IRA-International Journal of Technology & Engineering
ISSN 2455-4480; Vol.04, Issue 01 (2016)
Institute of Research Advances
http://research-advances.org/index.php/IRAJTE

Survey on Relay Selection Techniques in Cognitive Networks

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DOI: http://dx.doi.org/10.21013/jte.v4.n1.p8

How to cite this paper:
BOUALLEGUE, T., & SETHOM, K. (2016). Survey on Relay Selection Techniques in Cognitive Networks. *IRA-International Journal of Technology & Engineering* (ISSN 2455-4480), 4(1). doi:http://dx.doi.org/10.21013/jte.v4.n1.p8

ABSTRACT

Cognitive radio holds great promise as a research area nowadays. By increasing the spectral efficiency, it is applicable to various areas where spectrum is a rare resource. Nevertheless, it still presents key challenges such as the interference and the false alarm possibilities. The community of research is committed to find the suitable solution in these cases. In some situations, it could be that the primary transmitter and the secondary receiver are very distant from each other and thus, direct communication is not possible. Relay nodes are used for establishing communication in such cases. Though selecting the best relay among others is a very difficult task. This paper offers a summary of cognitive radio, the significance of relaying network and the algorithm of relay selection.

Index Terms— Cognitive Radio, Cooperative communication, relaying network, spectral efficiency

I. INTRODUCTION

Since the technology of wireless communication is quickly developing; heterogeneous wireless communication system must be adjusted in reduced frequency bandwidth. The efficiency of the conventional orthogonal spectral separation of heterogeneous system is not sufficient to sustain the unceasing growth of wireless device deploying exigency, making spectrum sharing amongst heterogeneous systems increasingly important. Two main challenges for the future of wireless systems are raised: the high data rate request of the growing number of users and the wireless spectrum availability. By reusing the underused licensed frequency bands, Cognitive Radio (CR) is presented as a new facet of telecommunication system to resolve the issue of spectrum availability. In such system, unlicensed wireless users (secondary users) are dynamically granted access to the licensed bands under the compulsion of tolerable interference to the Primary Users (PU). To facilitate the spectrum sharing among Secondary Users SUs and PUs, there are two existing techniques: The spectrum overlay and the spectrum underlay. In the first method, the SU shares some its power resources with the PU to give a relay-assisted transmission. Hence, the secondary network offsets the forced interference by the increase in the signal to interference plus noise ratio (SINR) of primary receivers. Thenceforth, the core idea of the overlay approach is to assign power and channel assets to the entire network, while using the requirements of PUs. To prevail over the spectral efficiency loss of one-way half duplex, [1] implements a two-way relaying.

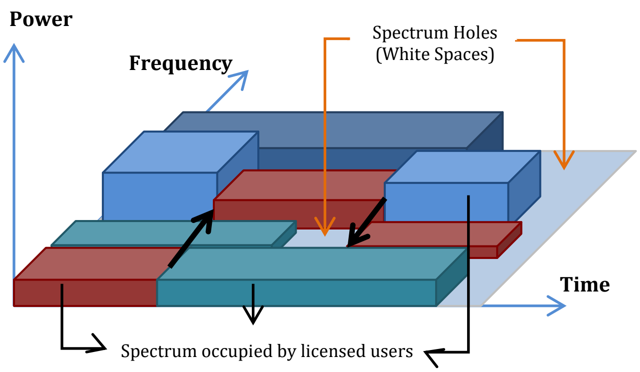
As for the underlay approach, the SU uses the identical spectrum alongside to the PU while preserving or enhancing the transmission of the PU by employing signal processing and coding [2]. Cooperative communications and networking is considered to be another recent communication technology pattern that permits dispersed stations in a wireless network to cooperate through some distributed transmission or signal processing in order to achieve a new kind of space variety to fight the damaging outcomes of fading channels [3]. Cooperative Communication (CC) can provide high channel capacity and consistency in an effective and inexpensive way by creating a virtual antenna array between single-antenna nodes that collaboratively share their antennas.

This article is structured as follow. In Section II, the fundamentals of cognitive radio are presented. Various proposed relay selection algorithms are explained in Section IV. Resource Allocation is discussed in Section IV. This paper is then completed by a Conclusion and upcoming work in Section VI.

II. COGNITIVE RADIO

Cognitive Radio (CR) is the allowing technology for sustaining dynamic spectrum access: the rule that approaches the spectrum rarity problem that is faced in many countries. Therefore, CR is commonly observed as one of the most rising technologies for future wireless communications [4]. CR varies from usual radio devices in a way that a cognitive radio can provide users with cognitive capability and dynamic configurability. Cognitive capability signifies the ability to sense and collect information from the adjacent environment, like information about the frequency of transmission, bandwidth, modulation, power, etc. With this ability, SUs can identify the best accessible spectrum. Dynamic configurability signifies the aptitude to quickly adjust the operational factors according to the detected information in order to reach the optimal performance. By opportunistically exploiting the spectrum, cognitive radio permits SUs to detect which spectrum parts are available, select the best accessible channel, synchronize spectrum access with other users, and free the channel when a PU regains the spectrum usage right.

