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Towards Improving Reliability in Cognitive Radio Ad hoc Networks

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Abstract: Cognitive Radio Ad hoc Networks (CRAHNs) are the next generation networking technology. Reliability is the major research paradigm in the field of CRAHNs. The proposed work is an extension to AODV routing protocol. This paper proposes a mechanism for improving reliability using Reliable Transmission Algorithm in CRAHNs. The proposed routing mechanism is tested in NS2 simulator. The performance metrics throughput, packet delivery ratio and packets drop are taken into account. Simulation results shows that the proposed routing mechnaism achieves better relaibility than AODV routing protocol.

Keywords: Routing, Cognitive Radio, Networks.

I. INTRODUCTION

Cognitive Radio Ad hoc Networks (CRAHNS), having been rewarded an incredible amount of research attention recently [30]. As a dynamic spectrum access method, CR networks are overlaid with licensed networks for opportunistic spectrum access is a promising solution to the spectrum underutilization. Cognitive Radio (CR) is a gifted technology, which is capable of dealing with the rising demand and scarcity of the wireless spectrum [26], [27]. CR permits secondary users (SUs) to access licensed spectrum bands. As primary users (PUs) have the spectrum priority, SUs must avoid interfering with the PUs. Based on spectrum sensing information or location awareness, the SUs may adapt their transmit powers and adopt strategies to protect the primary link. In [28] it was described the working of CR networks that is equipped with location awareness features, and CR positioning systems were presented in [29], [5]. In [6], the effects of location awareness on concurrent transmissions for cognitive radio ad hoc networks (CRAHN) were analyzed. Many related works are based on similar concurrent spectrum access models. The specturm band in primary netwok versus cognitive radio ad hoc network is shown in Fig.1.

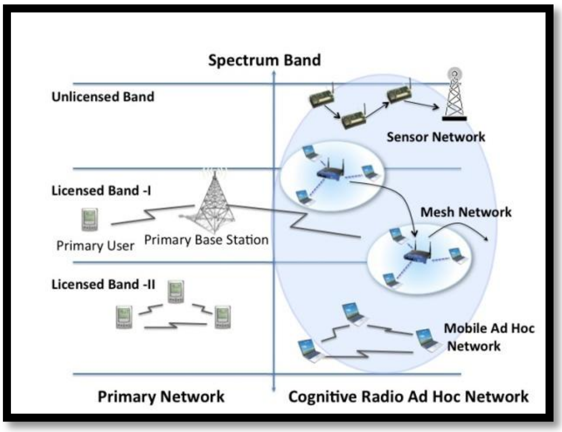

Fig.1 Spectrum Band in Primary Network Vs CRAHN [31]

CR will collect and process information about co-existing users within the spectrum of interests. It requires advanced sensing and signal-processing capabilities [7]. Enthused by universal spectrum sensing [8], sensing information of both the CR's transmitter (CR-Tx) and the CR's receiver (CR-Rx) is critical. The spectrum map shows the obtainable spectrum with geographic area, through sensing and locationing. Also a variety of inference techniques is possible to be applied for constructing the spectrum map [9]–[14]. Therefore, for the dynamic and the opportunistic nature of a CRAHN, the spectrum map serves as an information aggregation to preserve increasing information in a reliable way and in a resource-efficient way. As the intermittently available link and heterogeneous nature of the CRAHN [15] induces another critical challenge in the routing algorithm design, cooperative communication emerges to support transmissions in such a highly dynamic wireless ad hoc network.

II. LITERATURE REVIEW

Akyildiz et al. [16] provided a complete survey that advocates cooperative spectrum-aware communication protocols, which considers spectrum management for its cross-layer design. Characterizing the behavior and constraints for a multihop CR network from multiple layers, Hou et al. [17] developed a mathematical formulation to minimize the required spectrum resource for a set of user sessions. For mobile CRAHNs, Chowdhury and Felice [18] proposed a SEARCH protocol that jointly undertakes path and channel selection to avoid Primary Systems (PS) activity regions during route formation. Chowdhury et al. [19] further incorporated spectrum awareness in a transport control protocol for CRAHNs. Abbagnale and Cuomo [20] provided the Gymkhana scheme as a connectivitybased routing protocol that routes the information to avid network zones without guaranteed stable and high connectivity. Cesana et al. [6] presented an extensive overview for routing in CR

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networks with respect to available spectrum knowledge. Examining a joint problem of relay node assignment and multihop flow routing, Sharma et al. [21] delineated the benefits of exploiting cooperative communication in multihop wireless networks. Feng and Yang [22] analyzed the throughput of secondary networks and provided the information on how a CR channel can be utilized at the network level. Yazane et al. [23] focused on a three-node chain topology and provided end-to-end throughput analysis for multihop wireless networks. To leverage multiple-input multiple-output in a cooperative CR network, Hua et al. [24] studied cooperative forwarding with two-phase transmissions among primary and secondary systems.

