

Cross Layer Design for Minimizing the Delay in Cognitive Radio Based WMNs

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ABSTRACT: Cognitive radio is a promising technology aiming at better utilization of available channel resources. Design of dynamic spectrum allocation algorithm is one of the challenges in cognitive radio network. The concept of dynamic spectrum allocation algorithm is to enable the secondary nodes to opportunistically access the available wireless spectrum without interfering with existing primary users. The objective is to minimize the average end to end delay and improves the packet delivery ratio. The performance gains are compared with other methods. It is shown that cross layer design scheme can accommodate higher traffic load and achieve half the delay compared to the disjoint scheme.

KEYWORDS: Cognitive radio Network, Cross layer design, delay minimization, disjoint scheme.

I. INTRODUCTION

The capability of a cognitive radio to best suit its surroundings greatly depends on the amount and accuracy of information it acquires about its radio environment. The process by which the cognitive radio becomes aware of its surroundings termed as spectrum sensing and is a key challenge in cognitive radio design. Radio mode identification is a comprehensive spectrum sensing algorithm that provides the cognitive radio with elaborate spectral information about the primary users. The approach has not been explored extensively due to its complexity and difficulties in real time implementation.

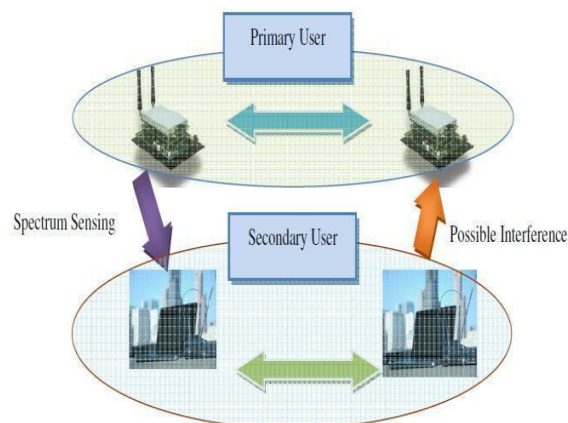


Fig.1 Dynamic Spectrum Access

However the recent advancements in the field of signal processing render the complexity problem rapidly evolving wireless communication industry has caused an apparent spectrum scarcity whereby, the available spectrum has already been allocated to various users by governing agencies under monetary agreements. Analysis has revealed that this apparent scarcity is attributable to the inefficient fixed spectrum allocation techniques. These techniques are simple to

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

implement but result in major portion of spectrum being underutilized. For example, federal communication commission places the spectrum usage in USA between the ranges 15% -85% at all times. This has opened a new avenue in research to explore more efficient but complex dynamic spectrum access techniques. Dynamic spectrum access envisions the use of licensed spectral bands by smart unlicensed cognitive users that can exploit any opportunities that may exist in the form of temporal or spatial holes.

A spectrum hole is that part of the spectrum where the primary users' transmission strength falls below a certain regulated level termed as interference cap by federal communication commission. The smart nodes that constitute the secondary users are called cognitive radios. A cognitive radio is an evolved software defined radio that in addition to reconfiguration capability also possesses the ability to analyze its surrounding radio environment. This allows the cognitive radio to decide how best to reconfigure itself in existing radio conditions. This paper reviews various spectrum sensing approaches highlighting the strength and weaknesses of each. Section 3 lays down the analytical framework for the proposed algorithm and introduces the proposed radio mode identification algorithm.

Spectrum sensing algorithms generally offer a compromise between accuracy and complexity. The attribute of accuracy is not only critical from a secondary user's perspective enabling it to optimally utilize the available opportunities but also for the primary user, minimizing the interference due to secondary users. Conversely the complexity of spectrum sensing algorithm has to be kept to minimum in order to allow real time operation of cognitive radio. Energy detection is a simple spectrum sensing technique. The received signal strength in a certain channel is compared against a carefully selected sensing threshold to ascertain the presence or absence of primary user in that channel. The sensing threshold is defined on the basis of noise floor and is a critical challenge.

This results in poor performance at low SNR and/or very small buffer sizes. Energy detection is desirable because of its simplicity and its non-parametric nature .i.e. it is independent of the type of primary user. The waveform based detection is carried out by identifying the preambles and cyclic prefixes that are generally used with various types of transmissions. This approach outperforms energy detection in convergence time and accuracy, but is dependent on the type of primary user transmission. The major drawback of the algorithm is its parametric nature. Cyclostationary feature detectors make use of the inherent periodicity in the radio signals. The correlation function is used to measure the periodicity of the received signal. The algorithm is computationally complex but the cyclic frequencies can also be used for signal classification. Improvement in energy detection performance based on Bayesian sequential testing considering previous spectrum states has been discussed. The most elaborate survey of spectrum sensing techniques has been carried out in. The broad categorization of these techniques is done and a comparison for varying condition of SNR, noise models and buffer size has been carried out. Various performance metrics that could be used for comparison have also been summarized.

