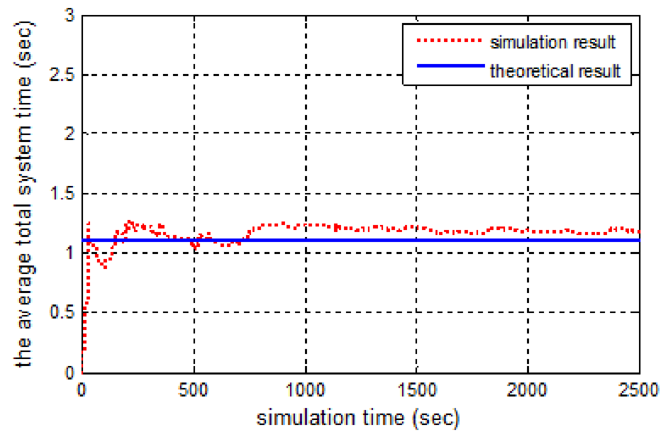

Fig.6. Comparison between the theoretical and simulation result for the average total system time for the PU.

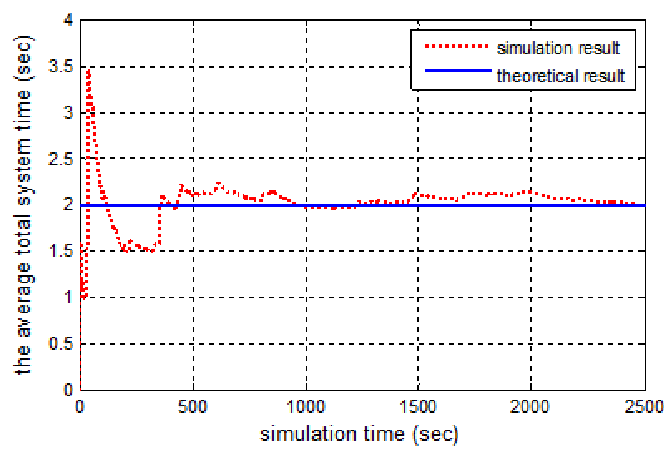

Fig.7. Comparison between the theoretical and simulation result for the average total system time for the SU

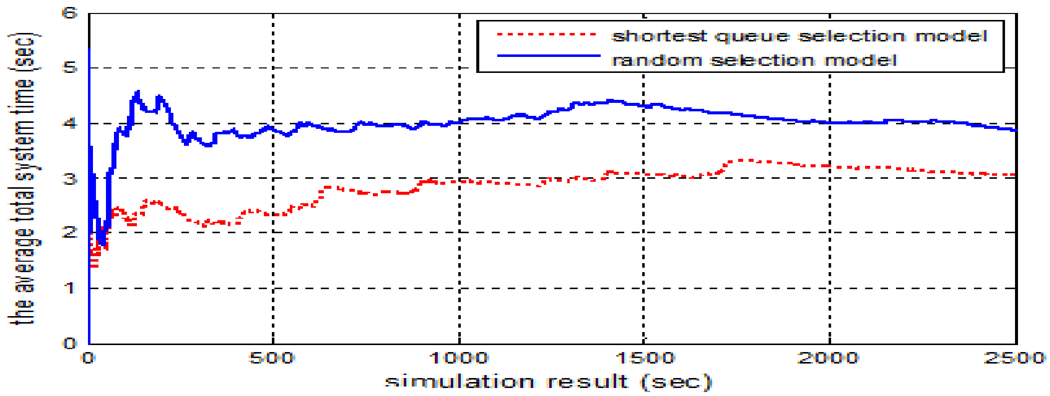

Fig.8 the average total system time for the SU in the backup channels.

I. Conclusion.

This paper proposed two models for spectrum handoff process by using M/M/1 queuing model. The first proposed model discussed the waiting time and the total system time for the SU. The second proposed model illustrated the selection of the best target channel depending on the shortest queue.

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