Pathway Collection below Resource Constraints in Multihop Cognitive Radio Networks

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Abstract - Cognitive Radio (CR) is an emerging technology to solve the spectrum underutilization problems by opens the licensed spectrum bands for opportunistic usage and initiates spectrum trading to improve the spectrum utilization. The path selection problem in multihop cognitive radio networks (CRNs) are investigated below constraints on flow routing, link scheduling and CR source's budget. Cognitive Radio session-based spectrum trading develops the spectrum trading mechanisms that are very effective based on the cross-layer optimization in multi-hop CRNs. New service provider, called secondary service provider (SSP) helps CR sessions to select the paths for packet delivery. The SSP purchases the licensed spectrum and jointly conducts flow routing and link scheduling under the budget constraints. A 4D conflict graph is used to characterize the conflict relationship among CR links and objective of maximizing the end-to-end throughput. The heuristic algorithm used to solve the NP-hardness of the problem and finding the path with source budget. The heuristic algorithm considers only single path routing which decreases the network performance. In order to increase the network performance the Multipath Routing and Spectrum Access algorithm has been proposed.

Keywords – **cognitive radio networks, multihop multipath routing, path selection, optimization, routing**

I. INTRODUCTION

Nowadays, more and more people, families, and companies rely on wireless services for their daily life and business, which leads to a booming growth of various wireless networks and a dramatic increase in the demand for radio spectrum. The rapid development of wireless communication technologies results in the problem of radio spectrum shortage. Additionally, the traditional fixed spectrum allocation scheme can lead to the significant spectrum underutilization. Experimental tests and measurements to show many licensed spectrum bands are not used in certain geographical areas and are idle most of the time. The FCC to open up licensed spectrum bands and pursue new innovative technologies to encourage dynamic use of the underutilized spectrum and solve the spectrum underutilization in wireless networks. As one of the most promising solution is Cognitive Radio (CR) technology. The idea of opportunistic using licensed spectrum in multihop cognitive radio networks (CRNs) has initiated the market of spectrum trading. Given a CR session and multiple routes between the CR source and destination, we endeavor to find a path with the maximum end-to-end throughput under the CR source's budget in multihop CRNs. To achieve this objective, we have to consider the price of the bands, budget constraints of CR source, link scheduling constraints, flow routing constraints, and possible returning of primary services, when selecting the path as well as the licensed bands for opportunistic accessing. In this paper, we mathematically formulate these concerns into an optimization problem and provide near-optimal solutions using linear programming. We also propose a heuristic algorithm to give feasible solutions to the path selection problem under multiple constraints.

We introduce a novel service provider for CR users, called secondary service provider (SSP), into the network and employ SSP to help the CR session select the path for packet delivery. Construct a 4D conflict graph to describe the conflict relations among CR links in competing for bands with the price of bands and the probability of primary services' returning in multihop CRNs. 4D conflict graph consisting of link band probability price quadruplets Based on the 4D conflict graph, the SSP can mathematically formulate the path selection as a joint routing and link scheduling optimization problem under the CR source's budget constraint. By carrying out simulations, we demonstrate the impact of the CR source's budget, the number of available bands, and the distance between the CR source and destination on the performance of path selection in CRNs. We also compare the path selection algorithms including the optimal path selection, heuristic path selection, the proposed Multipath Routing and Spectrum Access (MRSA) and show that the MRSA algorithm is much better than the heuristic algorithm, and is close to the optimal one in terms of the path capacity.

II. RELATED WORK

How to find the path with the largest end-to-end throughput under joint link scheduling and routing constraints has been extensively studied in both SR-SC networks and MR-MC networks. Considering the uncertain spectrum supply, M. Pan, C. Zhang, P. Li, and Y. Fang [4] proposed how the CR users optimally distribute their traffic demands over the spectrum bands to reduce the risk for monetary loss, when there is more than one unoccupied licensed band is available and provide a novel architecture of CRNs for spectrum harvesting and sharing, investigated the joint frequency scheduling and routing problem in multi-hop CRNs under uncertain spectrum supply. H. Zhai and Y. Fang [5] described the path capacity of a given path considering joint routing, link scheduling and leveraged the interference clique transmission time (CTT) to select the high throughput path in SR-SC networks. According to the interference relationships between links, to construct the link conflict graph, where each node represents one link and each edge represents that there is a conflict between the two corresponding links. The link conflict graph used to characterize the interference relationship and find the path capacity of any given path in the network.

