Quadrant based Routing in WSN with Efficient Channel Allocation in Cognitive Radio

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Abstract: The collaboration of nodes in cognitive wi-fi networks is a huge undertaking. This paper studies the collaborative multi-hop routing in cognitive networks. We advise a new set of rules to construct the collaborative routing in multi-hop cognitive networks. Our set of rules takes into account the interference among nodes which include number one and secondary users. The clustering and collaboration are exploited to enhance the overall performance of collaborative routing in multi-hop cognitive wi-fi networks with a couple of number one and secondary users. By reading the most transmission distance, collaborations, transmission angle manipulate and electricity control, and channel allocation, we suggest a brand new clustering-based collaborative multi-hop cognitive routing set of rules to reap better network performance. Simulation effects display that our approach is feasible and effective.

Keywords: Cognitive Radio, Node collaboration, Multi-hop wireless communications, WMN

1. Introduction:

Wireless networking has been growing very rapidly in popularity around the world today. Several new applications of wireless networks have recently emerged such as broadband home networking, community networking, building automation, high speed metropolitan area networks, and enterprise networking. Wireless multi-hop networks, especially wireless mesh networks (WMNs), can enlarge the coverage of wireless internet access with minimal infrastructures [1, 2]. WMNs are promising directions in the future of wireless networks. The primary advantages of a WMN lie in its inherent fault tolerance against network failure, simplicity of setting up a network, and the broadband capability. Deploying a WMN is not too difficult, because all the required components are already available in the form of ad-hoc network routing protocols and IEEE 802.11 MAC protocol. However, the available MAC and routing protocols applied to WMNs do not have enough scalability; the throughput drops significantly as the number of nodes or hops in a WMN increases [2, 3, 4, 7]. This is because of the interference experienced from the neighbor nodes. Many research challenges still remain open in the design of the WMNs [1, 3]. Routing protocols may not be able to find a reliable routing path, transport protocols may loose connections, and MAC protocols may experience significant throughput reduction. As a typical example, current IEEE 802.11 MAC protocol and its derivatives cannot achieve a reasonable throughput as the number of hops increases.

Today's wireless networks are characterized by a fixed spectrum assignment policy [13]. However, a large portion of the assigned spectrum is used sporadically. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically. This new networking paradigm is referred to as cognitive radio networks [4]. If nodes of WMNs have CR functionality, the networks performances will increase [15, 16, 17]. The WMN with cognitive radio functionality is a cognitive radio wireless mesh network (CR-WMNs) that can be a solution for the spectrum scarcity problem. The basic idea of cognitive radio wireless network is that the secondary users need to vacate the channel once the primary user is detected, which means that the available spectrums of each node in the CR-WMN is dynamically changed [18]. Although these Cognitive radio technologies are still in their infancy, they are expected to be the future platform for wireless networks due to their capability of dynamically controlling the radios. These advanced wireless radio technologies all require a revolutionary design in higher layer protocols especially MAC and routing protocols. Routing constitutes a rather important but yet unexplored problem in cognitive radio networks. Especially in CR-WMNs with multi-hop communication requirements, the unique characteristics of the spectrum heterogeneity necessitate a novel routing algorithms to be developed. A major design choice for routing in the CR wireless network is the collaboration between routing and spectrum management. In the multi-hop wireless network (WMNs and CR-WMNs), nodes are forwarding packets for each other a routing protocol is necessary to make the routing decisions. Many problems in routing are remain to be solved. This thesis focuses at some of these problems and proposed three routing protocols for WMNs and CR-WMNs.

Throughput maximization is one of the main challenges in multi-hop wireless network. Throughput of the multi-hop wireless network seriously degrades as the number of hop increases. This is due to the interference experienced from the neighbor hidden nodes. Interference in a mesh network can be classified into two types, Self-flow or Intra-flow Interference: Self-flow interference occurs when two or more links of a single path operate on the same channel. Interference range of a node is typically bigger than a single hop and hence the links on same channel in a multi-hop path can still interfere with each other and not just restricted to immediate neighbors. It is shown in the Fig. 1.

