EOAODV: Routing Protocol for Cognitive Radio Network

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Abstract— Cognitive Radio (CR) technology provides promising and a new solution to improve the spectrum utilization. In recent years, cognitive radio technology (CR) has been proposed to allow unlicensed secondary users (SUs) to opportunistically access the channels unused by primary users (PU). This paper focuses on designing Enhancement of Opportunistic Ad-hoc On Demand Distance Vector (EOAODV) routing protocol that uses shortest distance, Expected Transmissions Count (ETC) and residual energy as a parameter to select the most reliable link and the next forwarding node. The selection of route in the network by the traditional AODV is based on hop count. It is proposed to achieve a gain of Opportunistic Routing (OR) with AODV for cognitive radio wireless sensor networks (CRWSN) to improve its efficiency. In the OR work the nexthop node selection was based on only Expected Transmission Count (ETC). In this case if the same node is selected as nexthop for many times, energy of that node is drained and node may be dead. To overcome this problem, a technique is contributed that is energy based nexthop selection ie. EOAODV. The ETC is computed based on the quantized value of RSSI of the links with residue energy in the forwarding node. Using ETC the reliable link is computed and stored in routing table. The packets are tranmitted to the destination using channel details and the next hop, available in the routing table. The next hop selection is based on high energy in the nodes, shortest distance and least ETC.

Keywords*- Expected Transmission Count (ETC), Opportunistic Routing (OR), EOAODV, residue energy*

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I. INTRODUCTION

Advances in technology and development of new wireless devices increase the need for better utilization of spectrum bands. The number of unlicensed spectrum bands are limited and according to FCC, up to 85% of licensed spectrum bands is wasted when the licensed users are not using their dedicated spectrum band. Cognitive radio networks (CRN) are developed to solve the underutilization problem of licensed spectrum bands. Cognitive radios make use of their own available band and also the vacant other user’s bands. The cognitive radio gets interrupted in its transmission upon the arrival of the other users. Since the transmission is subjected to licensed (primary) user’s random interruptions, the communication environment is stochastic. Protocols should be designed to cope with the stochastic behavior of primary users and include the uncertainty in the availability of spectrum in their implementation. In traditional wireless networks, a link is said to be stable if it is less prone to interference. In cognitive radio networks, however, a link might break due to the arrival of primary user. Therefore, links’ stability forms a random process with OFF and ON states; ON, if the primary user is absent. Clearly, traditional network protocols cease to operate correctly in this environment. New sets of protocols are needed in each layer to cope with the random dynamics of cognitive radio networks. The new MAC and routing layer protocols should consider the stability of a link because each time the communication fails, packets are lost. In addition, radios restart the handshaking process, which increases communication overhead and severely damages the performance in terms of throughput and delay. By using a routing protocol that guides the packets through the paths with higher probability of stability than others, CRNs throughput and delay will substantially improve. With acknowledging CRNs true nature and using probability and stochastic theory tools, can develop protocols that nicely adapt to any uncertainty in the communication environment.

The two major concerns of the wireless communication system are throughput of the network and underutilization of wireless channels. Opportunistic routing (OR) aims at improving the former and coping with the latter. Due to the unreliable characteristics of such channels, traditional routing achieves poor throughput. Since traditional routing arbitrarily selects high lossy links among diverse paths of same minimum length. The proposed work is designing a multipath, multichannel opportunistic ad-hoc on demand distance vector routing protocol that uses shortest distance as well as expected transmissions count (ETX) as a parameter to choose the next forwarding node and the most reliable link respectively. The conventional AODV uses hop count for the selection of route in the network. It is proposed to harvest the advantage of OR with AODV for cognitive radio wireless sensor networks (CRWSN) to improve its efficiency. The ETX is computed based on the quantized value of RSSI of the links. Using ETX the reliable link is computed and stored in routing table. The packets are forwarded to the destination using the next hop and channel details available in the routing table. In the work the nexthop node selection is based on only expected transmission count (ETC). In the case if the same node is selected as nexthop for many times in that case energy is drained and node becomes dead. To overcome this problem is a technique is contributed that is energy based nexthop selection.

