International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072

Enhancing Opportunistic Routing for Cognitive Radio Network

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Abstract - *In recent years, cognitive radios that follow routing policies have been proposed to overcome spectrum scarcity and to make better utilization of spectrum opportunities while avoiding interference to primary users. Cognitive radio technology (CR) allows unlicensed secondary users (SUs) to opportunistically access the channels unused by primary users (PU). In traditional AODV, the selection of forwarding node in the network is based on hop count. This paper mainly focuses on Enhancing Opportunistic Ad-hoc On Demand Distance Vector (EOAODV) routing protocol, to choose the most reliable path and the next forwarding node with the help of parameters like Expected Transmissions Count (ETC), residual energy and shortest distance. EOAODV is proposed to accomplish a gain of Opportunistic Routing (OR) with AODV. In the OR, only Expected Transmission Count (ETC), where ETC is computed based on the quantized value of RSSI, was used for the nexthop node selection. In this case if any node is selected as nexthop for several times, then there are chances of drained energy of that node and node may be dead. To surmount this problem, a technique is kicked in, ie. energy based nexthop selection which is called here as EOAODV. Here ETC is computed of the links with residue energy in the forwarding node. Using ETC the reliable link is found and stored in routing table. Based on least ETC, shortest distance and high energy in the nodes, the next hop selection is made.*

Key Words: *Expected Transmission Count (ETC), Opportunistic Routing (OR), EOAODV, residual energy, RSSI*

1. INTRODUCTION

In recent days, most wireless networks follow fixed spectrum allocation policy which results in only 15% - 85% spectrum usage with high variance in time. Due to the inefficiency of fixed spectrum access schemes, cognitive radio technique has been proposed for utilizing the spectrum opportunistically. Unlicensed devices can use licensed spectrum as approved by Federal Communications Commission (FCC). In cognitive radio networks, there are two types of users, one is Primary Radio (PR) user, which operates in its licensed spectrum band and the second is Cognitive Radio (CR) user, which operates either in unlicensed spectrum band or in the licensed spectrum band of PR nodes while ensuring that it does not interfere with PR nodes. If CR node is using licensed spectrum band of PR node and PR node arrives at that time, then CR node has to vacate this spectrum by selecting another spectrum from the spectrum pool. This is known as spectrum handoff [11].

1.1 Opportunities and Sharing

Obviously, shared medium approach has been applied from the beginning of wireless technology. Maritime radio systems, for example, have always used shared channels in order to establish a connection to communicate with each other. In that era, 2,182 KHz is specified to be used as a calling frequency as well as emergency signalling frequency between different maritime radio systems where other frequencies are used as working frequencies. When two ships want to communicate, one should identify a working frequency and then make a call on the calling frequency. By using this technique, a working channel can be identified and then a communication between the two ships can be hold. Moreover, by specifying a channel (or channels), that ships keep watch on facilitates both emergency signalling and establishing connections between ships. In fact, channel sharing was necessary and effective due to the lack of communication medium offered to every single ship and due to the fact that, the typical ship required far less than a full channel of capacity [14].

1.2 Spectrogram

The Spectrogram allows an idea of variation of energy, of the signal as a function of both time and frequency. The study investigates the use of the global energy of the signal or any node estimated through spectrogram as a tool for discrimination between signals obtained from various objects. The vertical axis of the spectrogram is frequency and it provides an analysis of signal into different frequency regions [20].

1.3 Wireless sensor network (WSN)

Wireless sensor network (WSN) offers a wide range of applications in areas such as traffic monitoring, medical care, inhospitable terrain, robotic exploration, and agriculture surveillance. The advent of efficient wireless communications and advancement in electronics has enabled the development of low-power, low-cost, and multifunctional wireless sensor nodes that are characterized by miniaturization and integration. In WSNs, thousands of physically embedded sensor nodes are distributed in possibly harsh terrain and in most applications, it is impossible to replenish energy via replacing batteries. In order to cooperatively monitor physical or environmental conditions, the main task of sensor nodes is to collect and transmit data. It is well known that transmitting data consumes much more energy than collecting data [9]. To improve the energy efficiency for transmitting data, most of the existing energy-efficient routing protocols attempt to find the minimum energy path between a source and a sink to achieve optimal energy consumption. However, the task of designing an energy-efficient routing protocol, in case of sensor networks, is multifold, since it involves not only finding the minimum energy path from a single sensor node to destination, but also balancing the distribution of residual energy of the whole network. Furthermore, the unreliable wireless links and network partition may cause packet loss and multiple retransmissions in a preselected good path. Retransmitting packet over the preselected good path inevitably induces significant energy cost. Therefore, it is necessary to make an appropriate tradeoff between minimum energy consumption and maximum network lifetime [7].