The papers suggest using the instantaneous frequency and delay spread obtained through time frequency analysis. Variable reduction is carried out and neural networks are used to predict which transmission scheme is present in the received signal. However the approach is limited only to identifying the modulation scheme of the primary user. In this paper we suggest a framework that in addition to identifying the modulation scheme may also be used to detect various features of the primary user transmission.

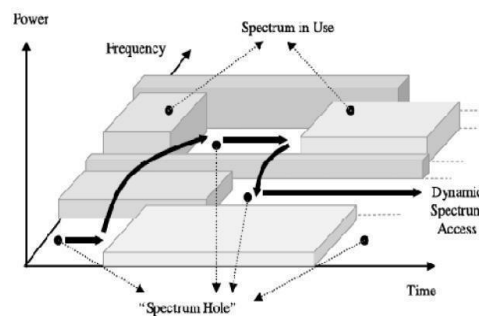


Fig.2 Spectrum hole

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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II. SENSING MODEL

The scenario we consider is sketched in Figure and comprises two low-power and duty-cycled sensor nodes, S_1 and S_2 , that communicate over an unlicensed channel: packets generated by S_2 , the transmitting node, need to be delivered to the receiver S_1 . Even though we focus on this single link, the two nodes might be part of a larger mesh network with arbitrary topology. The same channel is also used by a set of other devices I_1, I_2 . That induces interference to sensor communications: this might cause loss of packets, requiring retransmissions and thus increasing energy consumption. At a certain time instant the considered channel can be in two different states: *Busy* if some of the interfering devices is transmitting or *Idle* otherwise. We describe channel occupancy using a simple two-state semi-Markov model: busy periods last for the time required to carry out packet transmissions while the length of idle periods follows a certain probability distribution function $F_{TI}(t)$.

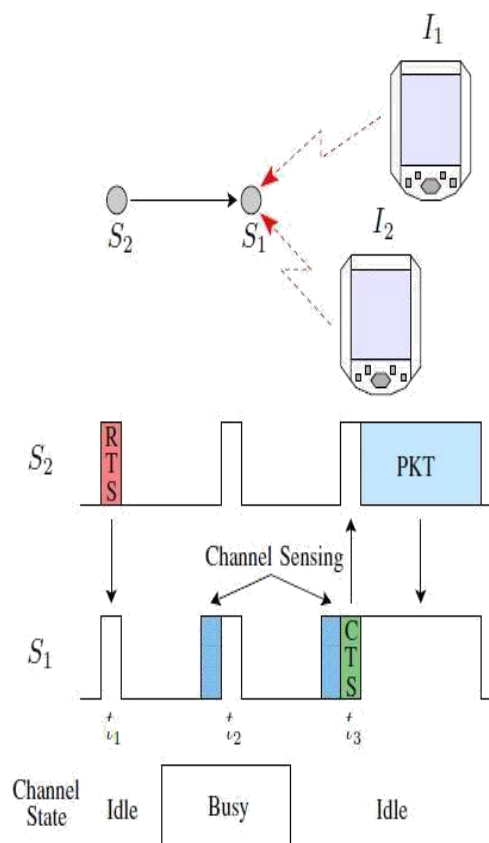


Fig.3 Channel sensing scenario

This model has been proposed in is based on the stochastic analysis of WLAN traffic patterns in the 2.4 GHz ISM band. Denoting the average fraction of time during which the considered frequency band is on the busy state. For the sake of simplicity and without loss of generality we assume that S_1 and S_2 are synchronized and periodically wake up at defined time instants t_i : a short preamble scheme like the one implemented in X-MAC could be alternatively adopted in unsynchronized networks. A packet transmission among the two nodes involves a simple handshake procedure (see Figure 1): S_2 first sends an RTS (Request To Send) to S_1 ; S_1 senses the channel before the upcoming wake-up period. If the channel is sensed idle, a CTS (Clear To Send) is sent back to S_2 , both nodes keep their radioactive and the packet transmission starts. Otherwise nodes enter in low-power mode and the channel is sensed again in the next wake-up

International Journal of Innovative Research in Science, Engineering and Technology

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period.

