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Channel Utilization in Cognitive Radio Systems by Reducing Collisions for Multiple users

P. Kawya[1],
[1]PG Scholar, Department of ECE,
SSM Institute of Engineering and Technology, Dindigul,
Tamilnadu, India

Dr. S. Karthigai Lakshmi[2],
[2]Professor, Department of ECE,
SSM Institute of Engineering and Technology, Dindigul,
Tamilnadu, India

***Abstract*-The cognitive radio (CR) system needs to optimally set the sensing period and sensing time for efficient utilization of the channel while protecting the primary users (PU). The optimal sensing period is used for maximizing the effective throughput of the CR system. It depends on not only the on/off pattern of the PU and the sensing error probabilities but also the size of a data packet, the transmission rate, and the forward error correction capability. In this paper, the optimal sensing period is obtained while taking all of these factors into account. On the basis of this optimal period, the sensing scheme for sensing a data packet transmission is proposed for single and multiple users. With the proposed sensing scheme, the CR system can protect the PU very well while achieving the high effective throughput and efficiently utilize the channel and improve the packet delivery ratio and reduce the end to end delay.**

Key Words: Cognitive radio, Primary user, Optimal sensing period, Forward error correction probability

I. INTRODUCTION

Cognitive radio (CR) is one of the new long term developments taking place and radio receiver and radio communications technology. After the Software Defined Radio (SDR) which is slowly becoming more of a reality, cognitive radio (CR) and cognitive radio technology will be the next major step forward enabling more effective radio communications systems to be developed. The idea for cognitive radio has come out of the need to utilise the radio spectrum more efficiently, and to be able to maintain the most efficient form of communication for the prevailing conditions. By using the levels of processing that are available today, it is possible to develop a radio that is able to look at the spectrum, detect which frequencies are clear, and then implement the best form of communication for the required conditions. In this way cognitive radio technology is able to select the frequency band, the type of modulation, and power levels most suited to the requirements, prevailing conditions and the geographic regulatory requirements. There are likely to be a variety of different views of what exactly what a cognitive radio may be. Accordingly, a definition of a cognitive radio may be of use in a number of instances. A cognitive radio may be defined as a radio that is aware of its environment, and the internal state and with a knowledge of these elements and any stored pre-defined objectives can make and implement decisions about its behavior. In general, the cognitive radio may be expected to look at parameters such as channel occupancy, free channels, the type of data to be transmitted and the modulation types that may be used. It must also look at the regulatory requirements. Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. Large discrepancies in radio spectrum allocation, assignment and actual radio spectrum usage indicate that spectrum shortages result from the outdated spectrum management policy rather than the physical scarcity of usable radio spectrum. In order to satisfy EU Digital Agenda goals and future market demand for mobile and broadband services, we can envisage deployment of next generation broadband wireless networks and services which will need rapid and more flexible access to the radio spectrum in the UHF band. The general trend towards more flexible and efficient spectrum management is further driven by the continuous development of new technologies. In this paper, we study a problem for determining the optimal sensing period to maximize the effective throughput, packet delivery ratio and node end to end delay of a CR system while protecting the PU, where the effective throughput means the average number of data bits successfully transmitted per second. It is obvious that the channel quality in the CR system can get worse abruptly, owing to the unexpected return of the PU, and if this occurs while a CR node is transmitting a data packet, the received packet might include uncorrectable errors. Then, the CR receiver requests the packet retransmission to the CR transmitter. Thus, the optimal sensing period for maximizing the effective throughput depends not only on the on/off pattern of the PU and the spectrum sensing error probabilities but also on the size of a data packet, data transmission rate, and the forward error correction (FEC) capability. In this paper, we derive the optimal sensing period while taking all of these factors into account. On the basis of this optimal period, we propose the sensing strategy that can be efficiently implemented within the data transmission framework of the CR node. With this strategy, since the CR transmitter has the breaks for sensing during a data packet transmission, the PU can be also properly protected.

II.PROPOSED CHANNEL UTILISATION SCHEME

The cognitive radio (CR) system opportunistically exploits the spectrum bands that are licensed to the primary users (PUs) but are not used at a particular time and a specific geographic location [2]. Since the coexistence of PU and CR users on the same channel may severely degrade the PU performance, the CR system should be able to detect the activation of the PU as fast as possible. The CR system that investigates the existence of the PU on spectrum by sensing is required to frequently sense its operating channel for the fast PU detection. The channel with the short on/off duration of the PU should be frequently sensed for PU protection; frequent sensing on the channel with low PU activity may degrade the performance of the CR system since the CR system usually stops data transmission during sensing.