2. Related Work:

Ding, (2015) [9] Cooperative relaying and dynamic-spectrum-access/cognitive techniques are promising solutions to increase the capacity and reliability of wireless links by exploiting the spatial and frequency diversity of the wireless channel. Yet, the combined use of cooperative relaying and dynamic spectrum access in multi-hop networks with decentralized control is far from being well understood. We study the problem of network throughput maximization in cognitive and cooperative ad hoc networks through joint optimization of routing, relay assignment and spectrum allocation. We derive a decentralized algorithm that solves the power and spectrum allocation problem for two common cooperative transmission schemes, decode-and-forward (DF) and amplify-and-forward (AF), based on convex optimization and arithmetic–geometric mean approximation techniques. We then propose and design a practical medium access control protocol in which the probability of accessing the channel for a given node depends on a local utility function determined as the solution of the joint routing, relay selection, and dynamic spectrum allocation problem.

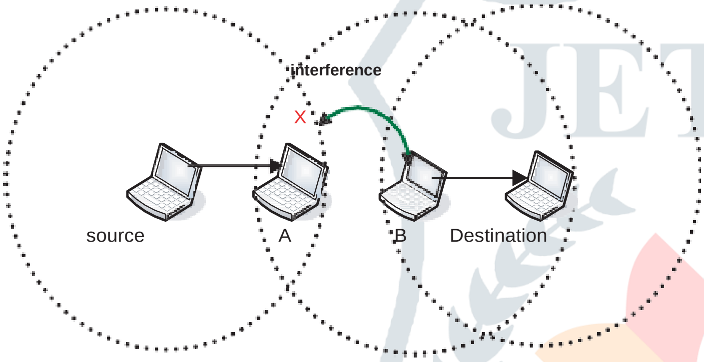


Figure 1. Self-flow interference.

Jianhui Huang,(2016) [10] In D2D communications, random contacts can be utilized to exchange data among nodes without the support from infrastructures or central control units. Because of the huge quantity and high mobility of the nodes, the scarcity of the available spectrum severely limits the data delivery capacity in D2D communications. CR technology gives D2D the ability to use idle licensed radio spectra from licensed networks to improve data delivery capacity. The advantages of opportunistic data delivery and CR technology make D2D communications an alternative that provides a complementary technology for big data applications. However, efficient routing algorithm design in D2D communications with CRD2D is nontrivial due to the spatial, temporal, and spectrum limitations introduced by node mobility and the available spectrum bands. This article investigates and analyzes the latest routing algorithms for D2D communications and CR networks.

Jiang Zhu (2017) [11] Wireless sensor networks are utilized in medical area to gather multimedia information from multiple sources, such as video streams, images, voice, heartbeat and blood pressure data, which call for higher bandwidth and more available spectrum. Whereas, today's radio spectrum is very crowded for rapid increasing popularities of various wireless applications. Hence, wireless sensor networks utilizing the advantages of cognitive radio technology, namely cognitive wireless sensor network (CWSN), is a pro¬mising solution for spectrum scarcity problem. A major challenge in CWSN is maximizing its network lifetime by appropriate power control mechanism. To solve the distributed power control issues in CWSN with imperfect information, a game-theoretic power control mechanism based on Hidden Markov Model (HMM) is proposed according to the difference and independence of channel sensing results among users of cognitive wireless sensor network (UCWSNs). UCWSNs can use HMM to infer whether its competitors take part in the game, which improves the information accuracy of game and leads to an optimal transmission power. Moreover, to meet the QoS (Quality of Service) of UCWSNs for multimedia information, a utility function based on the tradeoff of signal to interference plus noise ratio and power efficiency is defined for the power control game. Simulation results indicate that the game-theoretic power control mechanism based on HMM can not only improve the power efficiency, but also meet the target SINR better compared with other methods. In order to improve power efficiency and meet of UCWSNs in distributed cognitive wireless sensor network, according to the difference and independence of channel sensing results among UCWSNs, a game-theoretic power control mechanism based on HMM is proposed. By the HMM mode, UCWSNs can infer the set of competitors accurately and choose an optimal policy of trans¬mission power. Simulation results indicate that the game-theoretic power control mechanism based on HMM can incur better power efficiency on the premise of QoS requirement compared with others, which is on the expense of implementation cost.

