Reliable Dynamic Opportunistic Routing Protocol for Energy Efficient Transmission in Cognitive Radio Sensor Networks

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***Abstract*—Cognitive Radio Networks attempts to resolve one of the biggest issues in wireless networks that are spectrum scarcity. While following this approach of routing in WSN traditional routing protocols does not prove to be efficient. There are several protocols proposed for Cognitive Radio Sensor Network but very less attention is being paid on reliable transmission of data. When we consider WSN energy limitations are inevitable. Thus combined focus on energy efficiency and reliable transmission needs to be studied. In this paper we have proposed a routing protocol for energy efficient reliable data transmission in CRSN. This protocol proves to be more reliable and energy efficient due to its energy efficient path selection and transmission power modulation model in dynamically changing environment. We studied our proposed protocol through computer simulations and observed that it proves more energy efficient.**

Keywords-*Cognitive Radio Sensor Network, Energy efficient, Reliable, Routing*

INTRODUCTION

Wireless sensor networks are now very popular due to their increasing applicability in applications like control and monitoring. These types of applications are commonly needed in fields like agriculture, forest monitoring and pollution monitoring. Two most significant challenges in WSN are the limited energy of nodes and overcrowded ISM band of frequencies. WSNs are usually deployed for long periods without less or no maintenance and nodes operate using non-rechargeable small batteries. Thus, energy efficiency will have significant effect on the cost, and therefore the usability, of the complete network. Since most of the energy is drained during transmission, they should be performed efficiently in order to avoid packet loss and retransmission. Routing paths must be chosen so that it will not lead to broken links due to dead intermediate nodes. In addition to it, transmit power adaptation can also be one of the options to save the energy of node and ensuring robust reliable communication.

Another issue of WSN is overcrowded ISM band since this band is already being used by many other wireless networks such as Bluetooth and IEEE802.11.9. On one hand ISM band is being overcrowded other bands like VHF band is being underutilized due increasing use of satellite television. This partial uses of frequencies are because of static frequency allocations. Thus in order to utilize all the available frequency resources equally we can approach for Cognitive Radio technology. As CR technology allows us to use frequency spectrum dynamically and opportunistically, which saves the packet losses due to collision in overcrowded ISM band[10].

In this paper we have given review of existing routing protocols as section II. Section III and VI describes proposed routing protocol and experimental analysis respectively.

RELATED WORK

Opportunistic routing has been undertaken for research since long as it seems to be promising solution to increasing spectrum scarcity. In [1] the protocol called cost and collision minimizing routing (CCMR), it attempts to reduce the number of retransmissions by reducing the number of collisions caused due to contention at the MAC layer. Next hop nodes along a path from a source to a destination are chosen based on the probability of successful contention at the receiver. This scheme has reduced Packet Loss Ratio and energy efficiency is achieved. In [2] the power-routing algorithm a routing metric that considers channel conditions, collisions and retransmissions is used in order to determine the optimum number of relay nodes that leads to lowest power consuming path. In their work, Biswas and Morris et al. proposed the ExOR opportunistic routing protocol, which needs the global knowledge of the network to select probable forwarding nodes and prioritize them, and it proves to have superior throughput than the traditional deterministic routing [3].SARR considers multiple attribute based routing metric to select the next hop nodes. Channel usage information, delay, energy consumption are attributes which plays key role to select the forwarding nodes. This algorithm is greedy approach of obtaining the optimal solution. If we go on selecting the routes based these parameters same nodes will be selected draining their energy faster [4]. MCORP is another multiple attribute based routing scheme which considers remaining power, delivery ratio and expected number of transmission.[5]

EERR follows two different routing metrics depending on the sensitivity of the data to be transmitted to achieve reliability. Relay node selection depends on the availability of channels and energy of neighboring nodes. For highly sensitive data nodes with highest remaining energy are selected whereas for others the remaining energy of relay node is kept fixed [6].In ERFLA leveling, sectoring and clustering techniques are used for route formation. [7] In addition to all the above stated routing metrics using the geographical location information is also popular routing metric to achieve the energy efficiency. Geographic adaptive fidelity (GAF) [8] and geographical random forwarding (GeRaF) [8] are two such protocols. Both these protocol considers availability of location information of all the neighboring nodes. By choosing the node that is closest to the destination at every hop, GAF and GeRaF reduce the number of nodes required for transmission from the source to the destination, thus reducing energy consumption. CNOR is a reactive routing protocol which selects relay node based on their distance from the sink node. The node which is closer to the sink node is selected as relay node. It maintains multiple routes for communication between two nodes thus as the network size grows options for multiple routes also increases thus ensuring reliable transmission. In the selection criteria of this protocol remaining energy of the node is neglected which hampers the reliability of the network.[9]

In this work we tried to fill in the gap by focusing the routing metric in two areas of energy efficiency and distance from the node to achieve the reliable transmission and longer network lifetime. We tried to focus on two issues in WSN that are energy wastage due to unnecessary retransmissions due to dead intermediate nodes and unadoptable transmission power and spectrum scarcity. We have considered a cross layer approach of network and MAC layer to achieve the greater goals of increased network lifetime and reliable transmission.