Fig. 1. Spectrum white space illustration



By sensing and analyzing the spectrum, CR can identify the spectrum white space (see Fig. 1), i.e., a section of the frequency band that is unused by the PUs and exploit the spectrum. Moreover, when PU begins to utilize the licensed spectrum again, CR can notice their activity by sensing, this way no damaging interference is spawned due to SUs' transmission. Hence managing the spectrum is effectively done [3].

Cognitive communications can intensify the spectrum efficiency and sustain higher bandwidth service because CRs are able to sense, detect and supervise the surrounding RF environment like interference, access availability, and dynamically set up their own functional features to best fit outside situations. Furthermore, the ability of real time independent choices for effective spectrum sharing also decreases the weights of unified spectrum management. Consequently, CRs can be used in various applications. The main tasks of CRs are [5]: Spectrum sensing, Power control and Spectrum management.

A. Spectrum sensing

A crucial requirement of the CR network to sense empty spectrum is to perceive vacant spectrum and sharing it, without damaging interference to other users. Sensing PUs is the most effective way to detect vacant spectrum. The spectrum sensing techniques can be clustered into three groupings: Transmitter detection, Cooperative detection and Interference-based detection.

1) Transmitter detection

CRs need to have the ability to conclude a primary transmitter signal is locally present in a given spectrum. For that purpose, there are multiple approaches to transmitter detection such as Matched filter, Energy and Cyclo-Stationary feature Detection.

2) Cooperative detection

Invokes spectrum-sensing methods that give information from multiple cognitive-radio users to primary-user detection.

3) Interference-based detection

Interference based detection to sense vacant spectrum in CR method is achieved through two different approaches: Primary Receiver Detection and Interference Temperature Model.

B. Power control

Power control is used for opportunistic spectrum access as well as spectrum sharing CR systems for detecting the cut-off level in SNR sustaining the channel allocation and granting interference power constraints for the PU's protection correspondingly.

C. Spectrum management

The goal is to capture the best obtainable spectrum to meet the user communication necessities, without creating excessive interference to other users. CRs should pick the best spectrum band of those available to fit the quality of service necessities; consequently, spectrum-management tasks are needed for CRs. Spectrum-management functions are organized as:

- Spectrum analysis
- Spectrum decision

The main prerequisite of these new radios is for them to be able to sense and measure interference from or on other radio systems and to have the ability of establishing cooperative sharing of spectrum. Automatic Modulation Classification (AMC) is the automatic detection of the modulation format of an identified signal. For a smart receiver, AMC is the midway step between demodulation and signal detection. AMC plays a crucial role in civilian and military applications, particularly in dynamic spectrum management and interference identification. Over two decades it has also had an important impact on electronic surveillance for over two decades.

The following are the main issues of CR

- Advance spectrum administration
- Unlicensed spectrum utilization
- Spectrum sharing approaches
- Concealed node and sharing matters
- Trusted access and security
- Complexity problems
- Cross-layer scheme
- Hardware and software architecture

Some of the previously cited issues can be resolved by the use of relaying network.

Certain core benefits of relaying network are clarified below:

Good Signal Strength: Distant communication provokes interference and noise, therefore sensing is bad. This way, if relay is introduced in the network scheme, the noise is removed and interference is reduced under a certain limit.

Amplified Coverage: With multi-hop relays the macro cell coverage can be enlarged to the spaces where the base station cannot reach.

Amplified Capacity: Creating hotspot solutions with reduced interference to increase the general capacity of the system.

Inferior CAPEX & OPEX: With having the relays spreading the coverage, it eliminates the necessity of supplementary base stations and matching backhaul lines reducing wireless operators deployment costs and reducing maintenance costs. The relays can be owned by the user and provided by operators. They can be mounted on rooftops or indoors.

Improved Broadband Experience: Greater data rates are thus now accessible as users are close to the mini RF entrance point.

Lower Transmission Power: Because the Relays are deployed, there is a substantial decrease in transmission power reducing co-channel interference and amplified capacity.

Quicker Network Rollout: The distribution of relays is simple and accelerates the network rollout process with a greater level of outdoor to indoor service and engendering macro variety, rising coverage quality with reduced fading and stronger signal level.