Arsany Guirguis, (2018) [12] In the scope of cognitive radio networks, typical routing protocols avoid areas that are highly congested with primary users, leaving only a small fragment of available links for secondary route construction. In addition, wireless links are prone to channel impairments such as multipath fading which renders the quality of the available links highly uctuating. In this paper, we propose Undercover: a multi-hop routing protocol for cognitive radio networks in which we integrate the collaborative beamforming technique with layer 3 routing. Speci_cally, our protocol revisits a fundamental assumption taken by the state of the art routing protocols designed for overlay cognitive radio networks; this assumption is that secondary users cannot use the spectrum when primary users are using it. In Undercover, we allow a group of secondary users, each with a single antenna, to collaborate together and transmit in the regions of primary users activity. This is done through nulling out transmission at primary receivers via beamforming. Moreover, Undercover is designed to enhance the transmission quality at the secondary destinations whenever possible. To account for the excessive levels of interference typically incurred due to cooperative transmissions, we allow our protocol to be interference-aware. Thus, cooperative transmissions are penalized in accordance with the amount of negatively affected secondary ows.

Yihang Du,(2019) [13] Transmission latency minimization and energy efficiency improvement are two main challenges in multi-hop Cognitive Radio Networks (CRN), where the knowledge of topology and spectrum statistics are hard to obtain. For this reason, a cross-layer routing protocol based on quasi-cooperative multi-agent learning is proposed in this study. Firstly, to jointly consider the end-to-end delay and power efficiency, a comprehensive utility function is designed to form a reasonable tradeoff between the two measures. Then the joint design problem is modeled as a Stochastic Game (SG), and a quasi-cooperative multi-agent learning scheme is presented to solve the SG, which only needs information exchange with previous nodes. To further enhance performance, experience replay is applied to the update of conjecture belief to break the correlations and reduce the variance of updates. Simulation results demonstrate that the proposed scheme is superior to traditional algorithms leading to a shorter delay, lower packet loss ratio and higher energy efficiency, which is close to the performance of an optimum scheme. In this paper, we developed a quasi-cooperative multi-agent learning scheme for multi-hop CRN called ERT-CMAQL.

3. Methodology:

In the cognitive collaborative multi-hop communication network based on directional antenna, the transmission radius that different secondary users use different channels is often not the same. When we construct multi-hop paths, the paths will change while sending message because the channels which users use are not constant. To decrease the algorithm complexity, we firstly use omni-directional antenna to construct multi-hop collaborative paths, and then change it into directional antenna by adjust antenna main lobe and sending angle. According to the different transmitting radius that different channels users use, each user who participate in communication are assigned to certain channel. In this section, we will discuss the maximum transmission radius, collaborative multi-hop transmission paths, sending angle, transmitting power control, channel allocation strategy and cognitive collaborative multi-hop algorithm of secondary users.

Algorithm:

Step l: Let time $t = 1$ and initialize the maximum T.
Step 2: Initialize the neighbor node set matrix B^t of each secondary user.
Step 3: Choose source node s_1, and initialize $L_1 = \{s_1\}$, $m = 1$.
Step 4: Construct all possible paths from source node to destination node and calculate the total path number M.
Step 5: Choose path L_i and let $m = m + 1$.
Step 6: Choose the largest receiving power node from $U_{s_j}^t$ as the next hop of node c_j and label as s_t.
Step 7: If s_t does not exist, update $B_{s_j}^t$ Or otherwise let $j = j + 1$ and go back to Step 6. Step 8: If s_j is the last node of path L_i, let $L_i = L_i \cup s_t$. Or otherwise build a new path as follows:

$$L_j = \{s_1, \dots, s_j\} \cup s_t, \{s_1, \dots, s_j\} \in L_i.$$

Step 9: Let $i = i + 1$. If $m < M$, go back to Step 5.
Step l0: If $B_{s_j}^t$ is updated, go back to Step 4.
Step ll: Update all the paths sets and delete repeated paths.
Step 12: Save the path information.
Step 13: Let $t = t + 1$. If $t > T$, save the results to the file and exit. Or otherwise go back to Step 2.