In the existing literature of multihop CRNs, there remains a lack of study on the path selection problem by jointly considering routing and link scheduling. Meanwhile, there is a lack of bond to connect the research on spectrum trading and the research on cross-layer optimization in multihop CRNs. Our work proposed the study on the path selection problem considering multiple factors including the price of the bands, budget constraints of CR source, link scheduling constraints, flow routing constraints, and activities of primary services. This work extends the single path selection into multiple paths and increases the network performance to achieve optimization.

III. NETWORK MODEL

We consider a spectrum market in multihop CRNs consisting of multiple primary users operating on different frequency bands and an SSP (e.g., a base station (BS) or an access point (AP)) who serves a group of CR users N= {1,2, . . . , n, . . .,N}. Suppose that the set of licensed spectrum bands B= {1,2, . . . , b, . . .,B} have the identical bandwidth. We also assume that a CR user has only one radio, but the radio can be tuned into any available frequency band for packet delivery, i.e., a CR user can only work on one of the available bands at one time. As shown in Fig. 1, some spectrum bands at certain geographical locations (the bands fully in shade) may be reserved for the exclusive usage of specific primary services.

Let s_r/d_t denote the source/destination CR node of this session, and E be the budget of the CR source s_r. To forward packets to the destination, the source CR node must pay for the opportunistic spectrum usage of the CR links along the selected path to primary users via the SSP. Meanwhile, the availability of the purchased bands is not guaranteed. CR links can opportunistically use the purchased licensed bands when the primary services are not on, but have to stop using those bands when primary services become active. Given such a CR session, in this work, the SSP collectively harvests licensed spectral resource, purchases spectrum bands for CR links at different locations, and jointly conduct link scheduling and route selection under the budget constraints with the objective of maximizing the end-to-end throughput.

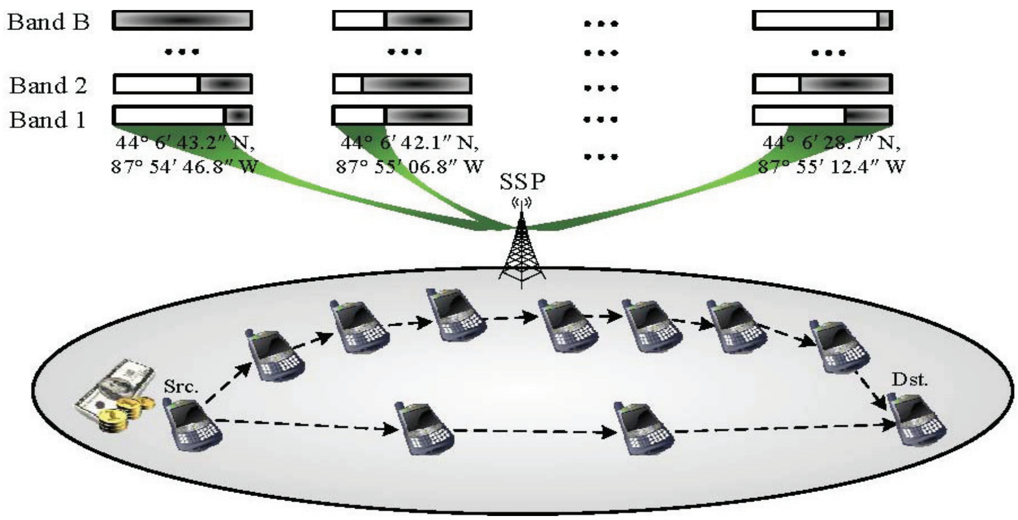

Figure 1. Spectrum market and opportunistic spectrum accessing for packet delivery under CR source's budget constraints in multihop CRNs.