If the PU suddenly returns to the channel where a CR node is transmitting a data packet, the data packet may be corrupted during transmission. When all erroneous bits within the received packet cannot be corrected by the CR receiver, the packet should be retransmitted, and in fact, this decreases the effective throughput of the CR system. Thus, when designing a sensing scheduling scheme for maximizing the throughput of a CR The CR receiver requests the packet retransmission to the CR transmitter. In this, the optimal sensing period while taking all of these factors into account is obtained. Lost in the system, the transmission errors due to the collision of the PU and the CR users are to be considered**.**

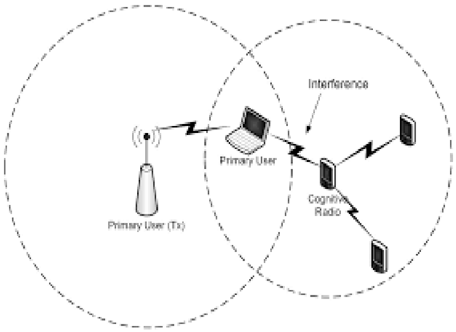

Fig 1: Channel sensing at Tx

In this, a problem for determining the optimal sensing period to maximize the effective throughput of a CR system while protecting the PU, where the effective throughput means the average number of data bits successfully transmitted per second is studied. It is obvious that the channel quality in the CR system can get worse abruptly, owing to the unexpected return of the PU, and if this occurs while a CR node is transmitting a data packet, the received packet might include errors.

In this the transmission/reception of data packets between a pair of the CR transmitter and receiver on the reserved data channels is focused. Hereafter, in description, a channel means the reserved data channel. When the size of a data packet is N_b bits and the number of symbols within an FEC block is N_c, the code rate is N_b/N_c. A fixed code rate, which is denoted by r_c, is assumed. It is also assumed that the CR transmitter adjusts the symbol transmission rate according to the channel quality, by adopting the continuous-rate M-ary quadrature amplitude modulation. Let W be the channel bandwidth and γ be the received signal-to-noise ratio (SNR). Then, according to the symbol transmission rate on the channel is

$$R_s = W\log 2(1+(-1.5/\ln(5p_e))\gamma) \qquad (1)$$

where p_e is the target symbol error rate. The interleaved FEC block is transmitted with the rate of Rs. Then, the transmission time of this block is $(N_b/r_c)/R_s$.

The PU suddenly returns to the channel while an interleaved FEC block is being transmitted, the received block may include many erroneous symbol bursts. If the error bursts within the received block are beyond the error correction capability of coding and interleaving, the CR receiver discards the block, and the CR transmitter should retransmit it. This may deteriorate the throughput performance of the CR system. Moreover, the transmission of the CR nodes can disturb the transmission of the PU, and this is much more critical than the performance degradation of the CR system. It is obvious that the CR transmitter accesses the channel only during off sensing intervals, to preserve the transmission qualities of both the PU and the CR user. When the sensing outcome is ―on, the transmitter suspends transmission and performs channel hopping during the corresponding sensing interval. The receiver also, when unable to hear from the transmitter, moves to a new channel according to the predetermined hopping sequence, i.e., the sequence of channels listed in CTS. Now, the transmission procedure of a data packet is described in more detail. Just after channel reservation, to get the channel quality information for determining the initial symbol transmission rate Rs, the CR transmitter transmits a probe packet through the operating channel.

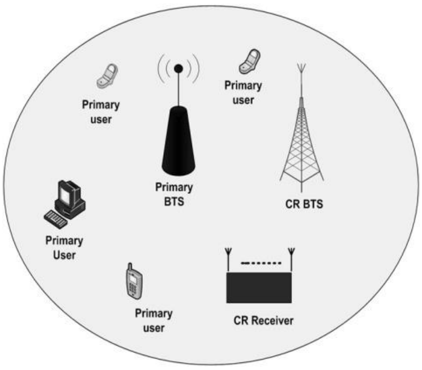

Fig 2: Multiple Primary users

Then, the CR receiver measures the received SNR of this packet, γ, and reports it to the transmitter. The CR transmitter determines Rs depending on γ and calculates the required number of off sensing intervals,

$$k = N_b/[(T-\tau_s)r_cR_s] \qquad (2)$$

After generating an interleaved FEC block from a data packet, the CR transmitter transmits the interleaved FEC block during k off sensing intervals. When receiving the entire block, the CR receiver performs deinterleaving and decoding for the block. The CR receiver that has successfully decoded the data packet sends an acknowledgement (ACK) packet; if it fails to recover the data packet, the CR receiver replies with a negative-ACK (NAK) packet. In addition, the CR receiver reports the measured SNR of the block to the transmitter, by piggybacking it on the ACK or NAK packet.

PDR is calculated on the basis of the number of the packet failure rate(PFR).

PDR=100-PFR (4)

The node end to end delay is the average time taken by a data packet to arrive at the destination. In this it is calculated on the basis of the delays that occur in the packet transmission.