4. Result and Discussion:

We will discuss the path achievable rate and collaborations of our quadrant based routing algorithm. When the transmission radius of secondary users becomes large, we can obtain the larger path achievable rate shown in figures as bar plot, where N denotes the number of secondary users. This is because the larger the transmission radius is, the more the collaborative nodes are. Thereby one can obtain the larger path achievable rate. Likewise, when the number of secondary users increases, we also get the higher path achievable rate. It is clear that the more secondary users is, the larger the density of nodes. In a result, there are more nodes

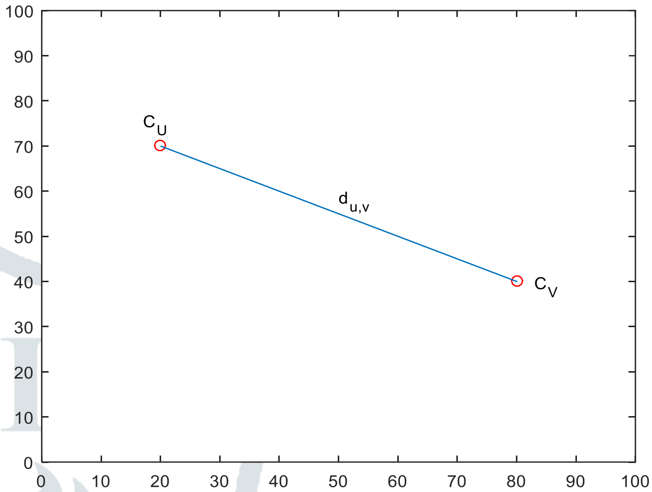


Figure 2: Two primary users u and v with distance $d_{u,v}$.

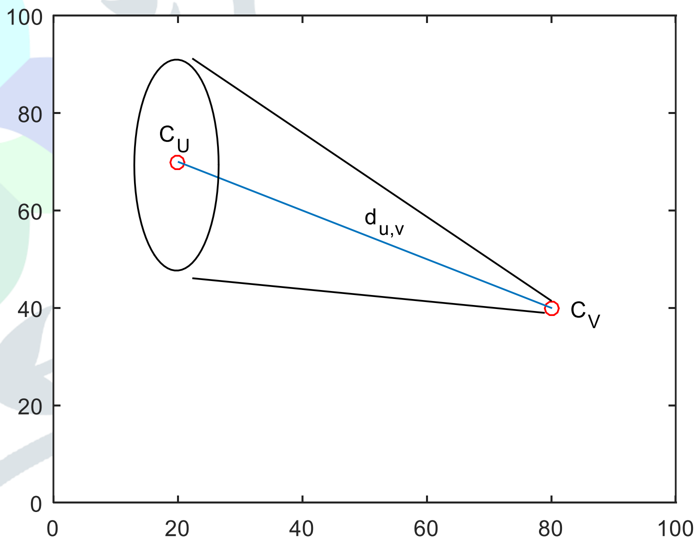


Figure 3: Transmission angle of coverage for omnidirectional antenna.

Able to take part in the process and the path achievable rate is raised. Figure plots the impact of transmission radius on the power of number of nodes. We can see that the larger transmission radius and secondary users' number lead to more power transmission of node to participate the collaborations among nodes. However, we also notice that when the transmission radius is 25, there are high power loss in nodes in the case of 25 secondary users that that of 15 ones. According to our algorithm, this case can lead to the larger interference and thus our algorithm only let less nodes participate the collaborations to avoid the interference. This shows that our algorithm holds the better performance.