IV. EXISTING ALGORITHM

The detailed procedure of the existing algorithm of the heuristic algorithm for path selection in CRNs is presented as follows:

Step 1: Construction of the 4D conflict graph

Regarding the unpredictable activities of primary services and the features of CR transceivers, to introduce a 4D conflict graph to characterize the interference relationship among CR links in CRNs a 4D conflict graph G (V, E) each vertex corresponds to an LBP^2 price quadruplet, where an LBP^2 quadruplet is defined as Link-band-probability-price: (l_{ij}, b, $q^{b}{}_{ij}$, $p^{b}{}_{ij}$). According to the definition of LBP^2 quadruplets, to enumerate all combinations of CR users, bands, and the availability of bands and the price of bands, this can potentially enable a CR communication link. Two quadruplets are said to interfere with each other if either of the following two conditions holds:

Condition1: Two different LBP^2 quadruplets have one or two CR nodes in common.
Condition2: If two different LBP^2 quadruplets are using the same band, the receiving CR node of one LBP^2 quadruplet is within the interference range of the transmitting CR node in the other LBP^2 quadruplet.

Step 2: Decoupling the 4D conflict graph into layers

With the established 4D conflict graph of the path, then further divide this $G_p(V_p, E_p)$ into different layers according to the number of bands |B| to be used.

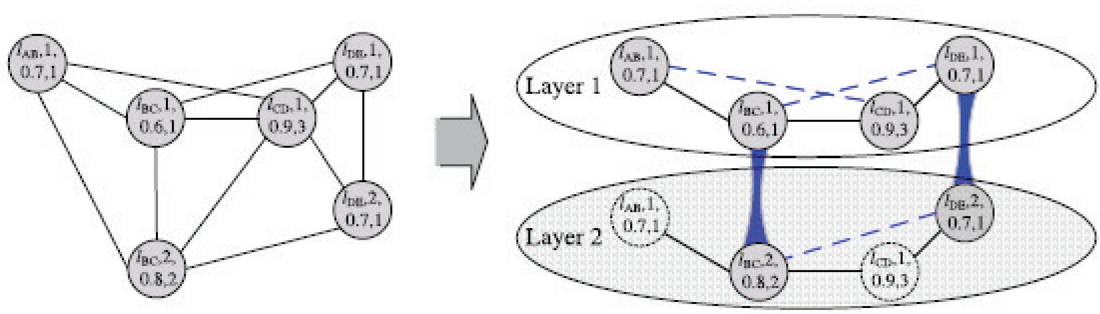

Figure 2. 4D conflict graph

Step 3: Differentiating two types of edges

Classify the edges on a layer of the 4D conflict graph into two categories. For layer b in G_p, one kind of edges connects two different LBP^2 quadruplets who have one CR node in common, i.e., LBP^2 quadruplets on layer b satisfying Condition 1. Then define these edges as non-reducible edges. The other kind of edges connects two different LBP^2 quadruplets who have co-band interference, i.e., LBP^2 quadruplets on layer b satisfying Condition 2. These edges are called as reducible edges.

Step 4: Selecting the benchmark layer

If there is only one layer in G_p, select it as the benchmark layer, if there is more than one layer in G_p, select the one which has the most edges (either non-reducible edges or reducible ones) because this layer can most effectively show the interference relationship among different links along the path P.

Step 5: Establishing the benchmark path capacity and Path Expense

After choosing the benchmark layer, estimate the benchmark expense. To calculate the benchmark expense, need information from two sides: 1) the unit price of the band used by a link and 2) the active time of that link along the path P for one time period τ, under the condition that layer b of G_p is selected as the benchmark layer 3) Given layer b as the benchmark layer, the unit price of the band used by l_{ij} is calculated as the following three cases:

Case 1: If $|Q_{ij}|=1$ there is only one LBP^2 quadruplet available for l_{ij}. Thus, the SSP can only choose the LBP^2 quadruplet for l_{ij} and pay the corresponding price for using the band enclosed in that LBP^2 quadruplet.

Case 2: If $|Q_{ij}|\geq 1$ and $(l_{ij}, b, q^b_{ij}, p^b_{ij}) \in Q_{ij}$, there are multiple LBP^2 quadruplet available for l_{ij} including $(l_{ij}, b, q^b_{ij}, p^b_{ij})$. Since layer b is the benchmark layer, the SSP will choose LBP^2 quadruplet $(l_{ij}, b, q^b_{ij}, p^b_{ij})$ for l_{ij} to calculate the benchmark expense and pay p^b_{ij} for using band b.($E_{ij} = p^b_{ij}$)

Case 3: If $|Q_{ij}|\geq 1$ and $(l_{ij}, b, q^b_{ij}, p^b_{ij}) \notin Q_{ij}$, there are some other LBP^2 quadruplets available for l_{ij} except $(l_{ij}, b, q^b_{ij}, p^b_{ij})$. In this case, the SSP can randomly choose an LBP^2 quadruplet $(l_{ij}, k, q^k_{ij}, p^k_{ij})$ in Q_{ij} for l_{ij} to estimate the benchmark expense and pay the corresponding price for using the band enclosed in that LBP^2 quadruplet, i.e., $E_{ij} = p^k_{ij}$.

