Distributed Channel Selection Protocol for Single-Hop Transmissions in Cognitive Radio Networks

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ABSTRACT

We propose a distributed channel selection protocol for cognitive radio networks that are organized as ad hoc architectures considering single hop transmission. The channel selection is performed over a common control channel in such a way that channel congestion as well as heavy sensing effort is avoided. Simulation results show that the proposed protocol significantly outperforms a random channel selection protocol.

Categories and Subject Descriptors

C.2.2 [**Network Protocols**].

General Terms

Algorithms, Performance.

1. INTRODUCTION

In this paper we focus on cognitive radio networks of secondary users which are built out as ad hoc networks. We assume ad hoc networks in a sense that secondary users are using spectrum holes in uncoordinated manner such as ISM-bands, but we do not assume any large-scale MANET operations. Hence there are no central units for managing spectrum allocation. The establishment of communication between two secondary users faces–in addition to spectrum holes detection–two main problems: spectrum handshake and interference management.

The problem of spectrum handshake involves the process of finding a mutually usable/available set of frequencies/channels between two secondary users. The secondary users need to make some sort of rendezvous mechanism to agree on joint channel(s). Since the existence and the characteristics of spectrum holes may vary in time and space, the spectrum handshake is a challenging problem. One of the approaches suggested to deal with this problem is to use a common control channel where the spectrum handshake negotiation is performed [2]-[4]. Over this common control channel, a pair of secondary users exchanges information on the channels that they have sensed to be idle. If mutually available channels are found the two users reach an agreement on which of those should be used. One option is to allow the communicating pair to "bundle" channels and transmit on all of those while the rest of the nodes are differed from accessing the channel. However, when this is not possible and especially considering CSMA/CA based radios, channel selection will strongly affect the performance of the secondary network. The number of secondary users assigned to each of the available channels will determine the total network throughput, hence the load-sharing problem for secondary users should be taken care of.

In this paper, we propose a simple distributed channel selection protocol that uses the control channel to exchange information about the available channels in single hop secondary ad hoc network cognitive radios to enable the latter to autonomously choose the suitable bands while also performing load-balancing. The basic difference between our work and existing work, for instance [2]-[6], is that in most (if not all) of those approaches a negotiation for channel selection is performed for each data packet transmission over the common control channel. This however leads to high overhead in the control channel and may also cause unnecessary delays. In our proposed algorithm the access to the control channel is performed only in the case of establishing a new communication session or when primary access is detected and the secondary users must renegotiate for changing to another (free) channel (if one is available).

2. PROTOCOL DESCRIPTION

In this paper, we assume that the identification of spectrum holes is performed using perfect sensing mechanisms. The availability of a channel is assumed to be known for all cognitive nodes and therefore, we do not consider the problem of interference between primary and secondary networks. Moreover, we consider that when a channel is available for a given node it is available for all nodes. The last assumption can be seen also as a preference or limitation that we consider scenarios with small regional area secondary networks.

We propose a channel selection protocol for secondary radios with the additional capability of avoiding channel congestion by means of load balancing the secondary users over the available channels while keeping signaling traffic and complexity at acceptable levels. We assume that licensed part of spectrum can be divided into n channels that can be used opportunistically by the secondary nodes and a control channel is always available at a fixed frequency. Channel availability is modeled using an on-off model. On-Off models are shown to be reasonable models for certain bands [1]. Finally we assume that each channel has a different pattern for state changes.

In our approach we assume that each secondary node has two transceivers. The first transceiver is equipped with an SDR module that enables the use of the n channels and is used to exchange data packets. The second transceiver monitors the control channel and collects the required information for performing channel selection. We define n counters C_f for each

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node, where f is the index of the channel. For a given channel f, C_f represents the number of nodes using this channel. Moreover, each node has a set F of available channels. The access to the control channel is based on CSMA/CA protocol. Moreover secondary nodes that share the same data channel will use this protocol to avoid collision and data loss. However, other multiple access techniques can be also used for spectrum sharing. The control channel is used by a node in the following cases:

- A node initializes a new connection with another node. In this case the Select Frequency (SF) control message is sent and a timer is triggered. It contains the identities of the source and the destination, the proposed channel and an empty field corresponding to the previously used channel. The two last fields are used to update C_f counters. If no confirmation is received from the destination after the expiration of the timer, the proposed channel will be eliminated from the set of available channels and a new channel will be selected.
- A node receives an SF message and it is the destination of this message. If the proposed channel is available, this node will confirm the availability of the proposed channel using the Confirm Selected Frequency (CSF) message that contains the proposed channel. Otherwise, no message will be sent.
- A node is transmitting its data on one of the data channels and gets interrupted by the appearance of a primary user. The node will halt its transmission, wait for a backoff time, perform the scanning process and send a new SF which contains the identities of the source and the destination, the proposed channel and the previously used channel.
- A node has ended its data transmission. It will send a Release Frequency (RF) message to notify the other secondary nodes that it releases this channel. This message contains the channel that has been used for the data transmission in order to allow all nodes that are listening to the control channel to update their counters.
- A node receives an RF message and it is the destination of this message. It will reply with a CSF message to confirm the release of the channel.

When a node receives an SF and it is not the destination, the counter corresponding to the channel id in the first field is increased by one while the channel id in the second field, if it exists, is decreased by one. Moreover, if it receives an RF and it is not the destination, it decreases the counter that corresponds to the channel. The node will set to 0 any counter having negative value that may occur due to lost SF or RF messages. The value of the counter reflects the number of neighboring secondary nodes that are using the corresponding channel. Hence, the node will attempt to choose the channel with the lowest counter in order to avoid channel congestion. In order to determine the available channels out of the set of the n licensed the node first sorts the n channels with an increasing order of their respective counter values. Then, the node will scan these channels one by one until it finds an available channel, which will be chosen for transmission. This will decrease the number of scanned channels. In turn, also the sensing time and the energy consumption will be decreased. If the counter of a scanned channel is higher than 0 and the channel is found to be not available, the counter is set to zero. This mechanism corrects the errors originated from the possible loss of RF and SF messages and can be used only in the case where all secondary nodes have the same pattern of channel availability.

3. RESULTS AND CONCLUSIONS

We evaluated our protocol, using the ns-2 simulator, under a variety of channel availability patterns (in time). We examined different cases of average channel availability under which we consider scenarios with different channel transition times. We also performed comparisons with a protocol which neglects the current secondary use of the data channels when performing channel selection. In this later protocol, called Blind Selection - Random Scan (BSR-Scan), each node starts to scan randomly one by one the n channels until it discovers the first available channel which is immediately chosen for the node’s transmission. We choose to compare our protocol to a protocol performing random selection based on the fact that random selection is simple and has also been shown to converge to a load balanced state for the channels [7]. The proposed protocol can achieve up to 80% less per packet delay compared to BSR-Scan while requiring similar scanning effort. This is because the BSR-Scan protocol cannot achieve load balancing, thus leading to unnecessary congestion in some channels while at the same time other available channels are underutilized. Due to space limits, more details on our simulation settings and detailed analysis of the results can be found in [8].

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