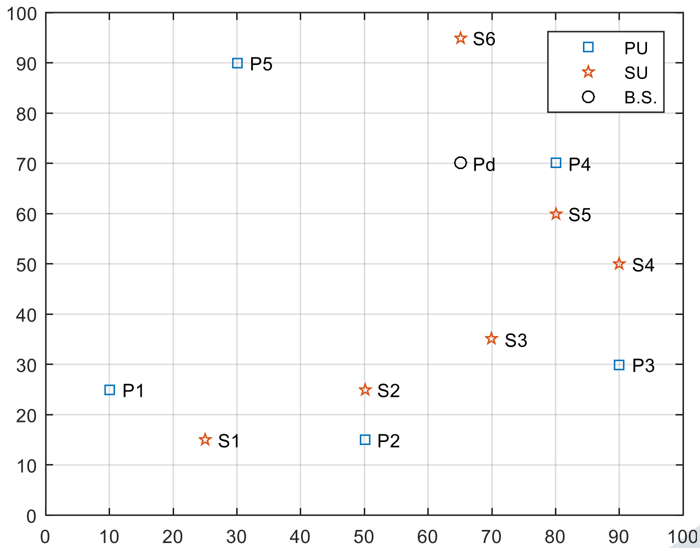


Figure 4: Multiple primary and secondary user communicating to base station

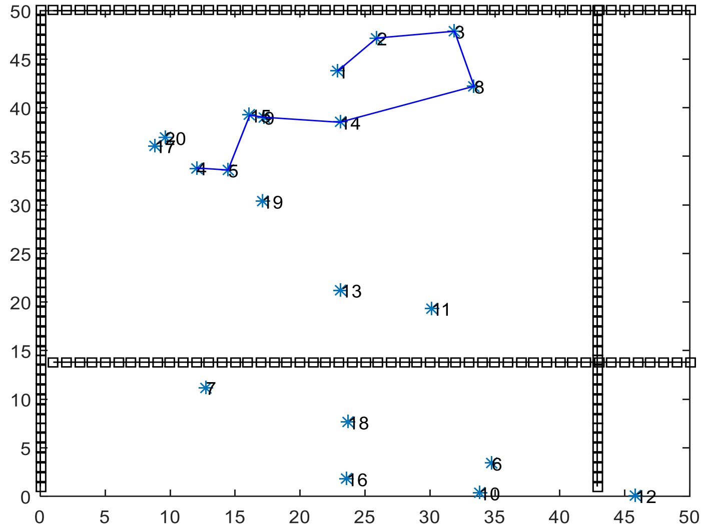


Figure 7: Routing within the nodes inside the quadrant.

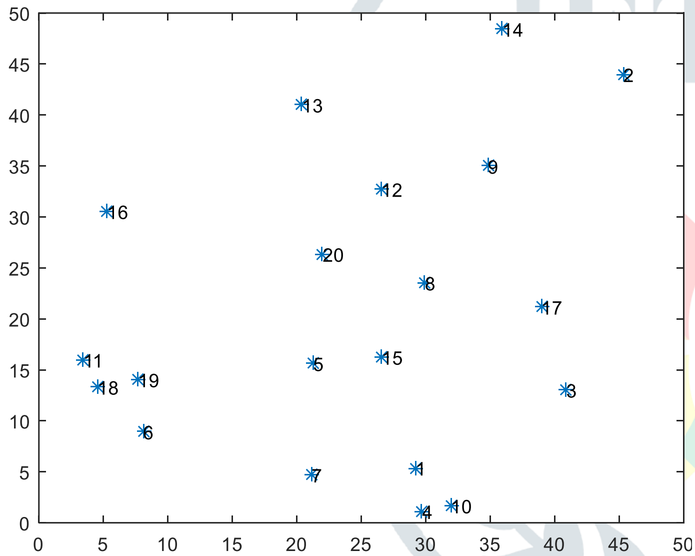


Figure 5: Multiple primsary usery deployed randomly.

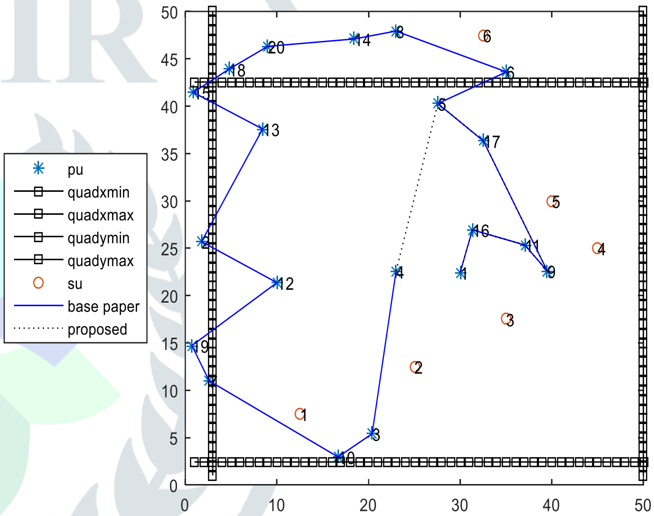


Figure 8: Route developed by quadrant approach and base paper.