II. RELATED WORK

Haitao Liu et. al. [1]demonstrate Opportunistic routing, which has recently attracted much attention as it is considered a promising direction for improving the performance of wireless ad hoc and sensor networks. With opportunistic routing, intermediate nodes collaborate on packet forwarding in a localized and consistent manner. Opportunistic routing greatly increases transmission reliability and network throughput by taking advantage of the broadcast nature of the wireless medium. The basic idea behind opportunistic routing, and then categorize current research work based on different criteria. **Yongkang Liu** et al [2] demonstrate the main contributions in their paper four-fold: (i) propose an opportunistic cognitive routing (OCR) protocol in which forwarding links are selected based on the locally identified spectrum access opportunities. Specifically, the intermediate SU independently selects the next hop relay based on the local channel usage statistics so that the relay can quickly adapt to the link variations; (ii) the multi-user diversity is exploited in the relay process by allowing the sender to coordinate with multiple neighboring SUs and to select the best relay node with the highest forwarding gain; (iii) A novel routing metric to capture the unique properties of CRN, referred to as cognitive transport throughput (CTT). Based on the novel metric, propose a heuristic algorithm that achieves superior performance with reduced computation complexity. Specifically, CTT represents the potential relay gain over the next hop, which is used in the channel sensing and relay selection to enhance the OCR performance; and (iv) Evaluates the performance of the proposed OCR in a multi-hop CRN. Simulation results show that the proposed OCR protocol adapts well to the dynamic channel/link environment in CRN. **Angela Sara Cacciapuoti** et al [3] This paper addresses problem of routing by evaluating the feasibility of reactive routing for mobile cognitive radio ad hoc networks. More specifically, design a reactive routing protocol for the considered scenario able to achieve three goals: (i) to avoid interferences to primary users during both route formation and data forwarding; (ii) to perform a joint path and channel selection at each forwarder; (iii) to take advantage of the availability of multiple channels to improve the overall performance. Two different versions of the same protocol, referred to as Cognitive Ad-hoc On-demand Distance Vector (CAODV), are presented. The first version exploits inter-route spectrum diversity, while the second one exploits intra route spectrum diversity. An exhaustive performance analysis of both the versions of the proposed protocol in different environments and network conditions has been carried out via numerical simulations. **Xufei Mao** et al [4] this paper focus on selecting and prioritizing forwarder list to minimize energy consumptions by all nodes. Study both cases where the transmission power of each node is fixed or dynamically adjustable. An energy efficient opportunistic routing strategy, denoted as EEOR. **SanjitBiswas and Robert Morris** [5] The proposed work ExOR, an integrated routing and MAC technique that realizes some of the gains of cooperative diversity on standard radio hardware such as 802.11. ExOR broadcasts each packet, choosing a receiver to forward only after learning the set of nodes which actually received the packet. Delaying forwarding decisions until after reception allows ExOR to try multiple long but radio lossy links concurrently, resulting in high expected progress per transmission. Unlike cooperative diversity schemes, only a single ExOR node forwards each packet, so that ExOR works with existing radios.Juan Luo et al [6] The proposed work focus on minimizing energy consumption and maximizing network lifetime for data relay in one-dimensional (1-D) queue network. Following the principle of opportunistic routing theory, multihop relay decision to optimize the network energy efficiency is made based on the differences among sensor nodes, in terms of both their distance to sink and the residual energy of each other. Specifically, an Energy Saving via Opportunistic Routing (ENS_OR) algorithm is designed to ensure minimum power cost during data relay and protect the nodes with relatively low residual energy.Geng Cheng et al [7] Previous research have offered both centralized and distributed solutions on combining the two, but since different nodes may sense different spectrum availability, efficiently sharing this information in the dynamic spectrum environment still remains challenging. The proposed approach to reactively initiate route computing and frequency band selection. A novel multi flow multi-frequency scheduling scheme for single node to relief the multi-flow interference and frequent switching delay.

III. PROBLEM STATEMENT

Cognitive radio wireless sensor network is one of the major areas where cognitive techniques can be used for spectrum access of sensor networks in an opportunistic manner. Emerging trends in sensor networks have paved the path to many new protocols exclusively designed for sensor networks. Energy awareness is a crucial concern in sensor networks. However, only routing protocols have been considered with prime importance, since they may differ based on the network architecture and application areas. Cognitive radio sensor networks have few universal features like energy constraint, storage capacity, spectrum sensing, spectrum hole occupancy, irregular connectivity and lack of end to end connectivity. These characteristics make the conventional protocol for communication technology cannot achieve its end to end communication. The fixed spectrum allocation policy of traditional wireless networks enables only primary user to access the licensed frequency band(s) which in turn leads to variations in usage of spectrum in terms of space and time, and hence poor utilization efficiency. Fluctuations in the quality of any of the links along the predetermined single path may lead to more number of retransmissions at the link layer or rerouting at the network layer. Cognitive communication can be used to rectify this over utilization of spectrum and reduce the number of transmissions. Under this background, the concept of opportunistic routing was introduced.

