A Cognitive Radio based Multi-hop Relay Cellular Network

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Abstract

In this paper, we investigate the throughput capacity of a multi-hop relay network with cognitive radio (CR) enabled relay stations (RS). We suggested a TDMA/FDMA based frame structure where RSs dynamically select unused channels to communicate with the base station (BS) using CR techniques to analyze the throughput capacity. We developed the throughput capacity model for the proposed system based on utilization factor. The analytical results based on those equations show significant improvement in throughput capacity for CR enabled multi-hop relay system.

I. Introduction

The purpose of enabling relay is to enhance coverage, range, and throughput and possibly capacity of a multi-hop relay network and to enable very low power devices to participate in the network. Since it is possible to have simultaneous transmission by both the BS and RS, throughput gains may also be achieved by either exploiting spectrum efficiency or spatial diversity. CR is a new technology that can improve the efficiency of spectrum usage by finding available spectrum in a crowded network, leading to gains in capacity.

Previous studies involved CR based multi-hop wireless networks in [1] where simple and efficient distributed heuristic for MAC-layer scheduling was proposed. Frequency sharing system with adaptive route selection according to the surrounding radio environment was narrated in [2] to avoid transmission in interference area of a multi-hop ad-hoc CR. However, throughput enhancement using CR based multi-hop relayis of paramount importance therefore which requires attention.

Hence, in this paper, we propose a system model where RSs with CR capabilities such as spectrum agility are deployed. We analyze the throughput capacity for multi-hop relay communication when CR is employed based on TDMA/FDMA multiple access technique. We formulate new throughput capacity model for our system model and evaluate our results for different temporal utilization factors.

II. Sysyrm Model

In a wireless multi-hop cellular network, the BS covers a fraction of all the mobile stations (MS) and communication to these MSs is carried out through direct path. To extend the coverage of the cell CR enabled RSs are deployed on the periphery of the BS's range. These RSs can intercept the packets sent from BS and relay those packets to MSs which are within its transmission range. So, communication with the MSs outside the coverage of the BS is carried out through an indirect path. In Figure 1, the communication between BS and MS through RS is depicted showing the coverage of the BS as well as the coverage of the RSs.

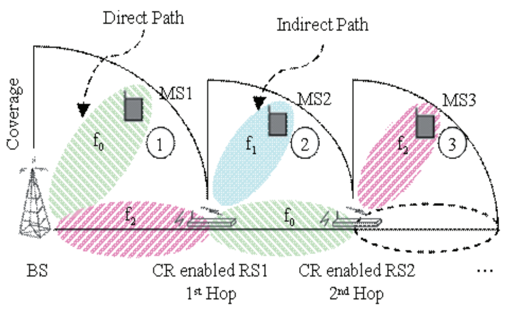

Fig.1. CR based Multi-hop cell architecture.

Communication among BS, RSs and MSs is achieved through multiple frequency bands namely as shown in the figure. The BS and RSs use a particular band for serving MSs while they choose a different band for relaying. One possible frequency reuse scheme is shown in figure 1, where communication between BS to RS1 and between RS2 to MS3 is occurring simultaneously using f2 band.

Ⅲ. Results and Discussion

According to the fixed relay throughput model expressed in [3] we can write

$$T_{RS} = \frac{\rho \alpha_r L C \tau + \sum_{j=1}^{N-\rho \alpha_r L} C_j \tau}{N} \qquad (1)$$

where the expected number of users that fall within the *L* relay cells is *?rL*, *?*is the duration of each *slot*, *C* is the highest data rate at which the RSs are transmitting, *Cj* is the data rates received by the MSs which are not covered by the relay nodes and *N* is the number of active users in a cell. Now, the utilization of the CR can be given as [4]

$$U_{CR} = \sum_{K=0}^{N} \min(M, K) \binom{N}{K} (1-u)^K u^{N-K} / M \qquad (2)$$

where *M* is the number of CRs and *u* is the primary user utilization. Therefore, throughput model for the RSs with enhanced capacity for the CRs is

$$T_{RS,CR} = \frac{\rho \alpha_r L C \tau + \sum_{j=1}^{N-\rho \alpha_r L} C_j \tau}{N} \left(1 + \frac{M U_{CR}}{N}\right) \quad . \qquad (3)$$