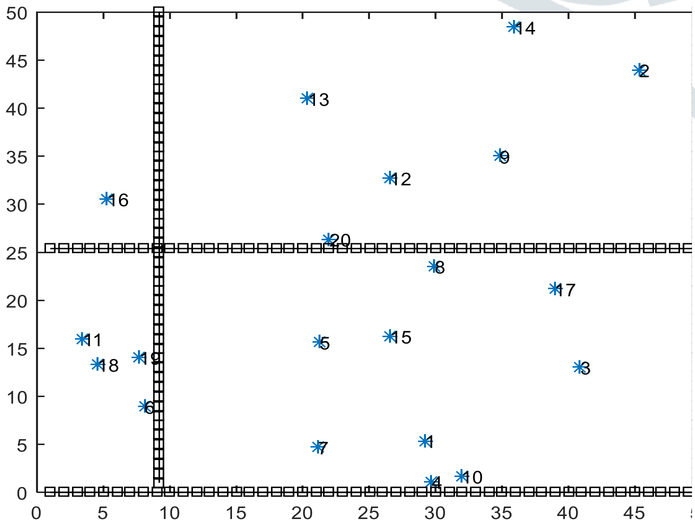


Figure 6: Quadrant ploting as per source and destination.

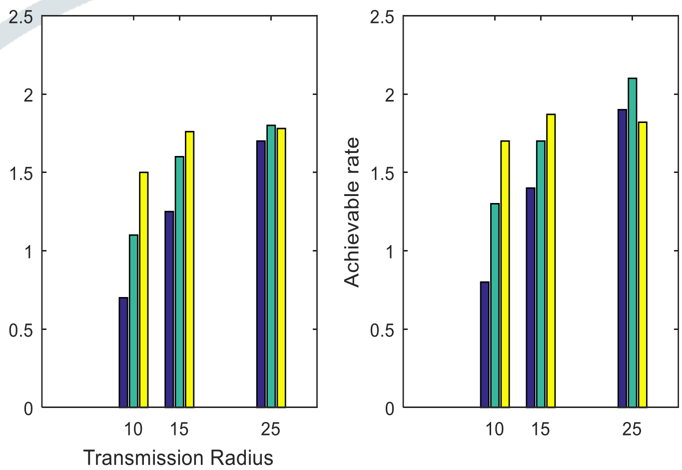
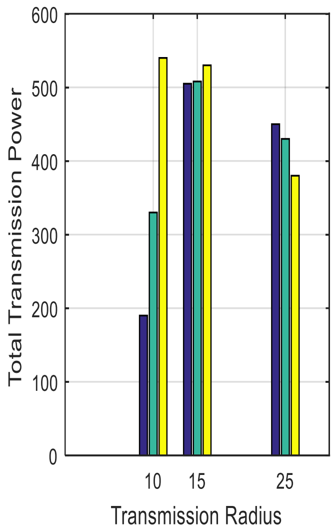


Figure 9: Achievable rate by base ppaper(left)and proposed (right)



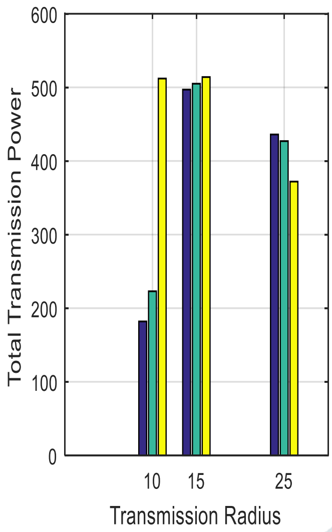


Figure 10: Transmission power by base ppaper(left)and proposed (right)

5. Conclusion:

This work propose a new algorithm to construct the collaborative routing in multi-hop cognitive networks with multiple primary and secondary users. Our approach considers the interference between primary users and secondary users. We take into account the interference between secondary users. After analyzing the maximum transmission distance, collaborations, transmission angle control and power control, and channel allocation, we propose a new clustering-based collaborative multi-hop cognitive routing algorithm. By a series of simulation tests, we find that if there exist more secondary users and larger transmission radius, we can let more nodes take part in the collaboration process and attain larger achievable rate. Moreover, we also see that our approach holds lower network energy consumption. Simulation results show that our approach is promising.

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