To establish spectrum map via cooperative sensors, Lien et al. [25] facilitated quality-of-service (QoS) guarantees in cyber-physical systems by proposing CR resource management. Novel opportunistic routing [1]–[4] allows assistance by intermediate nodes in a probabilistic manner to explore cooperative diversity efficiently and practically with significant throughput gain. Aiming for dynamic ad hoc networks, Cedric [26] dealt with the mobility issue through continuously modifying the packet header. Via a network coding approach, MORE [27] provides opportunistic routing for a multicasting scenario. Under Rayleigh fading channels, Zheng and Li [28] provided analytical models to characterize the performance of routings. Khalifé et al. [29] indicated that the proper time for opportunistic forwarding in CR networks depends on the proportional timescale of the primary bands' idle time with cognitive communication duration.

Most of the routing protocols proposed for CR-MANETs so far involve on-demand route discovery and thus require each intermediate node to maintain significant amount of state information. In particular, existing protocols [34]–[36], [37], [38] are adaptations of AODV [39] or DSR [40] to CR-MANETs. They all involve on-demand route discovery to find spectrumaware end-to-end routes as well as route maintenance in case of route breaks due to node mobility or dynamic spectrum availability.

III. SYSTEM MODEL

For opportunistic spectrum access, a CRAHN is overlaid with a primary network where PUs operate in a set of licensed channels. The number of licensed channels is denoted by N_c. Due to PU activity, the channels available to each SU in the CRAHN may only be a subset of all licensed channels. Thus, SUs rely on local spectrum sensing to observe channel conditions and identify spectrum opportunities. For spectrum sensing and data transmission, each SU is equipped with two half-duplex transceivers that can be tuned to any licensed channel. One radio, which is called the control radio, is dedicated to allocated control channels, and the other, which is called the data radio, is used for data transmission.

Each radio can transmit data, receive data, or sense a channel at a time but cannot perform more than one of these operations simultaneously. The PU or SU transmit power decays with distance based on the free-space path loss model. When the shadow fading is considered, the combined path loss and shadowing model is used [32]. For correlated shadowing, we use the exponential correlation model [33].

IV. PROPOSED WORK

The proposed protocol is an extension of AODV [39] routing protocol. The regular CRAHN aims for the network with regular size as the required information for transmissions is likely aware for each CR. In the following, under four kinds of traffic patterns, we examine essential characteristics (i.e., spectrum availability, wireless fading, and link service rate) for networking in the regular CRAHN and then provide the end-to-end delay for data transportation via queueing network analysis. To mitigate intersystem interference for networking in the CRAHN, CRs' link transmissions will notice PSs' spectrum usage. For a successful transmission over opportunistic link, the transmission should not interrupt other's traffic from the CR-Tx aspect, and it should not be disturbed by other's traffic from the CR-Rx aspect. Specifically, CR-Tx's transmitted power must not affect PSs' used spectrum blocks along the route to CR-Rx. Moreover, CR-Rx's occupied block must be unused by PSs for successful reception from CR-Tx. The length of the spectrum block (i.e., l) is suggested by the area that CR-Rx can conduct successful signal reception, even under interference. While CRs' traffic might be interrupted by PSs' traffic, end-to-end delay regarding CR's link access delay accounts for reliable communications.

4.1. Relaible Transmission Algorithm

1) *Source* partitions its traffic into batches of packets for transmissions.
2) At each *Source*s available time slot, *Source* collects link information (i.e., $\delta i,j$ and vi,j , i, $j \in \{CRS, n, CRD\}$) from the map to prioritize forwarders into the candidate list regarding node metric mi, $i \in n$, randomly mixes packets in a batch via random network coding [43], and broadcasts coded packet with the list.
3) While the ACK message is not heard from *Destination*,

a) *Source* repeats Step 2 until it hears ACK.

b) For each relay node *z*, if *z* receives a packet from node *y*, it decodes the packet, saves unheard information in its buffer, and checks the list.

i) If *z* lines before *y* in the list, *z* advances its counter by its triggering ratio Φz.

c) At each *z*'s available time slot, *z* examines whether its counter is positive.

i) If so, *z* randomly mixes its buffered packets, broadcasts coded packet with the list, and decrements its counter by one.

