



A Study on Semi-Structure Routing mechanism in Cognitive Radio Networks

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Abstract— Cognitive Radio Networks (CRNs) is mainly resulting to trim down the drawbacks of current unbalanced and inefficient spectrum utilization on licensed spectrum bands. Routing is one of the most important and fundamental mechanism in the cognitive radio networks. To overcome the limitations of existing routing mechanism, many researchers develop a routing framework which is based on Semi Structure Routing (SSR). Semi Structure Routing framework incorporates power control strategy. By adopting the Forwarding Zone concept, efficiency of spectrum utilization is improved. Hence, Semi Structure Routing enhances the spectrum utilization. Hence the overall performance of Semi Structure Routing can be guaranteed. This mechanism can also avoid the high-cost complex and tortuous routes from sources to destinations. This paper gives review of some routing mechanisms in cognitive radio networks which improves and guarantees the performance of network.

Keywords— Cognitive Radio Networks, SSR, Forwarding Zone, tortuous routes, routing framework.

I. INTRODUCTION

Basically, Cognitive Radio is an intelligent radio that can be planned and configured dynamically. Such a radio automatically detects existing channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. Cognitive Radio Networks (CRNs) is mainly derived to reduce the drawbacks of current unbalanced and inefficient spectrum utilization on licensed spectrum bands. [1] In the CRN standard, routing is the most fundamental operations. The existing routing protocols for CRNs can be categorized as Optimization based routing protocols [2], and Resource aided routing protocols [3]. Most of the existing metric/rule based routing protocols utilize some global/network-wide measurements, e.g. accumulated spectrum opportunity. They also employ some local measurements to obtain routes from sources to destination. Existing routing protocols usually cannot fully measure the local real-time spectrum dynamics of CRNs. Local measurements usually cannot grant any overall performance assurance to the induced routes. For the resource aided routing protocols, they need some special extra resources, e.g. Common Control Channel (CCC), common link to achieve the desired route selection.

Recently, new routing mechanisms are developed based on Semi-Structure routing framework. This framework is motivated from the existing open problems in analytical model of routing protocols. Considering the two objectives i.e. spectrum aware and overall performance-assurance Semi-Structure Routing (SSR) framework with power control is proposed. For a data communication task from source S_u to destination S_v , first a rectangular routing zone is created denoted by $Z_{u,v}$. It connects source and destination. The routing zone $Z_{u,v}$ of communication pair (S_u, S_v) is a rectangle $\text{Rct}(XY UW)$, where X, Y, U , and W are the four vertices of the rectangle. S_u and S_v are located at the midpoints of edges XY and UW , respectively. As shown in Fig.1 (a), the routing zone of (S_u, S_v) is $\text{Rct}(XY UW)$. [4] Next, division of the routing zone into smaller rectangular zones starting from the S_u side, named the forwarding zones. Fig.1(b), shows the division of $Z_{u,v}$ into k forwarding zones starting from the S_u side. All the forwarding zones have same area size of s except for the last one $f^k_{u,v}$ which may have a smaller area size. Definition of forwarding zones shows that S_u is in the first forwarding zone and S_v is in the last forwarding zone. $f^1_{u,v}$ is the starting point for routing while $f^k_{u,v}$ is the ending point for routing. SSR measures and analyses both the local real-time spectrum dynamics and the global routing efficiency. The reasons are as follows: first, by providing forwarding zones, each intermediate forwarding node can choose its next hop from a set of nodes based on the real-time spectrum dynamics. [4] From the microscopic view, it significantly enhances the choices of an intermediate node as well as the spectrum opportunities, especially in CRNs with heavy-loaded primary activities. [4] Hence, SSR can successfully make use of the local real-time spectrum dynamics. Second, by initializing a routing zone, the actual recognized route from the source to the destination is limited to the routing zone and has a surrounded by number of hops.