IV. OPPORTUNISTIC ROUTING

The redundancy nature of nodes is exploited in OR to transmit packets to nodes that are available for routing, which gains benefit from the broadcast characteristics of wireless transmission. Following the network conditions, the link can change dynamically making it appropriate for cognitive radio network which has rapid variation of spectrum availability. In OR, several nodes are potentially chosen as next hop node for forwarding unlike conventional routing where single specific node is preselected as a forwarder for a packet. Thus multiple

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potential paths may be used by the source to deliver the packets to the sink, where the reliable link is chosen using the metric Expected Transmission Count (ETX). ETX is the average number of transmissions necessary to send a packet reliably across a route or a link counting retransmissions also. The ETX of a single path is given by the addition of ETX of every link in the route. ETX is computed as inverse quantized value of Received Signal Strength Indicator.

ETX = 1 / Q (RSSI)

By using ETX metric, bad links can be avoided thereby decreasing energy consumption which otherwise lead to more retransmissions. ETX is computed based on delivery ratios which help to optimize throughput by minimizing the expected total number of packet transmission. For networks in real time scenario, paths with the least ETX have the maximum throughput. The exact link loss ratio measurements on each channel forms the base by which ETX selects the best route and channel for transmission.

V. ENHANCED OPPORTUNISTIC AD HOC ON DEMAND DISTANCE VECTOR PROTOCOL (EOAODV)

A. Energy based nexthop selection

In the existing work the nexthop node selection is based on only expected transmission count (ETC). In the case if the same node is selected as nexthop for many times in that case energy is drained and node become dead. To overcome this problem is a technique is contributed that is energy based nexthop selection. This technique selects the nexthop selection based on energy and ETC. Selection factor for nexthop selection is as follows:

Selection factor = ETX + Residual energy

Selection factor = (((RxPr / TxPr) * 0.5) + (ResidualEnergy/InitialEnergy)*0.5))
Where, RxPr- Received Power
TxPr - Transmitted Power

B. Determining Forwarding Direction Neighbour

Distance = distance calculated from source to destination - distance calculated from neighbor of source node to destination

If the distance greater than 0 the node is forwarding node. Otherwise its not the forwarding node.

```
	if (distance > 0.0) {
		Forwarding node selected
	}
	else {
		Not forwarding node
}
```

VI. SIMULATION PARAMETERS

OAODV and Enhanced OAODV routing protocols are compared for the scenarios of varying number of flows. Scenario is kept same for both protocols with same topology, energy, source and destination. Totally 3 simulation runs are made by varying number of nodes as 1, 2 and 3. Parameters such as average residual energy, throughput and packet delivery ratio are computed and plotted as Xgraph.

TABLE I. SIMULATION MODEL

SIMULATOR	Network Simulator 2
NUMBER OF NODES	Random
TOPOLOGY	Random
INTERFACE TYPE	Phy/WirelessPhy
MAC TYPE	802.11
QUEUE TYPE	DropTail/Priority Queue
ANTENNA TYPE	Omni Antenna
PROPAGATION TYPE	TwoRay Ground
NETWORK AREA	800 * 800
ROUTING PROTOCOL	OAODV, EOAODV
TRANSPORT AGENT	UDP
APPLICATION AGENT	CBR
SIMULATION TIME	50seconds

VII. RESULTS AND DISCUSSION

A. Throughput

It is the amount of time taken by the packet to reach the destination.

Throughput (bits/s) = Total Data / Data Transmission duration

It is an **important** metric for analysing network protocols. It can be seen from the below graph, that when the number of flows increases, throughput decreases. In this work EOAODV provides better throughput when compared to the OAODV routing protocol.

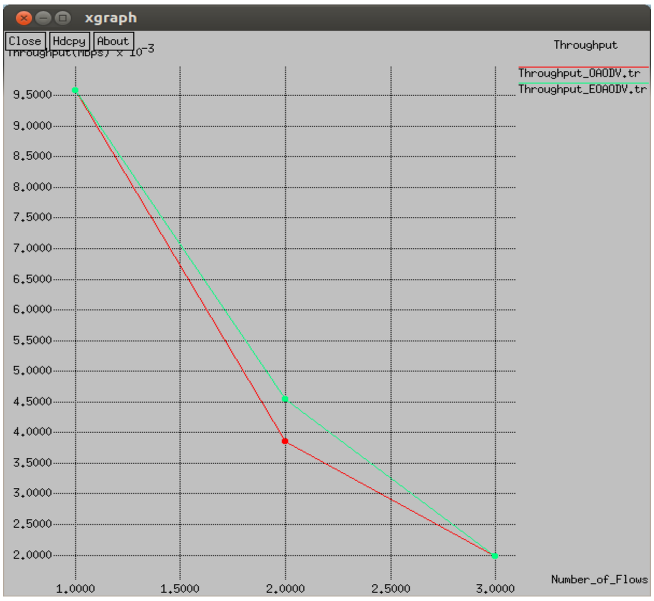

Figure 1. Throughput vs No. of Flows

B. Packet Delivery Ratio(PDR)

Packet delivery ratio is defined as the ratio of the number of packets received at the destination to the number of packets sent by the source.