4) *Destination* continuously decodes the collection of coded packets to verify whether it gets all packets of the batch.

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If so, *Destination* broadcasts ACK back to *Source*, eliminating the packets buffered in relay nodes and enabling the next transmission batch.

V. SIMULATION RESULTS

This chapter discusses on results and discussion of the existing routing protocol and the proposed routing protocol. This chapter also deals with simulation settings and the performance metrics taken for simulation.

Table 5.1. Simulation settings

No. of Nodes	50, 100, 150, 200 and 250
Area Size	1000 X 1000
Mac	802.11
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512 KB
Mobility Model	Random Way Point
Pause time	100 Seconds

5.1. Performance Metrics

- Throughput
- Packet Delivery Ratio
- Packets Drop

5.2. Results

From the Fig.2, it is shown that the proposed protocol achieves better throughput than that of AODV [39]. From the Fig.3, it can be clearly observed that the proposed routing protocol has better packet delivery ratio when compared to AODV [39] routing protocol. From the Fig.4, it can be clearly understood that the proposed protocol has less packets drop than AODV [39] routing protocol.

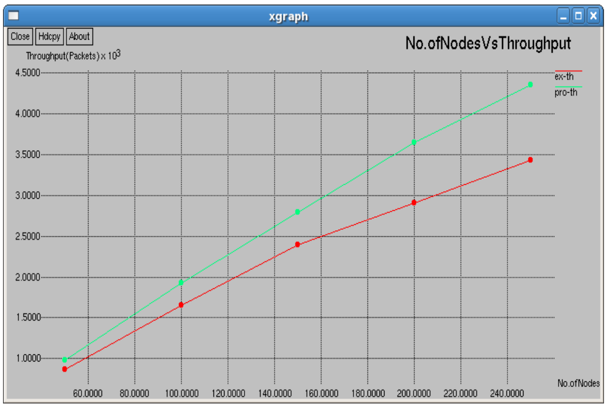

Fig.2 Number of Nodes Vs Throughput

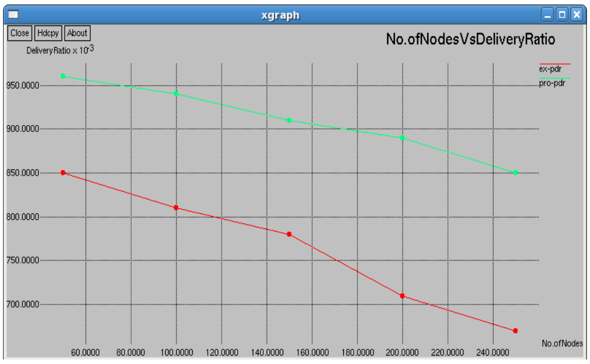

Fig.3 Number of Nodes Vs Packet Delivery Ratio

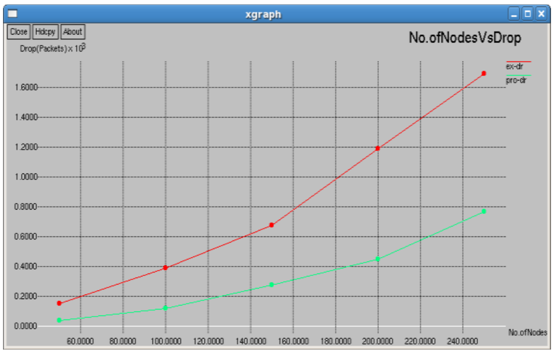

Fig.4 Number of Nodes Vs Packets Drop

VI. CONCLUSION

Reliability is one among the major research issue in CRAHNs. The proposed work is an extension to AODV [39] routing protocol. This paper proposed a mechanism for improving reliability using Reliable Transmission Algorithm. The proposed routing mechanism is tested using NS2 simulator. The performance metrics throughput, packet delivery ratio and packets drop are taken into account. Simulation results shows that the proposed routing mechnaism achieves better relaibility than AODV routing protocol.

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