Note that since interference corrupts packets at the receiver side, there is no need for S_2 to perform interference detection: S_2 might eventually perform carrier sensing (using matched filter detection, thus achieving reliable outcomes with very limited energy requirements) in order to prevent that its RTS/packet collides with transmissions of neighboring nodes. We assume that the channel noise as well as the superposition of noise and interfering signals are both perceived by S_1 as white Gaussian processes with average power respectively equal to σ^2_0 and σ^2_2 . We further suppose that the state of the channel does not change while these are gathered.

Sensing is prone to errors: these might originate missed opportunities or cause loss of packets that will have to be retransmitted. Nodes normally operate in low-power mode and activate their radio unit only at wake-up instants. Energy consumption for exchanging a packet is determined by the energy required for channel sensing and the energy needed to transmit and receive packets and control messages (RTS/CTS). We assume that transmitting or receiving one bit and collecting a single channel sample x_i result in the same elementary energy cost E_u . We further suppose that while receiving packets or idle listening nodes consume the same amount of energy.

A. Spectrum Sensing For Spectrum Sharing

Detection of any phenomenon, based on stochastic data, can lead to errors in decision. When a PU is present, the sensing device could declare that it is not present, leading to a miss, which is the complement of detection. Similarly, when a PU is absent (or spectral hole), the sensing device could declare that a PU is present, leading to a false alarm. If a sensing device is designed to control one type of error, say, the probability of miss, which is One minus the probability of detection, below a specified value, the other probability of error, the probability of false alarm, is determined by the quality of the received signal and the noise in the system. From a PU point of view, a larger probability of detection would provide it with better protection, as the chance of a SU transmitting while the PU is present will be less. From a SU point of view a low probability of false alarm is better, as it provides a SU with more access.

It is interesting that, depending on the values of these probabilities, one can classify the sensing system in three different categories as Conservative System which has an opportunistic spectrum utilization rate less than or equal to 50% and a probability of interference less than 50% that is . Aggressive System which expects to achieve more than 50% opportunistic spectrum utilization while maintaining less than 50% probability to interfere with the PU. Hostile System that targets more than 50% opportunistic spectrum utilization and is likely to cause interference to the PU with a probability greater than or equal to 50%.

Furthermore, according to the nature of sensing techniques we can divide the sensing systems into two major groups: Blind Sensing that does not rely on any target signal features, like energy detection and autocorrelation detection or Signal Specific Sensing that utilizes specific target signal features, like matched filter detection and cyclostationary detection. On the other hand, IEEE 802.22 standard proposal mentions that no specific spectrum sensing technique is mandatory in the standard and designers will be free to implement whatever spectrum sensing technique they choose as long as it meets the specified sensing requirements.

B. Energy Aware Sensing

High energy budgets will result in accurate sensing outcomes but on the other hand, investing too much on this task might not be worth if interfering signals are sporadic or are perceived with very high power and are thus easy to detect. Furthermore, in order to achieve the highest energy efficiency, the sensing energy budget should be dimensioned accounting for the size of transmitted packets. The loss of long packets caused by sensing errors results in costly retransmissions and has to be avoided, by achieving sensing outcomes as reliable as possible; when transmitting shorter packets instead, lower energy budgets might originate sensing inaccuracies but result in lower overall energy consumption. It should be noted that this problem is of extreme interest for wireless sensor networks. It should be noted that this problem is of extreme interest for wireless sensor networks. Packets can be as small as a few tens of bytes therefore selecting the right amount of energy devoted to spectrum sensing might improve the energy efficiency.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

The cross-layer joint design of routing and resource allocation protocols in cognitive radio based WMNs. Optimizing these two layers independently can lead to sub-optimal solutions at best. The joint routing and resource allocation design problem is then formulated as an optimization problem having as objective the minimization of the end-to-end delay, and having integer valued decision variables. As formulated, the optimization problem is a non-linear integer programming problem, which has combinatorial complexity. It is shown that by relaxing the integer constraints imposed on the decision variables, one can efficiently find a solution to the relaxed optimization problem. A distributed solution to the optimization problem is presented. The performance of the proposed protocol is thoroughly studied and compared to the performance of a disjoint protocol. The resource allocation part aims at minimizing the end-to-end delay along the reselected routes.

III. JOINT ROUTING AND RESOURCE ALLOCATION METHOD

The primary objective of the proposed design scheme is to accommodate higher traffic load, and achieve lower delay compared to the disjoint design and throughput maximization.