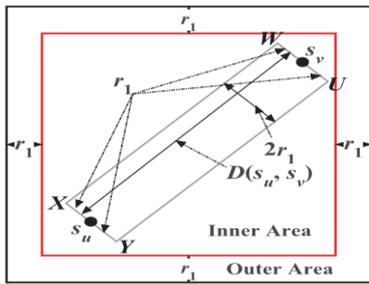


Fig. 1(a)

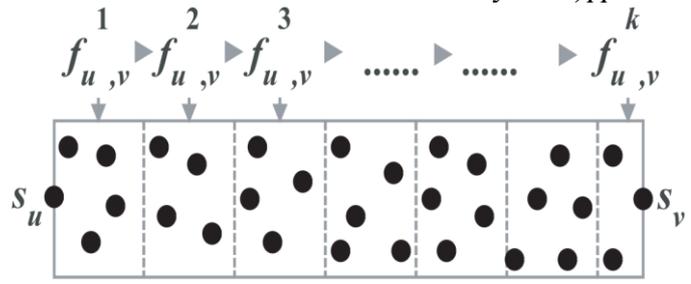


Fig. 1(b)

Fig. 1(a) & (b) Routing zone and forwarding zone [4]

II. RELATED WORK

A. Coolest Path: Spectrum Mobility Aware Routing Metrics in Cognitive Ad Hoc Networks

Xiaoxia Huang, Dianjie Lu, Pan Li and Yuguang Fang proposed a new routing metrics called the Spectrum Mobility Aware Routing Metrics to measure the time varying spectrum availability.[5] The proposed metrics support the “coolest” path, or the path with the most balanced and very low use of the spectrum by the primary users.

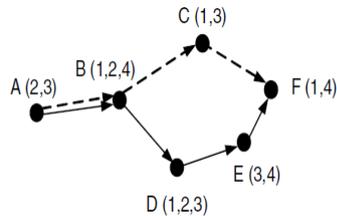


Fig. 2(a)

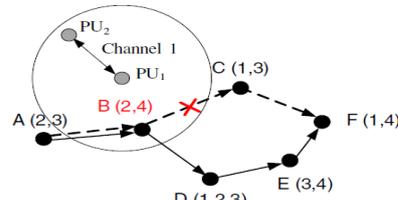


Fig. 2(b)

Fig. 2(a) Shortest path (dotted line) and path with higher frequency diversity [5]

Fig. 2(b) Shortest path fails when the channel 1 becomes unavailable at node B [5]

By selecting the path which is most unlikely to experience spectrum mobility, it addresses the problem of routing instability in cognitive ad hoc networks. The variation of the spectrum usage of all nodes can be predicted accurately. It is more important to choose the statistically more stable path. Because of the spectrum mobility has significant impact on path quality; the routing problem in cognitive ad hoc networks is diverse from existing wireless networks. Since existing routing metrics are not appropriate for cognitive ad hoc networks, a new concept of path stability is proposed, which measures the spectrum mobility. Path stability can be determined by two factors, frequency diversity and channel stability. Frequency diversity is related to the size of the common channel pool, or sub-link set at each hop over the path.[5] Each common channel between two nodes is called a sub-link. Frequency diversity refers to the minimum number of sub-links over all the hops on the path.[5] The path is more flexible to spectrum dynamics which has more free sub links at each hop with maximum frequency diversity. Fig. 2 shows that when primary user 1 appears on channel 1 then channel 1 is no longer accessible at node B. Result of this is link (B,C) over the shortest path fails. In contrast, the path with more sub-links still works as node B and D could switch to common channel 2 and continue transmission. This link repair procedure is apparent to other links. Channel stability is defined as the probability that the channel is claimed by a primary user. A path with better channel stability experiences less frequent spectrum mobility and path breakage.[5]

This paper concludes that it could achieve greater network capacity compared to the traditional ad hoc networks. This supports bandwidth-demanding applications. This is new routing metrics to capture the effects of the time-varying spectrum accessibility on routing in cognitive ad hoc networks.

B. Power Control in Cognitive Radio Networks: How to Cross a Multi-Lane Highway

Wei Ren, Qing Zhao and Ananthram Swami propose a power control strategy in cognitive radio networks without interfering to the primary users.[6] This power control strategy qualitatively characterizes the impact of the transmission power of secondary users on the occurrence of spectrum opportunities and the reliability of opportunity detection. The transmission power of a secondary user determines its communication range. It also affects how often it sees spectrum opportunities. If a secondary user wants to use a high power to reach its proposed receiver directly, it has to stay for the right opportunity. It also checks that no primary receiver is active within its relatively large interference region, which happens less often. On the other hand, if it uses less power to reach destination, it must depend on multi-hop relaying, and each hop must wait for its own opportunities to appear.