Expected Transmissions Count (ETC)

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. Designing a multipath, multichannel opportunistic ad-hoc on demand distance vector routing protocol uses shortest distance as well as expected transmissions count (ETC) 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. The advantage of OR with AODV for cognitive radio wireless sensor networks (CRWSN) to improve its efficiency. The ETC is computed based on the quantized value of RSSI of the links. Using ETC 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) [1].

2. RELATED WORK

Haitao Liu et. al. [2] 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 [3]** 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 [4]** 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 [5]** 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. **Sanjit Biswas and Robert Morris [6]** 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 [7]** 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 [8]** 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.

3. 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 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 (ETC). ETX is the average number of transmissions necessary to send a packet reliably across a route or a link counting retransmissions also. The ETC of a single path is given by the addition of ETX of every link in the route. ETC is computed as inverse quantized value of Received Signal Strength Indicator.

$$ETC = 1 / Q(RSSI) \quad (1)$$

ETC is computed based on delivery ratios which help to optimize throughput by minimizing the expected total number of packet transmission. The exact link loss ratio measurements on each channel forms the base by which ETC selects the best route and channel for transmission [1].

4. EOAODV (ENHANCED OPPORTUNISTIC AODV) ROUTING PROTOCOL: PROPOSED WORK

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 residue and ETC. For networks in real time scenario, paths with the least ETC and higher energy will have the maximum throughput. By using ETC metric, bad links can be avoided thereby decreasing energy consumption and allowing more energy to reside in the node, which otherwise lead to more retransmissions.

4.1 Protocol design

This section describes the features of enhanced opportunistic Ad-hoc On-demand Distance Vector (EOAODV) routing protocol and derives the algorithm to compute routes on multi-hop wireless networks based on ETX and Energy Residue.

EOAODV Routing Protocol Algorithm

In the proposed algorithm, source node (S) and destination nodes (D) are chosen. The neighboring nodes are named as N, neighboring nodes in the direction of destination as ND and the forwarding nodes from ND are termed as F. Under the initial assumption that every node know its own location and source node know the location of destination, the algorithm is as follows

STEP 1: Sense the free channels between S and its neighbour nodes (N) using energy detection technique.

STEP 2: Broadcast the beacon signals from S to N via all the available free channels. Beacon signal contains information about the location of S and D along with the distance (DSD) between S&D

STEP 3: Calculate the new distance DSD'
Distance = distance calculated from source to destination - distance calculated from neighbor of source node to destination

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

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

STEP 4: Apply candidate selection algorithm for the source node (S) as given below.
1 Get the value of DSD' and RSSI from all its neighboring nodes in the direction of destination (NDi)
2 Set threshold distance DT and threshold energy

STEP 5: Estimate the best channel to the forwarding node F based on RSSI, energy residue in node and hence ETX.

STEP 6: Transmit the data packets to the selected forwarder set F through the selected channel.

STEP 7: Each forwarder will further transmit the data to its ND node with shortest distance (DSD) i.e., F through the channel having best ETX and higher energy left in it.

STEP 8: Repeat the same process until the packet reaches its destination (From step 6)

4.2 Determining Forwarding Direction Neighbor

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

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

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

4.3 Selection Factor

Source node is 35
Destination node is 17

Selection factor = ETX + Residual energy
Selection factor = (((RxPr / TxPr) * 0.5) + (ResidualEnergy/InitialEnergy)*0.5))

Where, RxPr - reception Power
TxPr - Transmission Power
Weight 0.5

5. 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 -1. 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

6. RESULTS AND DISCUSSIONS

6.1 Packet Delivery Ratio

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.

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

From the fig., when the number of flows increases, packet delivery ratio decreases still EOAODV routing protocol provides better packet delivery ratio when compared to the OAODV routing protocol.