$$\text{Packet Delivery Ratio} = \frac{\text{Received Packets}}{\text{Generated Packets}}$$

As can be seen from the below figure, when the number of flows increases, packet delivery ratio decreases. In our work, EOAODV routing protocol provides better packet delivery ratio when compared to the OAODV routing protocol.

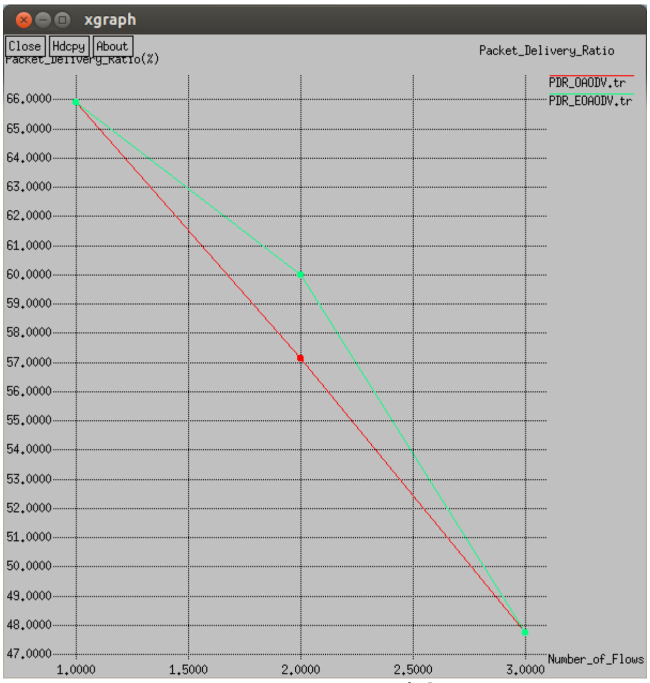

Figure 2. PDR vs No. of Flows

C. Average Residual Energy(ARE)

It is the amount of energy remaining in the node after certain network operation.

As we can see from the below graph, when the number of flows increases, average residual energy in nodes increases. In this work, EOAODV routing provides increased residual energy when compared to the OAODV routing protocol.

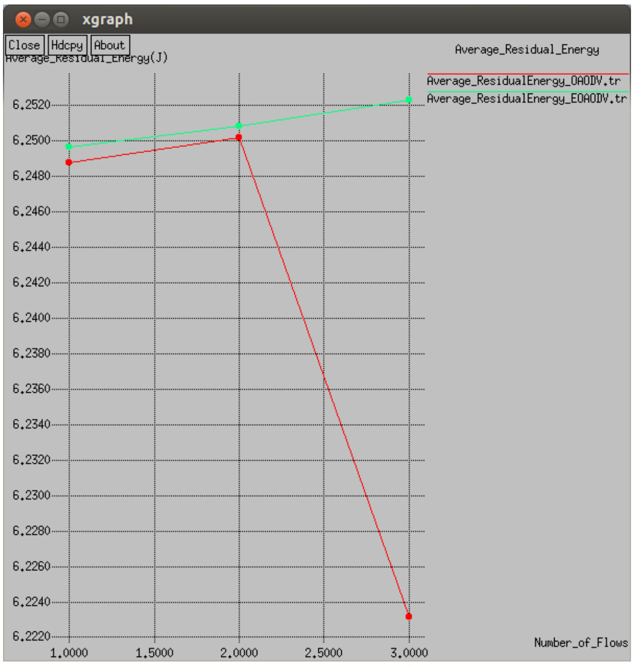

Figure 3. ARE vs No. of Flows

VIII. CONCLUSION

A routing protocol which uses all the opportunities in the network has been implemented for cognitive wireless sensor networks and its performance is analyzed by using the NS-2 simulator. The protocol is designed such that it chooses the node with shortest distance as next forwarder and chooses reliable channel with best ETX and high energy residue in node for link establishment. This increases the efficiency and utilization of the available spectrum in the network. This enhanced opportunistic AODV (EOAODV) routing protocol takes advantage of opportunities and increases the PDR, ARE & throughput on comparison with the OAODV protocol.

IX. REFERENCES

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