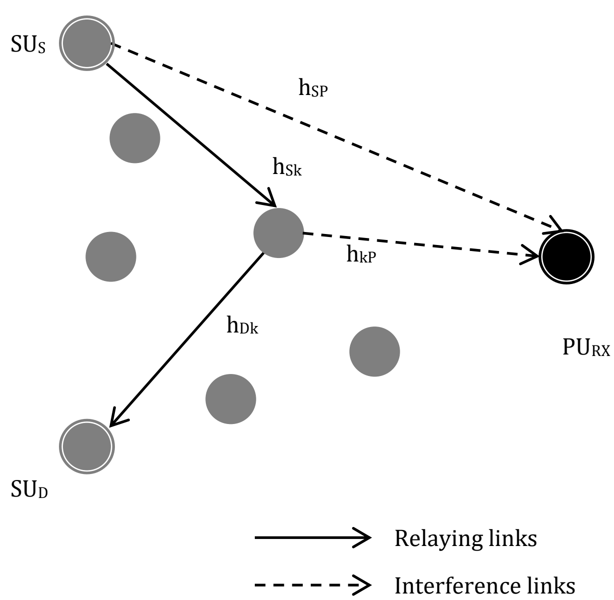
Most of the work in CR has focused on the lower layers of the protocol stack, mainly at the physical and MAC layers with single-hop forwarding. Their goal is to address the channel scarcity problem and achieve efficient wireless communication. It allows CR networks to discover spectrum holes, and utilize them, which decreases contention on channels, minimizes interference between communicating nodes and improves the average channel efficiency.

Recently, multi-hop secondary networks using relays have gained attention as a promising design to leverage the full potential of cognitive radio networks.

Link quality and reliability improvement and coverage expansion are some of the benefits on Relay assisted wireless communication approaches.

We generally consider an underlay cognitive relay network (CRN) where a secondary transmitter (secondary source, SUS) communicates with a secondary receiver (secondary destination, SUD) through the assistance of L secondary relays in coexistence with a primary receiver, as illustrated in Fig. 1.

Fig. 1. Network scheme of cognitive relay networks; PU_{RX}, SU_S, SU_D, and SU_K respectively symbolize a primary receiver, a secondary source, a secondary destination, and the *k*th possible relay.



III. RELAYING TECHNIQUE OR COOPERATIVE COMMUNICATION

Cooperative techniques utilize the broadcast nature of wireless signals by observing that a source signal intended for a particular destination can be “overheard” at neighboring nodes. These nodes, called relays process the signals they overhear and transmit towards the destination.

Since Cover and El Gamal work in [6], the idea of using relays in communication has been introduced. Later, in 2004, Sendonaris formulated in [7] and [8] the scheme of cooperative communication and the detailed of the system.

Still in 2004, Laneman studied the cooperative communication network and presented its capacity and outage comportment [9]. These works represent the basis for all following researches in that field. Since then, many studies have been conducted in that area.

The source node communicates signal to both relay and destination nodes. The received signals at the destination and the relay node, respectively $y_{s,d}$ and $y_{s,r}$ can be denoted as:

$$y_{s,d} = \sqrt{P_s} h_{s,d} x + \eta_{s,d}$$
$$y_{s,r} = \sqrt{P_s} h_{s,r} x + \eta_{s,r}$$

Where P_s is the transmit power at the source code, x is the transmitted information symbol, $h_{s,d}$ is the channel coefficient linking the source and the destination nodes, $h_{s,r}$ is the channel coefficient linking the source and the relay nodes, $\eta_{s,d}$ and $\eta_{s,r}$ are the additive noises, presented as zero-mean complex Gaussian random variables with variance σ^2. The transmission impedance is assumed to be 1Ω to simplify the calculation. Then, the received signal at the relay node will be dispatched to the destination node following the forwarding scenario.

There are mainly three relaying protocols: amplify-and-forward (AF), decode-and-forward (DF), and compress and-forward (CF).

- For AF, we amplify and retransmit the received signal to the destination. The advantage of this protocol is its simplicity and low cost implementation. But the noise is also amplified at the relay. Where the received signal at the destination from the relay is expressed by:

$$y_{r,d} = \sqrt{P_r} h_{r,d} x + \eta_{r,d}$$
$$x' = \frac{y_{s,r}}{|y_{s,r}|}$$

- x is the normalized transmitted signal from relay node to the destination node, Pr represents the transmitted power from the relay node, $h_{r,d}$ is the channel coefficient linking the relay and the destination node. Finally, $\eta_{r,d}$ represents the additive noise, modeled as zero-mean complex Gaussian random variables with variance σ^2. The transmission impedance is assumed to be *1Ω* to simplify the calculation.
- For DF, the relay tries to decode the received signals. If positive, it re-encodes the information and forwards it. The received signal at the destination is expressed as:

$$y_{s,d} = \sqrt{P_r} h_{r,d} \hat{x} + \eta_{r,d}$$

- Finally, CF tries to generate an estimate of the received signal. This is then compressed, encoded, and transmitted in the hope that the expected value can assist in decoding the original code-word in the destination side.

The performance of AF protocol is mainly limited by the noise amplified at the relay during the forwarding process, especially at low SNR. The performance of DF will be degraded when the relay fails to decode the received signals correctly and the process of decoding and re-encoding will cause serious error propagation.

To overcome these limitations, relay selection is an important issue for improving the system performance. Determining which of the potential relays should be selected is a difficult cross-layer problem. For example, a relay node may have a strong channel to the destination, but it may also be heavily loaded with traffic from other sources. Also, relays are usually battery-powered, and a potential relay may need to enter a sleep cycle to conserve energy.