Delay=transmission delay+propagation delay+packet drop delay. (5)

Delay=(1/throughput)+(d/3*10^8) (6)

III. OPTIMAL SENSING PERIOD FOR MAXIMIZING THROUGHPUT OF CR USER

The optimal sensing period for maximizing the effective throughput of the CR user while properly protecting the PU is investigated. After determining the transmission rate Rs using γ reported from the CR receiver, the CR transmitter transmits the block at the rate of Rs during k off sensing intervals, where $k = Nb/(T - \tau_s)r_cR_s$. For given N_b, r_c, τ_s, and R_s, determining the optimal k is equivalent to determining the optimal sensing period T. Since Rs depends on γ, the optimal k and the optimal T are also dependent on γ. A —transmission round is defined as the time period from the instant at which the CR transmitter is ready for a block transmission to the instant at which it again becomes ready for transmitting the next block. During a transmission round with k off sensing intervals, let X(k) be the effective throughput and Φ(k) be the ratio of the coexistence time of the CR user and the PU to the total channel reservation time. It is assumed that, for protecting the PU properly, Φ(k) should not be larger than a predefined threshold, ΦTH. Then, the problem that finds k for maximizing the effective throughput with this constraint is formulated as

$$K^* = \operatorname{argmax} \chi(k), k \in N \quad (3)$$

where N denotes the natural number set.

In state B_0,m, when a PU detection alarm is not issued, the data block is transmitted until before the next sensing. Since the probability that a PU returns during this interval is ϕ0,1(T), the state transition from B_0,m to B1,m+1 occurs with probability (1 − pf)0,1(T). Also, since the probability of a vacant channel during this sensing interval is ϕ0,0(T), the transition probability from B_0,m to B_0,m+1 is $(1 - p_f)$0,0(T).

IV. PERFORMANCE ANALYSIS

In this, the performance of the proposed sensing scheme is evaluated. The result of the scheme is as follows.

Parameters	Existing work	Proposed work
Packet delivery ratio	97.8072	99.3981
Packet failure rate	21.7858	10.6055
Node end to end delay	8.2358	8.4754
Optimal sensing period	0.0017	0.0522
Code rate	3.75	3.75
Transmitter block rate	7.1929e04	5.0894e05
Mean length of transmission round	1.7668	1.4321

Table 1: Performance analysis

The (m, n) Hamming code, which encodes n data bits into an m-symbol codeword, and a block interleaver are considered. It is well known that a single bit error can be corrected with a Hamming code. Thus, $r_c = n/m$ and $\Lambda TH = 1/(m-1)$. For checking the validity of analysis, the simulation results are additionally presented. First, the optimal sensing period T^* according to γ is investigated.

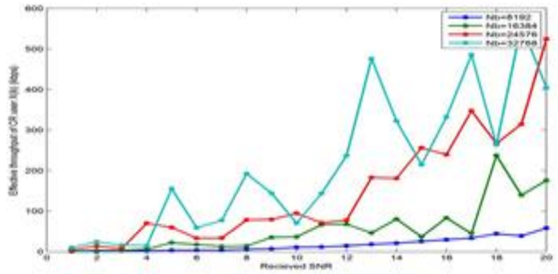

Fig 3: Effective throughput

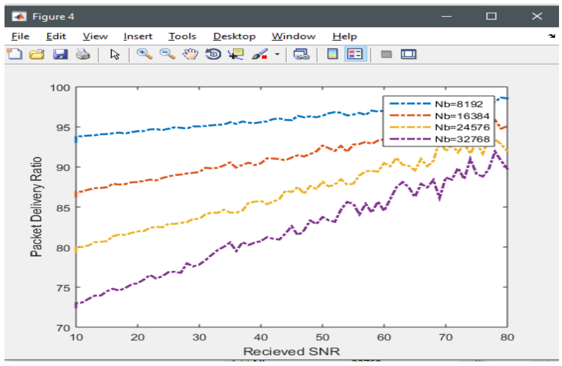

Fig 4: Packet delivery ratio

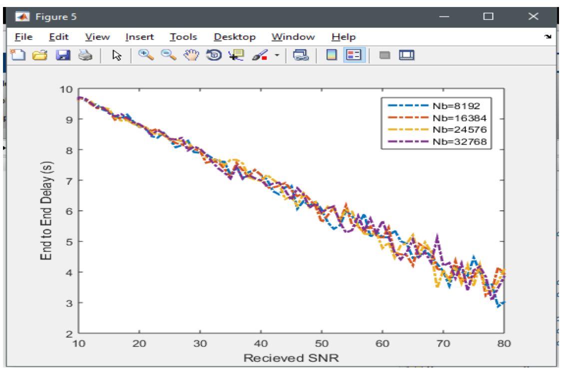

Fig 5: End to end delay

On the other hand, with the higher Λ_{TH}, the CR transmitter has the longer sensing interval because more corrupted symbols within an FEC block can be allowed. Accordingly, the optimal sensing period is longer when $\Lambda_{TH} = 1/4$ than when $\Lambda_{TH} = 1/14$. In addition, for the same size of a data packet, the throughput performance gets worse, and the transmission round gets longer with the lower code rate, since the larger FEC block should be transmitted. The proposed scheme achieves a high throughput performance while protecting the PU very remarkably, by allowing the breaks for sensing during a block transmission.

V. CONCLUSION

In this paper the optimal sensing period has been derived on the basis of the size of the data packet, transmission rate and forward error correction capability. Based on this optimal period, the sensing scheme for data packet transmission is proposed. With this sensing scheme, the cognitive radio protects the primary user very well and high effective throughput is achieved and hence the channel is efficiently utilized. And also the end to end delay is reduced and the packet delivery ratio is improved for multiple users.

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