Considering the link l_{ij} and any one packet successfully delivered from the CR source to the CR destination, the packet takes time T_p to travel through all the LBP^2 quadruplets in lij. The benchmark path capacity C_p can be approximated as $1/T_p$.

Given benchmark path capacity C_p, the SSP will establish the benchmark expense Π_p, the benchmark expense of the path P can be expressed as

$$\Pi_{\mathcal{P}} = \sum_{(l_{ij},b,q^b_{ij},p^b_{ij})\in Q_{ij}} \frac{T_{(l_{ij},b,q^b_{ij},p^b_{ij})}}{\hat{T}_{\mathcal{P}}} E_{ij} + \sum_{(l_{uv},b,q^b_{uv},p^b_{uv})\notin Q_{uv}} \frac{T_{(l_{uv},k,q^k_{uv},p^k_{uv})}}{\hat{T}_{\mathcal{P}}} E_{uv}.$$

Calculate the Transaction time and Sum up the benchmark expense of each link along the path P and establish benchmark expense of P.

Algorithm: Establishing the benchmark expense

Require: Initialize the procedure after layering G_p and selecting layer b as the benchmark layer.

1: for all $l_{ij} \in P$ do
2: if $|Q_{ij}|==1$ then
3: The SSP chooses that LBP^2 quadruplet for l_{ij}.
4: else if $|Q_{ij}|\geq 1$ and $(l_{ij}, b, q^b_{ij}, p^b_{ij}) \in Q_{ij}$ then
5: The SSP chooses $(l_{ij}, b, q^b_{ij}, p^b_{ij})$ for l_{ij} and set $E_{ij} = p^b_{ij}$
6: else if $|Q_{ij}|\geq 1$ and $(l_{ij}, b, q^b_{ij}, p^b_{ij}) \notin Q_{ij}$,then
7: The SSP randomly chooses $(l_{ij}, k, q^k_{ij}, p^k_{ij}) \in Q_{ij}$ for l_{ij} and set $E_{ij} = p^k_{ij}$
8: end if
9: Calculate the transmission time for $l_{ij} \in P$.
10: end for
11: Find the maximum value of the local clique's transmission time T_p and estimate the benchmark path capacity with $1/T_p$

12: Given the benchmark path capacity, calculate the transmission time and the corresponding benchmark expense at l_{ij} Є P.
13: Sum up the benchmark expense of each link along P and establish the benchmark expense of P.
Step 6: Switching quadruplets for high throughput

Depending upon the value of benchmark expense, transmission time and budget the SSP may apply different strategies to Switch LBP^2 quadruplets. If the benchmark expense is beyond the budget, i.e., the budget of the CR source, the SSP will switch LBP^2 quadruplets to reduce the overall expense for the given path P. The benchmark expense increases when the transmission time decreases. Thus, the SSP would switch the LBP^2 quadruplets on other layers.

The SSP first sorts the LBP^2 quadruplets on the benchmark layer. According to the number of reducible edges associated with the LBP^2 quadruplets, the SSP indexes the LBP^2 quadruplets in a decreasing manner; then the SSP starts the switching process with the LBP^2 quadruplet having the smallest index. Let the LBP^2 quadruplet (l_{ij}, b, q^b_{ij}, p^b_{ij}) on benchmark layer b. If $|Q_{ij}|=1$, then this LBP^2 quadruplet cannot be switched, and the SSP continues to check the next LBP^2 quadruplet. If the new benchmark layer expense less than the source budget then switch into another layer.

The heuristic algorithm provides a useful metric to the SSP for the path selection. Given possible paths of a CR session, the SSP can exploit the heuristic algorithm above to calculate the throughput for selected paths by using local cliques, and select the path with the highest throughput.