Based on the Poisson model of the primary network, it quantify the impacts by showing that (i) the probability of spectrum opportunity decreases exponentially with respect to the transmission power of secondary users, where the exponential decay constant is given by the traffic load of primary users; (ii) reliable opportunity detection is achieved in the two extreme regimes in terms of the ratio between the transmission power of secondary users and that of primary users.[6] This analytical method helps to study power control for secondary users under constraints on the interference to primary users. Hence it is well known that the difference between identifying primary signals and identifying the spectrum opportunities, and reveal the complex relationship between physical layer spectrum sensing and MAC layer throughput.

This paper characterizes the impact of secondary user's transmission power on the incident of spectrum opportunities and the reliability of opportunity detection. These impacts of secondary users' transmission power show the way to unique design tradeoffs in cognitive radio systems. These tradeoffs are fictional in traditional wireless networks. It has not been recognized in the literature of cognitive radio. The recognition and characterization of these tradeoffs put in to the basic consideration of cognitive radio systems. This clarifies two fundamental concepts that the presence/absence of spectrum opportunities is totally determined by primary transmitters. The detection of the primary signals is same as to detecting the spectrum opportunities. This paper shows that the critical role of primary receivers in the terms of spectrum opportunity. It results in the dependency of the incident of spectrum opportunities on the transmission power of secondary users. Hence, it is well understood that the dependency on the transmission power of primary users. Furthermore, this paper shows that spectrum opportunity detection is an issue to error even when primary signals can be absolutely detected. Such non-equivalence between detecting primary signals and detecting spectrum opportunities is the source for the connection between the reliability of opportunity detection and the transmission power of secondary users.

C. Joint Optimization of Spectrum Handoff Scheduling and Routing in Multi-hop Multi-radio Cognitive Networks

Wei Feng, Jiannong Cao, Chisheng Zhang and Chuda Liu propose a spectrum handoff scheduling routing protocol for the cognitive radio networks.[7] Performance degradation of the cognitive radio network usually happen because of the spectrum handoff. For the multi-hop cognitive network, multiple links are involved in the routing of the data. Performance of the cognitive radio networks becomes even worse since multiple links are involved. Spectrum handoff of multiple links critically affects the network connectivity as well as routing. This paper describes a cross-layer optimization come up to solve the spectrum handoff problem with joint consideration of spectrum handoff scheduling and routing. It proposes a protocol, called Joint Spectrum Handoff Scheduling and Routing Protocol (JSHRP).[7] This paper extended the concept of "spectrum handoff of single link" to "spectrum handoff of multiple links" termed as the "multi-link spectrum handoff". Under the network connectivity, the problem of coordinating the spectrum handoff of multiple links is minimized the total spectrum handoff latency. This paper shows both centralized and distributed insatiable algorithms to minimize the overall latency of spectrum handoff for multiple links in a multi-hop cognitive network. The spectrum handoff scheduling algorithm improves the network throughput. The rerouting mechanism is also performed. This rerouting mechanism is executed before the spectrum handoff actually happens. This is very different and appropriate method to solve the problems of the routing in the network as compared to traditional methods.

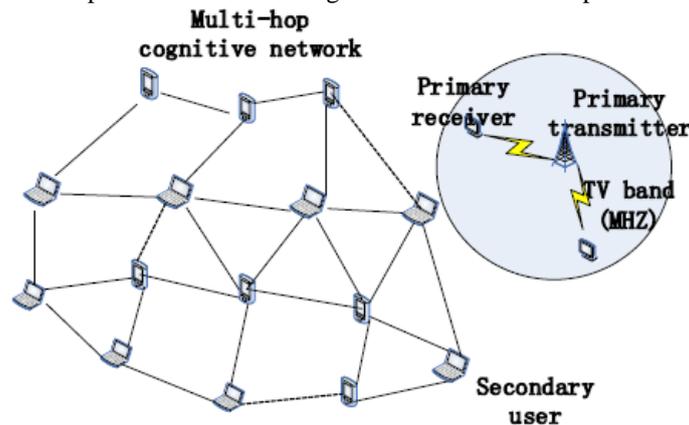


Fig. 3 Multi-hop multi-radio cognitive radio [7]