In this paper, we propose to analyze the current works on relay selection methods for secondary spectrum access.

IV. RELAY SELECTION ALGORITHMS

Although it is possible for multiple relays surrounding a source node to cooperatively help with its transmission to the destination node, this does not enhance the performance significantly compared with the relaying via a single node, considering that extra resources are required and the processing complexity is increased [10]. Additionally, activating multiple relays results in concerns on inner node coordination, synchronization, and interference. In addition, more active relays bring more interference within the network. Thus, from the view of overall network design, most literature works deals with two-hop network model (Figure 2).

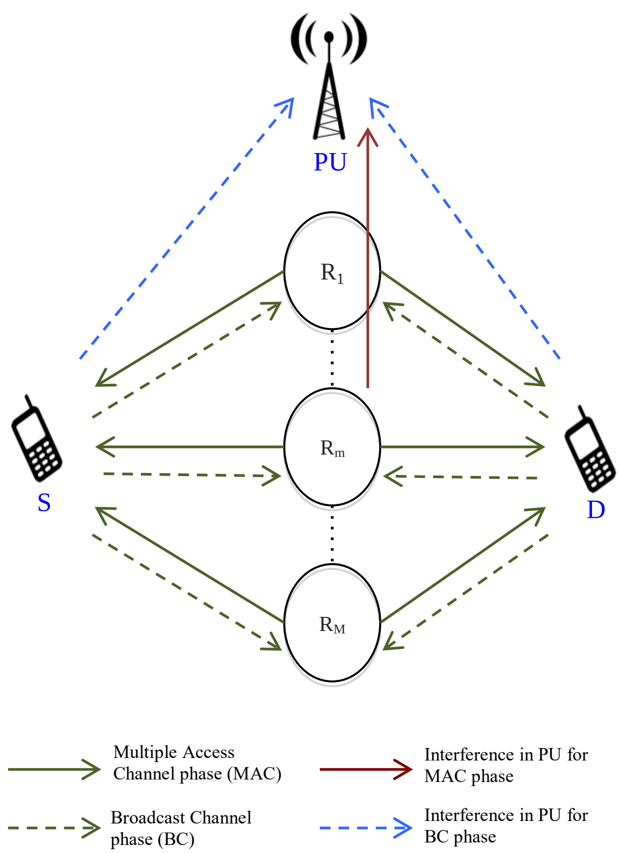


Fig. 2. Proposed resource management procedures

The task of relay selection in cognitive networks is as follows. We consider a source S that wants to transmit a message to a destination D. There are numerous contiguous nodes between S and D, which are candidates to become a relay node. Relay selection defines the "best suited" node to act as a relay R. The selection process would operate in a spread way; introduce only an acceptable overhead in terms of message complexity, and delay [10].

There are various protocols proposed to choose the best relay among a collection of available relays in the literature.

These algorithms can be classified according to different categories such as:

- The number of selected relays: single [11]–[13]-[14]–[15] versus multiple relays [12]-[16] selection have been proposed for DF and AF relaying.
- Pro-active versus reactive: In proactive mode [17], a specified relay selected prior to the source transmission participates in the cooperation, whereas in Reactive mode, relays that successfully decode the message take part in the cooperation.
- Opportunistic versus partial: Two relay selection strategies that have been widely investigated in the literature are opportunistic relay selection (ORS) and partial relay selection (PRS). Partial relay selection was first proposed in [18], and then extended to the DF protocol in [19]. Opportunistic relay selection was proposed in [20] to activate the relay based on the channel state information (CSI) in both the first and second hops. Common to many works dealing with ORS and PRS is the assumption of perfect transceiver hardware (i.e., ideal hardware) of the terminals. However, in practice, the transceiver hardware is imperfect due to phase noise, I/Q imbalance and amplifier nonlinearities.
- Half versus full duplex: Most schemes consider half-duplex (HD) relays where reception and transmission occur separately, resulting in resource loss in time and/or frequency [21-023]. In order to alleviate this loss, buffer-aided successive schemes have been proposed where two relays are concurrently activated, one for reception and the other for transmission, thus mimicking full-duplexity but at the cost of inter-relay interference (IRI). In a different line of research, full-duplex (FD) relays have been employed, in order to increase the spectral efficiency of relay networks.
- Under-laying wireless technologies: The idea of relaying has formerly been studied in the 3GPP as an ad-hoc peer-to-peer multi-hop protocol identified as opportunity-driven multiple access (ODMA). In this protocol, the cell-edge WSs interacts with the BS via other WSs that are closer to the BS. Still, the ODMA protocol did not meet the standard due to complexity and signaling overhead concerns. However, various lessons were learnt. Presently, various standardization forums, bodies, and consortiums have been working on architectures based on relays in scenarios going from wireless local area networks (WLAN) [24-025] to wide area cellular networks such as [26-028]. IEEE 802.16m and 3GPP advanced long term evolution (LTE-A), which cope beyond 3G standards are the two most prominent standards to promote relaying.