V. PERFORMANCE EVALUATION

It demonstrates the impact of the CR source's budget, the number of available bands, and the distance between the CR source and destination on the performance of path selection in CRNs. When CR Node source's budget increases, the end-to-end throughput also increases. The heuristic path selection algorithm selects the optimal path with highest end-to-end throughput. It also shows the performance between selected routes within source budget and throughput. Consider a single flow scenario and ignore the interference from the other flows. The network performance improvement is still hindered by the inherent single-radio of CR devices. Another issue is the mobility of CR users, which may have negative impact on the scheduled transmissions. .

VI. PROPOSED ALGORITHM

In the proposed work we describe the multi-path routing and spectrum access (MRSA) algorithm, multiple routes are discovered for any destination and then some best routes among discovered route are selected based on different parameters. Multi-path routing has many benefits such as fault tolerance, increased bandwidth and reduction of primary to secondary user interference. MRSA is the first multi-path protocol for CRNs that minimizes the inter path contention and interference. It overcomes the interruption of primary users with minimum degradation by distributing the traffic of each flow over multiple paths. For traffic distribution it uses round robin fashion that is not an effective technique.

In MRSA "spectrum wise disjointness" concept is revised as if multiple paths do not have any interfering bands between them then these paths are spectrum wise disjointed. MRSA assumes that there will be total N channels for data traffic and signaling is delivered over these channels together with data traffic. It uses dynamic source routing (DSR) mechanism for route discovery in which source node broadcasts an RREQ message with new RREQ_ID and attaches its band radio usage table (BRT). When an intermediate node receives RREQ before forwarding, it verifies if the RREQ_ID is new or if RREQ_ID is not new then it counts the hop count from source. If RREQ has fewer hop count than the previous RREQ it will append its BRT and then forwards it. Thus destination will receive the same RREQ from multiple paths. Thus it first assigns band and radio to each link then evaluates all the candidate paths by their available bandwidth. RERR message of DSR is extended to overcome the sudden arrival of primary user and it's the part of route recovery process.

The protocol constructs multiple paths to maximize spectrum wise disjointedness and to minimize contention and interference. It achieves higher throughput than other routing approaches and effectively utilizes the network resources. It also provides better resilience from the dynamic interruption of primary users.

VII. CONCLUTION

In this paper we have proposed a Multi-path Routing and Spectrum Access algorithm for increasing the network performance and effectively utilize the network resources. It also achieves the end-to-end throughput using multipath. The path selection problem in multi-hop cognitive radio networks (CRNs) are investigated under constraints on flow routing, link scheduling and CR source's budget with the objective of maximizing the end-to-end throughput for the CR session.

REFERENCES

[1] C. Gao, Y. Shi, Y.T. Hou, H.D. Sherali, and H. Zhou, "Multicast Communications in Multi-Hop Cognitive Radio Networks," IEEE J. Selected Areas in Comm., vol. 29, no. 4, pp. 784-793, Apr. 2011.

[2] K. Jain, J. Padhye, V.N. Padmanabhan, and L. Qiu, "Impact of Interference on Multi-Hop Wireless Network Performance," Proc ACM MobiCom, Sept. 2003.

[3] Kanchan Hadawale and Sunita Barve, "Routing Schemes in Cognitive Radio Network" International Journal of Mathematics and Computer Applications Research (IJMCAR) ISSN 2249-6955 vol. 3, Issue 2, Jun 2013.

[4] M. Pan, C. Zhang, P. Li, and Y. Fang, "Spectrum Harvesting and Sharing in Multi-Hop CRNs Under Uncertain Spectrum Supply," IEEE J. Selected Areas in Comm., vol. 30, no. 2, pp. 369 378, Feb. 2012.

[5] H. Zhai and Y. Fang, "Impact of Routing Metrics on Path Capacity in Multirate and Multihop Wireless Ad Hoc Networks," Proc. IEEE Int'l Conf. Network Protocols(ICNP'06), Nov. 2006., A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[6] H. Li, Y. Cheng, C. Zhou, and P. Wan, "Multi-Dimensional Conflict Graph Based Computing for Optimal Capacity in MR-MC Wireless Networks," Proc. Int'l Conf. Distributed Computing Systems (ICDCS '10), June 2010.