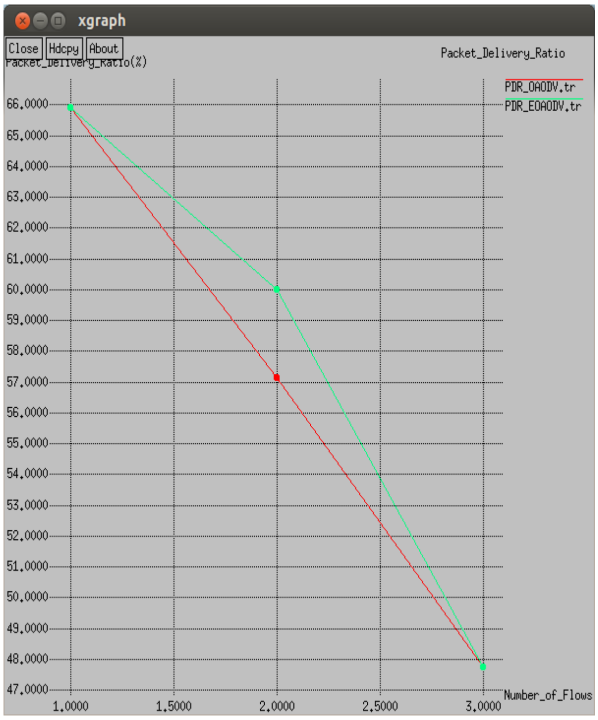

Figure -1. PDR vs No. of Flows

6.2 Throughput

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

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

As can be seen from fig., when the number of flows increases, throughput decreases but still EOAODV provides better throughput when compared to the OAODV routing protocol.

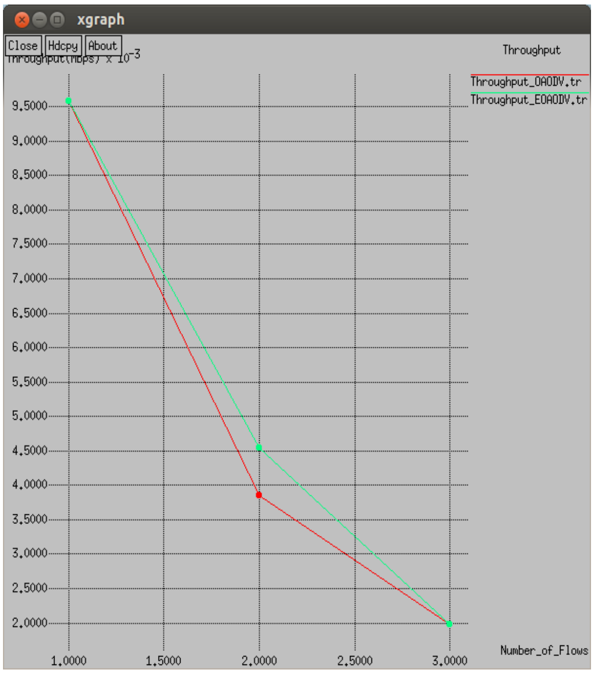

Figure -2. Throughput vs No. of Flows

6.3 Average Residual Energy

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

When the number of flows increases, average residual energy in nodes increases. Here we can see that EOAODV routing provides increased residual energy when compared to the OAODV routing protocol.

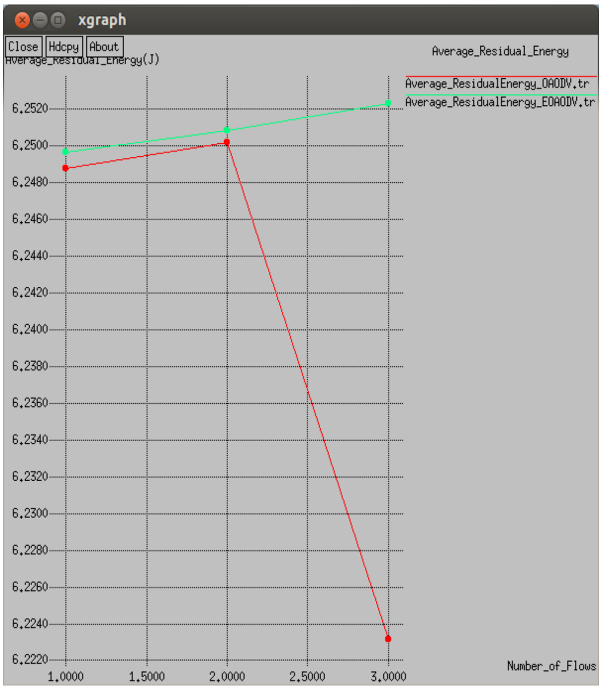

Figure -3. ARE vs No. of Flows

7. CONCLUSIONS

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

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