Performance analysis of the best-relay selection algorithms is widely reported in the literature. We choose to present it according to a new classification that point out network QoS optimization parameters:

1. *Distance based methods*

An intuitive scheme of optimal relay assignment is using distance, either towards the source or the destination, as the criterion of optimal relay selection [29-030]. In [31-032], the authors proposed to choose the best relay depending on its geographic position, based on the geographic random forwarding (GeRaF) protocol.

2. Energy efficiency based methods

Zhou et al. in [1] considered an energy-efficient relay selection for a two-way relay channel using analog network coding. Elhawary and Haas in [33] proposed an energy-efficient routing protocol for cooperative networks by employing relay clusters along a non-cooperative path and revealed that the proposed cooperative transmission protocol can save up to 40% of energy compared with the disjoint-path and the one-path scheme using only direct transmission.

Another work presented in [10] describes a basic protocol for relay selection and assessing its performance with the goal to extend it with focus on strategies to save energy required for receiving. It proposes two refinements of cooperative relaying: a relay selection on demand arrangement in which relays are only determined if really needed by the destination and an early retreat arrangement in which nodes with poor channel conditions do not contribute in the relay selection. Based on simulations, both enhancements improve the energy efficiency, while the degradation in terms of outage rate depends on a configurable parameter and is negligible for the target packet error rate.

3. SINR based methods

In [6] a novel optimization algorithm is presented. This work is based on the Artificial Bees Colony (ABC. It treats non-convex issues. ABC emulates honeybees' smart conduct of seeking quality food source with highest nectar (i.e., the best solution) and sharing that information with their coworkers in the hive. Hence, the purpose of the entire Bee Colony is to maximize the quantity of nectar (SNR).

4. Interference based methods

Interference can be a basis for a relay selection criterion as well. Transmission performance cannot be guaranteed in a relay selection that is based on the calculation of the instantaneous SN in either the destination or the relay node because of the effect of interference from other nodes on the system performance. Krikidis in [34], considers the relay nodes to receive interference, the result of the relay selection criterion is hence changed. This work groups the network nodes into clusters.

5. Capacity enhancement based method

[35] Presents a survey on algorithms based on capacity enhancement. This article states that wireless networks are quickly evolving to offer connectivity to an expanding number of mobile devices. The necessity of the high data rate and improved capacity is unquestionably increased in order to fit the requests of new multimedia applications.

Enhancing the capacity of the pair (source, destination) should be the final outcome of the relay node assignment. Important to keep in mind: that an algorithm does not always have to assign the relay node to the pair. In the case where the assignment of the relay node reveals a smaller capacity in comparison with the direct transmission, no relay will be assigned.

6. *Data rate based methods*

In [36] an optimal relay allocation (ORA) algorithm is suggested to maximize the minimum data rate between multiple source-destination pairs. [37] maximizes the minimum throughput among all BSs under routing and PHY constraints, for a two-hop case in decode and forward mode. [38] considers a multi-hop scenario (more than two hops), it maximizes network sum utility by optimally choosing the active data stream in each tone in combination with the selection of the best relay node and the best relaying method (the system picks between decode-and-forward or amplify-and-forward relaying, depending on the conditions of the channel and power allocation). The schemes described in [37] and [38] need to operate in a slow-fading environment in order to get the CSI for applying the adaptive power and bit-loading in a centralized way. That is the reason why the receiver needs to consistently estimate channel and carry it to the BS.

7. Security based methods

The main goal of these methods is to boost the capacity of the primary (confidential) links by diminishing instantaneously the capacity of the eavesdropper links. To fulfill this purpose, numerous PHY-based approaches have been proposed in the literature [39-041]. The interaction of the cooperative diversity concept [42-044] with secret communications has also lately been reported as an interesting solution [45-047]. In these systems a relay node located closer to the main destination delivers a higher capacity to the main link than the eavesdropper link [45]. This been said, relay selection for cooperative networks with secrecy constraints has arisen as an interesting research topic Alternatively, jamming techniques which produce an artificial interference at the eavesdropper node to reduce the capacity of the associated link seem to be an attractive approach for practical applications [48-051]. In [52] the interaction between relay and jammer is presented as a non-cooperative game where both nodes have conflicting objectives and the Nash equilibrium (NE) of the system is derived.

V. RESOURCE ALLOCATION IN CR

Assets in cognitive radio involve power, channel capacity, and bandwidth. Some of the algorithms are suggested according to the restraints for allocation of power, bandwidth and channel. The paper [2] present two optimal resource allocation patterns that maximize output and symbol correct rate (SCR). The throughput and SCR are derivative. The resulting throughput and SCR are enhanced while respecting the detecting time, transmission power of the source and the relay transmission power. Arithmetical consequences demonstrate that the ideal sensing time hangs on the signal-to-noise-ratio (SNR) of the primary user. They also prove that SCR rises with the growth in the number of relays. The relay assigns its amplify-and-forward matrix for reachable sum-rate maximization, while the mobile transmitters egotistically assign their diffusion codes for separate reachable rate maximization. The proposed algorithm demonstrates its convergence of which performance is contrasted against a centralized method.