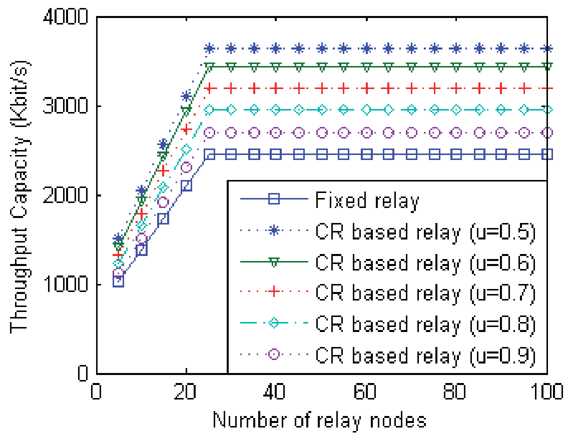

Fig.2. The throughput capacity of the proposed system varying utilization factor

Figure 2 and 3 represent the throughput capacity of our proposed system model for different number of RSs. In Figure 2, a significant improvement is found in throughput capacity when primary utilization factor is low. Similar throughput enhancement is also found in Figure 2, when large number of CRs is considered. However, after M=30, throughput enhancement is not that much higher than the M=10 or M=20 case. This can be explained from the fact that after a saturation point, there is no spectrum opportunities left for the additional CR

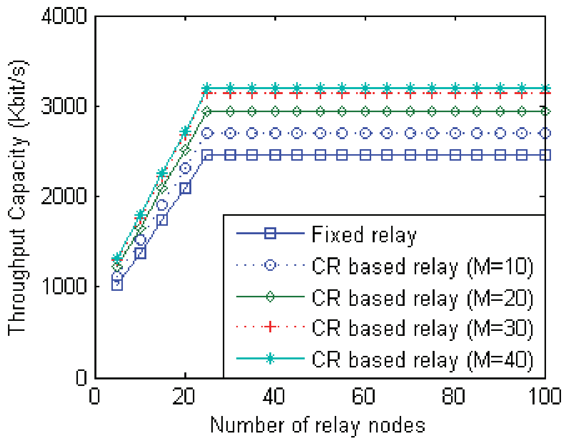

Fig.3. The throughput capacity of the proposed system varying number of CRs.

Ⅳ. Conclusion

In this paper, we investigated the throughput capacity of a new architecture for cognitive radio enabled multi-hop relay network. We suggested a cognitive radio based frequency band selection method. We derived a new throughput capacity model for theproposed architecture. The results show that our proposed system performs better than traditional fixed relay based systems where no cognitive radio capabilities are assumed in terms of the system throughput capacity of a multi-hop relay networks as well as reducing interference between RSs.

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References

[1] M. Thoppian, S. Venkatesan, R. Prakash, R. Chandrasekaran, "MAC-layer Scheduling in Cognitive Radio based Multi-hop Wireless Networks," Proc. of the 2006 Int. Symp. on a World of Wireless, Mobile and Multim. Net., pp. 10-19.

[2] T. Fujii, Y. Suzuki, "Ad-hoc Cognitive Radio Development to Frequency Sharing System by using Multi-hop Network," DySpan 2005, pp. 589-592.

[3] S. Sengupta, M. Chatterjee, S. Ganguly, and R. Izmailov, "WRN: Improving System Performance in 3G Networks Through Fixed Multi-hop Relay Nodes," WCNC 2005, pp. 1708-1713.

[4] S.N. Shankar,Chou,Challapali, and S. Mangold, "Spectrum Agile Radio: Capacity and QoS Implications of Dynamic Spectrum Assignment," GLOBECOM 2005, vol. 5, 28 Nov.-2 Dec. 2005, pp. 2510-2516.