Rendezvous in Cognitive Radio Networks without Common Control Channel

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Abstract

In this paper, we propose a rendezvous mechanism for cognitive radio networks. In this mechanism, no prior knowledge of wireless nodes is required and it is totally distributed. Node can simply choose one of two strategies to rendezvous with its neighbors. The main benefit of this mechanism is eliminating the use of common control channel and centralized controller.

Key words: channel rendezvous, cognitive radio networks.

1. Introduction

Cognitive radio technology is a new way to compensate the spectrum shortage problem of wireless environment. It allows secondary users to utilize the free portions of licensed spectrum while ensuring no interference to primary users' transmissions. Therefore, all secondary users in the network need information about primary users' activities, channel states, number of available channels etc. A pair of nodes needs to negotiate by exchanging necessary information before initiating any communication between them. Generally, necessary information is embedded in control packets and these are exchanged via a channel which is available for every user. Many MAC protocols for cognitive radio networks assume the existence of that channel and it is called Common Control Channel (CCC) [3]. However, it is impractical due to the dynamic nature of cognitive radio networks. Moreover, the usage of CCC also introduces major problems such as availability and reliability of CCC, control packets overhead, security and control channel saturation problem etc [2]. Therefore, many research works proposed to eliminate the use of CCC [4].

If there is no CCC in the network, nodes need to find a common channel for negotiation. It is, sometime, called rendezvous problem [5]. Many works have been targeted for this problem and most of previous works could be generally categorized as sequential based approaches [4] and probabilities solutions [1].

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In this paper, we proposed a probabilistic mechanism which provides how a node could find its neighbors without CCC. In our proposal, when a node (secondary user) needs to find its neighbors, it chooses one of two actions which are called neighbors discovery strategies and simply follows the instruction.

2. Neighbor Discovery Strategies

We assume that two node successfully rendezvous when they meet on the same channel and exchange necessary control packets (i.e. neighbors discovery message (*DOV*) form sender side and acknowledge (*ACK*) from receiver side). When a node needs to find its neighbor, it chooses one of the following strategies:

- *Strategy one*: Node switches one channel after another without repeating and finds its neighbor.
- *Strategy two*: Node chooses one available channel randomly and waits for its neighbors.

Node that chooses *strategy one* selects a channel randomly and broadcasts neighbor discovery message (*DOV*). If the node, let say *node a*, does not receives any *ACK*, it will switch another available channel and broadcast *DOV* again. This process is repeated and one round of neighbor discovery for *node a* is over when it receives *ACK* from one of its neighbors or after it has switched all available channels. The maximum time interval of one round can be estimated as $T_{round} = t.N$. N is the total number of available channels and t is the time interval that *node a* spends on a channel. We define the interval of t as one time slot and it can be estimated as

$$t = \frac{DOV+ACK}{T_{rate}} + DIFS + SIFS + R \qquad (1)$$

where T_{rate} represents transmission rate and R is random back-off.

Node that chooses *strategy two*, let say *node b*, just selects a random channel and waits its neighbors for one round. If it receives *DOV* from its neighbor, suppose from *node a*, it will reply *ACK* and neighbor discovery has been successfully done between these two nodes, node a and b. One round of *node b* is over after it has received *DOV* and replied *ACK* or one T_{round} has expired.

If a node does not meet its neighbor within one round, it will start the next round of neighbor discovery by selecting one of two strategies again. Decision making for choosing strategy is memoryless, which means selecting strategies for next round is independent on previous.

3. Analysis

We analysis this mechanism based on expected time to rendezvous, *E[TTR]*. According to neighbor discovery strategies, one of these three following events can occur in a round.

- *Event A* : Both nodes select the same strategy, *strategy one.*
- *Event B* : Nodes choose *different strategies.*
- *Event C* : Both nodes choose the same strategy, *strategy two.*

If *event A* occurs, both nodes try to find each other by switching one channel after another. In this event, the probability of meeting at least once within one round between two nodes is $P_r = 1 - P(N,0)$. $P(N,0) = \binom{N}{0}\left(1 - \frac{1}{N}\right)^N$ implies probability of no meeting at all in one round. The expected time slots for this event can be estimated as

$$E_A[TTR] = N\left\{1 - \left(1 - \frac{1}{N}\right)^N\right\} \qquad (2)$$

If *event B* occurs, a node that chooses strategy one switches one channel after another and finds its neighbor that chooses strategy two, which is waiting on an available channel. In this event, the expected time for rendezvous is given by

$$E_B[TTR] = \left(\frac{N+1}{2}\right) \qquad (3)$$

Moreover, this event provides upper bound of time to rendezvous which is simply N time slots. With another words, these two nodes definitely meet within a round.

If *event C* occurs, it is clear that these two nodes will not meet each other within a round. The expected time to rendezvous for this event can be expressed as

$$E_C[TTR] = \min(\mathrm{N}, \infty) \qquad (4)$$

Suppose P and Q *(= 1-P)* are probabilities of choosing *strategy one* and *two* respectively, Then, the overall expected time to rendezvous can be expressed as

$$E_{overall}\,[TTR] = (N+1)\,P(1-P) + N\left\{1 - \left(1 - \frac{1}{N}\right)^N\right\}P^2 + N(1-P)^2 \qquad (5)$$

We take derivative to (5) and we get optimal value of P as

$$P = \frac{N-1}{2N\{1-\left(\frac{N-1}{N}\right)^N\}-2} \qquad (6)$$

This provides that node should choose strategies according to the P and Q (=1-P) as described in (6), in order to meet its neighbors with minimum E[TTR].

4. Conclusion

In this paper, we have proposed a probabilistic solution for rendezvous problem in cognitive radio networks. It is totally distributed and it can minimize time to rendezvous with proper P value. It can also be used for other networks such as multi-channel wireless mesh networks.

5. References

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