They presented a power-refreshing pattern [53] that aims to maximize the exposure and throughputs of the secondary network, whereas enlarging the SINR condition of the primary transceivers. This pattern is applied to one channel at a time. The following actions are carried out for the cth channel: Initialization, Power updating, Termination. After completing the power-refreshing pattern for each channel c, we need to consider a channel assignment problem. A bipartite that can be resolved by Kuhn-Munkres (Hungarian) algorithm such as the sum of secondary networks throughput is pondered as the weighted corresponding parameter.

The power allocation pattern for relay-assisted Infrastructure system is provided in [1] in order to diminish the interference to the Ad-hoc links, as to sustain a stipulated QoS level. This resource allocation issue is expressed as a convex optimization problematic. Ensuing the duality concept, initially for fixed twin variables then the dual issue is resolved. By applying the Karush-Kuhn-Tucker optimality restrictions, the issue is then solved.

The difficulties of joint bandwidth and power allocation with AF or DF (Amplify-and-forward or Decode-and-forward) protocol are expressed in [54]. For these relaying protocols, the shared bandwidth and power allocation issue points to increase the sum output of the CR network, as well as to minimize the CR network total transmit power, and finally to boost the energy effectiveness. We assume, in this situation, that relay SU can implement the DF relaying protocol if the data rate between source and relay SUs is superior to zero. Withal, this previously mentioned data rate should actually be higher than r(r>0) to guarantee consistent decoding in relay SU. This decoding rate condition will result into some bad quality relaying link and will necessitate more resource. In this situation, a part of the resource will be misused. Hence, a hybrid relaying protocol to solve this issue is proposed, in which, a relay SU utilizes the AF protocol in the only situation where it is not able to decode the reliably of the source data. Otherwise, a relay SU utilizes the DF relaying protocol.

VI. CONCLUSION

Cognitive radio technology has been recommended in latest years as a radically changing solution for more efficient usage of the rare spectrum resources in an dynamic and intelligent way. By tuning the frequency to the momentarily unused licensed band and adjusting functional parameters to environment changes, cognitive radio technology offers future wireless devices with added bandwidth, reliable broadband communications, and flexibility for quickly rising data applications. In this paper, we present, the basic concept of cognitive radio features, purposes, the relaying concept, some relay selection methods, and then several research topics on cognitive radio networks are considered. Relay selection, based on collaborative variety schemes, increases the SNR at the level of the cognitive relay destination and consequently, optimizes the performance of the system.

REFERENCES

[1]. Yunzhou Li, Yin Sun, Resource Allocation for the Cognitive Coexistence of Ad-hoc and Cooperative Relay Networks, IEEE Communication Society, 2010.
[2]. Tao Jing, Hongjuan Li, Shixian Zhu, Cooperative relay selection in cognitive radio network, IEEE INFOCOM, 2013.
[3]. Qian Zhang, Jin Zhang, and Juncheng Jia, Cooperative relay to improve diversity in cognitive radio networks, IEEE Communications Magazine, February 2009.
[4]. Kwang Cheng Chen, Ying-Chang liang, ”Cognitive radio networking and communications: An overview, IEEE Transaction, Volume 60, Issue 7, June 2011.
[5]. Beibei Wang, K.J.Ray Liu, Advances in CRN :A Survey, IEEE Journal of selected topics in signal processing, Vol 5,No.1, Feb 2011,1-23.
[6]. A. El Gamal and T. M. Cover, "Multiple user information theory," Proceedings of the IEEE, vol. 68, pp. 1466-1483, 1980.
[7]. A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity. Part I. System description," IEEE Transactions on Communications, vol. 51, pp. 1927-1938, 2003.
[8]. A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity. Part II. Implementation aspects and performance analysis," IEEE Transactions on Communications, vol. 51, pp. 1939-1948, 2003.
[9]. J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior," *IEEE Transactions on Information Theory,* vol. 50, pp. 3062 - 3080, 2004.
[10]. Helmut Adam ,Sidi Mohammed Senouci and Christian Bettstetter, “Adaptive Relay Selection in Cooperative Wireless Networks”
[11]. T. Oechtering and H. Boche, “Bidirectional regenerative half-duplex relaying using relay selection,” *IEEE Trans. Wireless Commun.*, vol. 7, no. 5, pp. 1879–1888, May 2008.
[12]. Y. Li, R. Louie, and B. Vucetic, “Relay selection with network coding in two-way relay channels,” *IEEE Trans. Veh. Technol.*, vol. 59, no. 9, pp. 4489–4499, Nov. 2010.
[13]. L. Ding, M. Tao, F. Yang, and W. Zhang, “Joint scheduling and relay selection in one- and two-way relay networks with buffering,” in *Proc. 2009 IEEE Int. Conf. Commun.*
[14]. K.-S. Hwang, Y.-C. Ko, and M.-S. Alouini, “Performance bounds for two-way amplify-and-forward relaying based on relay path selection,” in *Proc. 2009 IEEE Veh. Technol. Conf. – Spring*.
[15]. S. Atapattu, Y. Jing, H. Jiang, and C. Tellambura, “Opportunistic relaying in two-way networks,” in *Proc. 2010 Int. ICST Conf. Commun. Netw. China*.
[16]. J.-C. Chen and C.-K. Wen, “Near-optimal relay subset selection for two-way amplify-and-forward MIMO relaying systems,” *IEEE Trans. Wireless Commun.*, vol. 10, no. 1, pp. 37–42, Jan. 2011.
[17]. D. Michalopoulos and G. Karagiannidis, “Performance analysis of single relay selection in Rayleigh fading,” *IEEE Trans. Wireless Commun.*, vol. 7, no. 10, pp. 3718–3724, Oct. 2008.

