Abstract
In this work, a cognitive user locates within a licensed network with several wireless nodes, which communicate with each other by using N licensed channels. We proposed and compared three spectrum utilization algorithms, namely: RSHS (Random Spectrum Hole Selection), RSHS-TT (RSHS using Threshold Transition) and RSHS using Minimum Rate (RSHS-MR). The numerical results confirm that the RSHS-MR technique has benefit of less average packet collision during specific period of the simulation time.

Introduction
Cognitive Radio (CR) technology is a promising solution of spectrum scarcity in emerging wireless communication networks. The idea of CR is based on overlay spectrum sharing, in this approach, the channel before the licensed signal appearance. In this work, sensing modules equipped on CRs and able to monitor licensed channels states in terms of their occupancy and vacancy in cooperative manner. To this end, sensing, recognizing and predicting licensed channel states are crucial challenges in cognitive radio context. In this work the aim is to reuse unused spectrum bands in an efficient method, without harming license transmission (Figure 1).

Motivation
In wireless communications a competitive scenario requires to explore and exploit appropriate licensed spectrum holes in network coverage area. Beside in this case primary channel usage obeys random distribution, therefore, an appropriate channel access mechanism could significantly improve the QoS of the both primary users and cognitive users. Here our aim is to evaluate and compare three spectrum hole selection approaches namely: RSHS, RSHS-TT and RSHS-MR. In addition, average channel collision and channel utilization are considered to be performance evaluation metrics.

System Model
The assumed network topology is shown in Figure 1 where utilisation of the licensed band by the PU is modeled as a Poisson process with arrival rate parameter λ. The licensed channels' states are estimated by an ON/OFF binary signal, in which interval OFF/ON times follow exponential distribution. Moreover the interval times are assumed to be identical independent random variables which have lambda arrival rates respectively. In sum, the probability that state OFF is in use at time t, on channel i, is given by:

\[ P_{off}^i(t) = \frac{\lambda_i^t}{t} \]

(1)

where binary state variable \( x(t) \) can be expressed by:

\[ \begin{align*}
  x(t) &= \begin{cases} 
  1 & \text{channel occupied} \\
  0 & \text{channel vacant} 
\end{cases} \\
  \begin{cases} 
  1 & \text{channel vacant} \\
  0 & \text{channel vacant} 
\end{cases} \\
\end{align*} \]

(2)

And

\[ C_i(t) = \left( P_{off}^i(t) > \eta^i \right) \quad 0 \leq i \leq N \]

(3)

where, \( C_i(t) \) indicates set of the proper unoccupied channels at time t. The proposed techniques explore appropriate spectrum hole with respect to the collected channels' characteristics. Also part of the proposed algorithms are illustrated in Figure 2. Finally the performance of the spectrum hole accessing techniques evaluated by Average channel Collision (AVC) and Average Channel Utilization (ACU) during specific simulation time (3000ms), which are defined by:

\[ AVC = \frac{\text{Number of packet collision}}{\text{Number of transmission packets}} \times 100 \text{ /sec} \]

(4)

Results and Conclusion
The performance evaluated over 10 licensed channels with different OFF/ON channels’ rates through Matlab software. The average collision during specific simulation time (3000ms) the performance analysis shows, SHS-MR algorithm has much more reliability in terms of the collision and disruption to the primary transmission (Figure 3a). Also Figure 3b represents that the licensed channels with maximum transition probability (channel 9) reaches at 2.25% channel utilization which is much more than the rest channels.

Figure 1 Network topology, cognitive radio network reuses unoccupied licensed channels

Figure 2 a) RSHS algorithm and b) RSHS-TT algorithm

* Steps 1 to 7 from a) repeat in RSHS-TT algorithm

Figure 3 a) Collision under proposed algorithms b) Channel utilization in 10 licensed channels

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References