In proposed approach, assume that the system model has the following properties:

- Primary and secondary nodes both employ a time slotted transmission structure.
- Cognitive nodes produce perfect spectrum sensing information.
- All secondary nodes use same transmission power.
- In a particular time slot, a secondary node can use at most one channel for transmission.

The proposed approach consists of three modules

- Distributed Resource Optimization
- Random Routing without Mesh Topology
- Joint Routing and Resource Allocation

1. Distributed Resource Optimization

Primary and cognitive networks both employ a time slotted transmission structure. Cognitive nodes have access to perfect spectrum sensing information. All cognitive nodes use the same fixed transmission power. In a given time slot, a cognitive node can use at most one channel for packet transmission. While cross layer design principles have been extensively studied by the wireless networking research community, the availability of cognitive and frequency agile devices motivates research on new algorithms and models to study cross-layer interactions that involve spectrum management-related functionalities.

2. Random Routing without Mesh Topology

The problem is formulated as a mixed integer non-linear problem, and a sequential fixing is developed where the integer variables are determined iteratively via a sequence of linear programs, Distributed implementations that build over the AODV routing protocol and enhance it for cognitive scenarios. A wireless mesh network (WMN) in which a large volume of traffic is expected to be delivered since it is able to utilize spectrum resources more efficiently. Therefore, it improves network capacity significantly. However, the dynamic nature of the radio spectrum calls for the development of novel spectrum-aware routing algorithms. In fact, spectrum occupancy is location dependent; therefore in a multi-hop path available spectrum bands may be different at each node. Hence, controlling the interaction between the routing and the spectrum management functionalities is of fundamental importance.

3. Joint Routing and Resource Allocation

Joint routing and resource allocation strategies in order to minimize the average end-to-end delay of multiple data connections in the cognitive radio based wireless mesh network. Because of the primary nodes activity, the spectrum

International Journal of Innovative Research in Science, Engineering and Technology

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resources available to the cognitive mesh nodes are varying in both space and time. Because of this strong interdependence between the routing and resource allocation strategies, we propose to deal with the routing and resource allocation strategies in a joint fashion rather than separating the two problems. Before presenting joint design strategy we need first to analyze the effect of the routing and resource allocation decisions on the network performance. This is achieved by relying on queuing theory to model the different aspects of the cognitive mesh network and to form a basis for our routing and resource allocation protocol design.

IV. RESULTS AND DISCUSSION

The Network Simulator version 2.0 (NS2) simulation of the proposed approach is done to evaluate the performance. There will be multiple destinations in the network. For each destination the path is constructed to improve the packet delivery ratio and to reduce the average end to end delay.



Fig.4 Average end-to-end delay as a function of time.

Figure 4 shows the delay measurement of the DORP and WSN protocol. The DORP protocol achieves half the delay compared to existing protocol.

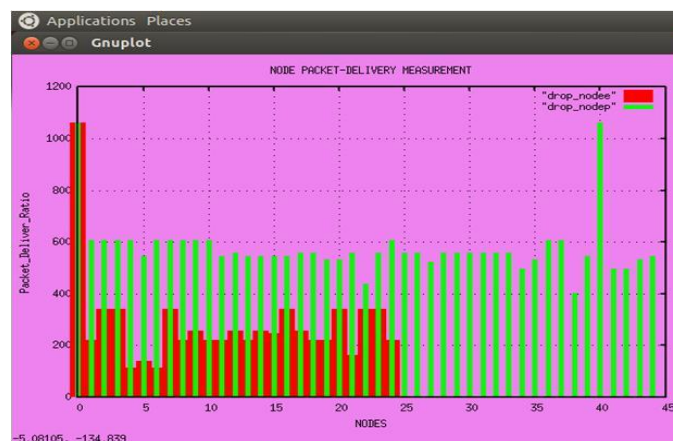


Fig.5 Drop node analysis of DORP and WSN

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Figure 5 indicates the particular node packet drop ratio. DORP reduces the loss percentage by increasing the delivery ratio. The following graph will explain about the performance of the proposed protocol in terms of protocol throughput.



Fig.6 Throughput of the DORP and WSN protocol.

The graph shows that the proposed protocol is better than the existing protocols such as AODV (Adhoc On demand Distance Vector). The packet delivery ratio is greater when compared with disjoint scheme.

V. CONCLUSION

The NS2 simulations show that when the network converted to mesh network, the proposed protocol outperforms disjoint scheme. Because the proposed protocol is a joint protocol, it reduces the average end to end delay and maximizes the throughput. All the secondary nodes can transmit data in the same TDMA time slot so that the transmitting delay is short. The proposed approach offers another simple approach to increase the packet delivery ratio.

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