[18]. I. Krikidis, J. Thompson, S. McLaughlin, and N. Goertz, “Amplify-andforward with partial relay selection,” *IEEE Commun. Lett.*, vol. 12, no. 4, pp. 235–237, Apr. 2008.
[19]. X. Rui, “Performance of selective decode-and-forward relay networks with partial channel information,” *ETRI J.*, vol. 32, no. 1, pp. 139–141, Feb. 2010.
[20]. A. Bletsas, A. Khisti, D. Reed, and A. Lippman, “A simple cooperative diversity method based on network path selection,” *IEEE J. Sel. Areas Commun.*, vol. 24, no. 3, pp. 659–672, Mar. 2006
[21]. D. S. Michalopoulos and G. K. Karagiannidis, “Performance analysis of single relay selection in Rayleigh fading,” *IEEE Trans. Wireless Commun.*, vol. 7, pp. 3718–3724, Oct. 2008.
[22]. I. Krikidis, J. S. Thompson, S. McLaughlin, and N. Goertz, “Max-min relay selection for legacy amplify-and-forward systems with interference,” *IEEE Trans. Wireless Commun.*, vol. 8, pp. 3016–3027, June 2009.
[23]. A. Ikhlef, D. S. Michalopoulos, and R. Schober, “Max-max relay selection for relays with buffers," IEEE Trans. Wireless Commun., vol. 11, no. 3, pp. 1124-1135, March 2012.
[24]. Aggelos Bletsas, Hyundong Shin and Moe Z.Win. Cooperative Communications with Outage-Optimal Opportunistic Relaying. *IEEE Transactions on Wireless Communications*, 2007, vol. 24, no. 3, 3450-3460.
[25]. Zhong Zhou, Shengli Zhou, Jun-Hong Cui and Shuguang Cui. Energy-Efficient Cooperative Communication Based on Power Control and Selective Single-Relay in Wireless Sensor Networks. *IEEE Transactions on Wireless Communications*, 2008, vol. 7, no. 8, 3066-3078.
[26]. H. Viswanathan and S. Mukherjee, “Performance of cellular networks with relays and centralized scheduling,” IEEE Trans. Wireless Commun., vol. 4, no. 5, pp. 2318–2328, Sep. 2005.
[27]. M. Kaneko and P. Popovski, “Radio resource allocation algorithm for relay-aided cellular OFDMA system,” in Proc. IEEE ICC, Glasgow, U.K., Jun. 2007, pp. 4831–4836.
[28]. M. Kaneko and P. Popovski, “Adaptive resource allocation in cellular OFDMA system with multiple relay stations,” in Proc. IEEE VTC—Spring, Dublin, Ireland, Apr. 2007, pp. 3026–3030.
[29]. Min Chen, Xuedong Liang, Victor C.M. Leung and Ilangko Balasingham. Multi-Hop Mesh Cooperative Structure based Data Dissemination for Wireless Sensor Networks. International Journal on Sensor Networks, 2009, 102-106
[30]. Gentian Jakllari, Srikanth V. Krishnamurthy, Michalis Faloutsos, Prashant V. Krishnamurthy and Ozgur Ercetin. A Cross-Layer Framework for Exploiting Virtual MISO Links in Mobile Ad Hoc Networks. IEEE Transactions on Mobile Computing, 2007, vol. 6, 579-594.
[31]. M. Zorzi and R. R. Rao, “Geographic random forwarding (GeRaF) for ad hoc and sensor networks: multihop performance,” IEEE Trans. Mobile Comput., vol. 2, no. 4, pp. 337-348, Oct.Dec. 2003. >> 31
[32]. M. Zorzi and R. R. Rao, “Geographic random forwarding (GeRaF) for ad hoc and sensor networks: energy and latency performance,“ IEEE Trans. Mobile Comput., vol. 2, no. 4, pp. 349-365, Oct.Dec. 2003.
[33]. M. Elhawary and Z. Haas, “Energy-efficient protocol for cooperative networks,” IEEE/ACM Trans. Netw., vol. 19, no. 2, pp. 561–574, Apr. 2011.
[34]. I. Krikidis, J. Thompson, S. Mclaughlin, and N. Goertz, "Max-min relay selection for legacy amplify-and-forward systems with interference," IEEE Transactions on Wireless Communications, vol. 8, pp. 3016 -3027, 2009.
[35]. Yogesh Bhute, A. R. Raut, A Survey on Relay Selection Strategies in Cooperative Wireless Network for Capacity Enhancement, International Journal of Computer Applications
[36]. Faouzi Bader, Ahmed Alsharoa, Optimal Relay selection and resource allocation for two way AF-DF Cognitive radio networks, Wireless Communication Letter, IEEE, VOl 2, Issue 4,2013.
[37]. S. Kim, X. Wang, and M. Madihian, “Resource allocation in multi-hop OFDMA wireless backhaul networks with cooperative relaying,” IEEE Global Telecommunications Conference, pp. 5205-5209, Nov. 2007.