Fig.3 shows a multi-hop ad hoc wireless network consisting of N cognitive nodes. Cognitive nodes coexist with the primary user system. The dashed link represents that the link is affected by primary user. The activity of the primary user can be predictable, so a secondary user could have enough time to finish coordinating the spectrum handoff with other nodes, rerouting, and evacuating the channel. Each cognitive node is operated with K number of radios, where K is greater than one. During the spectrum handoff, the link which performs spectrum handoff will be broken for some time, and then recovered after the spectrum handoff. With the given algorithm of channel selection and the hardware condition, the time for spectrum handoff in one round is assumed to be constant. The total latency of multilink spectrum handoff is defined as the total time require for the spectrum handoff of multiple links to finish, which can be calculated using the following formulation.[7]

$$T_M = \bar{T} * N \tag{1}$$

Where \bar{T} is the average time of one-round spectrum handoff and N is the number of rounds. Hence, the total spectrum handoff latency for multiple links is determined by the number of rounds.[7]

This paper concludes that the method to jointly optimize spectrum handoff of multiple links and routing via a cross-layer is an appropriate. It significantly enhances the network performance. Hence, it decreases the degradation of the performance due to spectrum handoff.

D. Minimum-Latency Broadcast Scheduling for Cognitive Radio Networks

Shouling Ji, Raheem Beyah, and Zhipeng Cai introduces a broadcast latency in multi-hop cognitive radio networks.[8] They propose a broadcast scheduling strategy with minimum latency. Wireless spectrum is one of the most

precious resources. Because of the rapid growth of the number of wireless devices, communications over the unlicensed spectrum bands become very busy. According to the information from the Federal Communications Commission (FCC), the utilization of the spectrum assigned to licensed users varies from 15% to 85% [8], which is not efficient. To improve the interference and collisions on the unlicensed spectrum band, as well as to improve the efficiency of the licensed spectrum band, researchers develop a new communication standard recently, named Cognitive Radio Networks (CRNs). It enables unlicensed users to sense and learn the communication atmosphere with an equipped cognitive radio, and opportunistically access the licensed spectrum without disturbing the activities of licensed users or primary users [1]. In the CRN paradigms, a secondary network consisting of Secondary Users (SUs) (unlicensed users) with a primary network consisting of Primary Users (PUs) (licensed users)[8]. They use the same time, space, and spectrum band. Before initializing a data transmission, SU senses and learns its local wireless environment. If there is a spectrum opportunity, this SU can conduct the data transmission without troubling any activity of the primary network. This paper studies the Minimum-Latency Broadcast Scheduling (MLBS) problem for CRNs.[8] In wireless networks, as well as in CRNs broadcast is one of the most important operation. It aims to deliver a message from a source to all the other nodes with minimum delay. For multi-hop CRNs, the broadcast latency is defined as the time consumption by which all the nodes in the network have received the broadcast message from the source directly or via a multi-hop manner.[8] Problem of the MLBS to seek a broadcast scheduling strategy with the minimum broadcast latency. The MLBS problem is not able to solve in traditional wireless networks. Therefore, to solve this problem many approximate algorithms are proposed in traditional wireless networks. But, it is not significant to adopt these algorithms to CRNs. CRN is a new communication paradigm. It consists of two networks primary network and secondary network. It has different priorities. The activity of the primary network introduces many constraints on the spectrum accessibility of SUs. Unlike traditional wireless networks, nodes can access the spectrum freely. SUs have to sense and learn its confined wireless environment. When there is a spectrum opportunity for SU i.e. the activity of SUs does not cause any unacceptable interference or disturbance to the primary network, they can access the original spectrum. Furthermore, the activities of PUs also induce more interference to SUs besides the interference produced in the secondary network. Hence this paper designs broadcast scheduling algorithms for CRNs. This is an elegant technique to solve the MLBS problem in Cognitive Radio Networks.

III. CONCLUSION

This paper reviews different methods to solve the routing problem in cognitive radio networks. Semi-structure routing mechanism provides a power control strategy. The performance of routing mechanism increases the spectrum utilization efficiency. The overall performance of SSR is guaranteed by avoiding high-cost and complex tortuous routes from sources to destinations.

The future work we can do to decrease the global routing cost in cognitive radio networks. We can try to improve the throughput of the network. Finally SSR can improve the energy efficiency.

ACKNOWLEDGMENT

I am indeed thankful to my guide Prof. Y. D. Chincholkar for his able guidance to complete this paper. I extend my special thanks to Head of Department of Electronics and Telecommunications Dr. M. B. Mali who extended the preparatory steps of this paper-work. I am also thankful to the Principle Dr. S. D. Lokhande, Sinhgad College of Engineering for his valued support and faith on me.

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