[38]. T. C. Ng and W. Yu, "Joint optimization of relay strategies and resource allocations in cooperative cellular networks," IEEE J. Sel. Areas Commun., 25(2), pp. 328-339, Feb. 2007.

[39]. Y. Liang, H. V. Poor, and L. Ying, "Wireless broadcast networks: reliability, security, and stability," in *Proc. IEEE Inf. Theory Appl. Work.*,. San Diego, CA, USA, pp. 249-255, Feb. 2008.

[40]. L. Dong, Z. Han, A. P. Petropulu, and H. V. Poor, "Secure wireless communications via cooperation," in *Proc. Allerton Conf. Commun. Cont. Comp.*, Urbana-Champaign, IL, USA, Sept. 2008.

[41]. I. Krikidis, J. Thompson, and S. McLaughlin, "On the diversity order and secrecy rate of non-orthogonal amplify-and-forward relay protocols," *IEEE Trans. Wireless Commun.*, submitted for publication Nov. 2008. [Available online: www.see.ed.ac.uk/~ikrikidi/paper_TWC.pdf]

[42]. J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks: efficient protocols and outage behavior," *IEEE Trans. Inform. Theory*, vol. 50, pp. 3062-3080, Dec. 2004.

[43]. A. Bletsas, H. Shin, and M. Z. Win, "Cooperative communications with outage-optimal opportunistic relaying," *IEEE Trans. Wireless Commun.*, vol. 6, pp. 3450-3460, Sept. 2007.

[44]. S. Yang and J.-C. Belfiore, "Towards the optimal amplify-and-forward cooperative diversity scheme," *IEEE Trans. Inform. Theory*, vol. 53, pp. 3114-3126, Sept. 2007.

[45]. L. Lai and H. El Gamal, "The relay-eavesdropper channel: cooperation for secrecy," *IEEE Trans. Inform. Theory*, vol. 54, pp. 4005-4019, Sept. 2008.

[46]. Y. Oohama, "Relay channels with confidential messages," *IEEE Trans. Inform. Theory*, submitted for publication Mar. 2007. [Available online: http://arxiv.org/pdf/cs/0611125v7].

[47]. V. Aggarwal, L. Sankar, A. R. Calderbank, and H. V. Poor, "Secrecy capacity of a class of orthogonal relay eavesdropper channels," *EURASIP J. Wireless Commun. Net.*, accepted for publication, June 2009.

[48]. I. Krikidis, "Opportunistic relay selection for cooperative networks with secrecy constraints," *IEEE Signal Processing Lett.*, submitted for publication, July 2009.

[49]. O. Simeone and P. Popovski, "Secure communications via cooperating base stations," *IEEE Commun. Lett.*, vol. 12, pp. 188-190, Mar. 2008.

[50]. P. Popovski and O. Simeone, "Wireless secrecy in cellular systems with infrastructure-aided cooperation," *IEEE Trans. Inform. Foren. Sec.*, vol. 4, pp. 242-256, June 2009.

[51]. E. Tekin and A. Yener, "The general Gaussian multiple access and two-way wire-tap channels: achievable rates and cooperative jamming," *IEEE Trans. Inform. Theory*, vol. 54, pp. 2735-2751, June 2008.

[52]. T. Wang and G. B. Giannakis, "Mutual information jammer-relay games," *IEEE Trans. Inform. Foren. Sec.*, vol. 3, pp. 290-303, June 2008.

[53]. Nafiseh Forouzan, Ardalan Alizadeh, A graph-based approach for relay selection and resource allocation in cognitive two-way relay networks, IEEE wireless Advanced,2011,101-105.

[54]. Wanbin Tang, Huogen Yu, Bandwidth and power allocation for cooperative relay in cognitive radio networks, Eurasip Journal on Advances in Signal Processing,2012.