PROPOSED SYSTEM MODEL

In this section basic terminologies related to the system are discussed along with the packet structures and channel models.In this system we have considered the PHY LAYER Cognitive Radio (CR) enabled thus we do assume the physical layer reconfiguration will be done automatically by assistance of spectrum sensing. We have also designed two new packet structures which will be an addition of network layer in traditional MAC layer RTS-CTS handshake.

RNP Packet

This packet is used by transmitter node to negotiate the power level used for transmission with the selected next hop node. Its main use is to get the power levels from the receiving node. This packet is encapsulated in the MAC-DATA frame. The details about this are discussed in the section VI.

Receiver Address	Sender Address	Duration	Frame Check Sequence

RNP Packet Structure

RRNP Packet

This packet is the reply send from receiver node in response to the RNP. This packet carries the information about minimum required power for transmission. Receiving node calculates the minimum required power for transmission based on Shannon's Channel Capacity theorem and enclose it into the RRNP packet and sends to the node from which it received RNP.

Receiver Address	Sender Address	~//~Power Info~//~	Frame Check Sequence

RRNP Packet Structure

RELIABLE DYNAMIC OPPORTUNISTIC ROUTING PROTOCOL

Reliable Dynamic Opportunistic Routing Protocol (RDORP) is dynamic and opportunistic protocol as it finds the routing path only when required and tries to acquire the licensed frequency band opportunistically. The proposed protocol is discussed in three phases as follows:

Network Establishment Phase

This process is SINK node initiated; SINK node sends initialization packets to initialize the addresses of the nodes with delivery test Cdst,dst set to zero. Every node receiving this packet updates its Cdst,dst to minimum number of hops it requires to reach SINK node and sends its own delivery criteria packets.

Each and Every sensor node i present in the network knows about its relative location due to its $C_{dst,dst}$, hence it can classifies the nodes around it into Neighbour nodes Ni, and candidate nodes Ci. Neighbour nodes Ni of node i, is a group of nodes that are in the transmission range R of node i.

$$N_i = \{j \in A_i \mid d_{i,j} \leqslant R\},\ i \neq j \qquad (1)$$

Where A_i is the set of all the nodes whereas $d_{i,j}$ is the distance between node i and node j. R indicates transmission range of the node. Candidate node set C_i of node i, is a group of those nodes that are in A_i and they are near to the SINK node d_{st} than the transmitter node i. Candidate nodes(C) is a subset of neighbour nodes, i.e. $C_i \leqslant N_i$ and can be defined as:

$$C_i = \{j \in A_i \mid d_{j,dst} \leqslant d_{i,dst}\},\ i \neq j \qquad (2)$$

By the end of this process all the nodes have necessary information to start the communication.

Packet Forwarding Phase

There are six types of packets for packet transmission phase, Request to Send (RTS), Clear to Send (CTS), Request to Negotiate Power (RNP), Reply to RNP (RRNP), DATA and acknowledgement (ACK). Whenever a node have packet to transmit it will first search for the free channel Ch_i. MAC layer will flood RTS over it and will listen the same channel until it is free. On other hand nodes who are listening on the same channel and are idle will respond to the RTS of transmitter node. Whenever a transmitter node receives CTS it will accept the reply from the node that are in the Candidate set and will forward the request to the network layer. CTS packet carries information about remaining battery of nodes. Depending on this information only that node from candidate set will be selected who have highest remaining battery. Once the node is selected the power negotiation will start. NET layer builds a packet called RNP and requests the selected candidate node to calculate minimum required power for transmission between them. As the receiver node receives RNP packet it will start calculating the minimum power required to communicate with sender node over Ch_i. This power is calculated by using Shannon's Channel Capacity theorem as follows:

$$C_{chi} = BW_{chi} Log_2(1+SNR_k) \qquad (3)$$

$$SNR_k = (P_i * |h_{chi}|2) / \delta 2 \qquad (4)$$

Using SNR equation we can obtain power as follows

$$P_i = \{(2^{(Rchi/BWchi)} - 1) * \delta 2\} / (|h_{chi}|^2) \qquad (5)$$

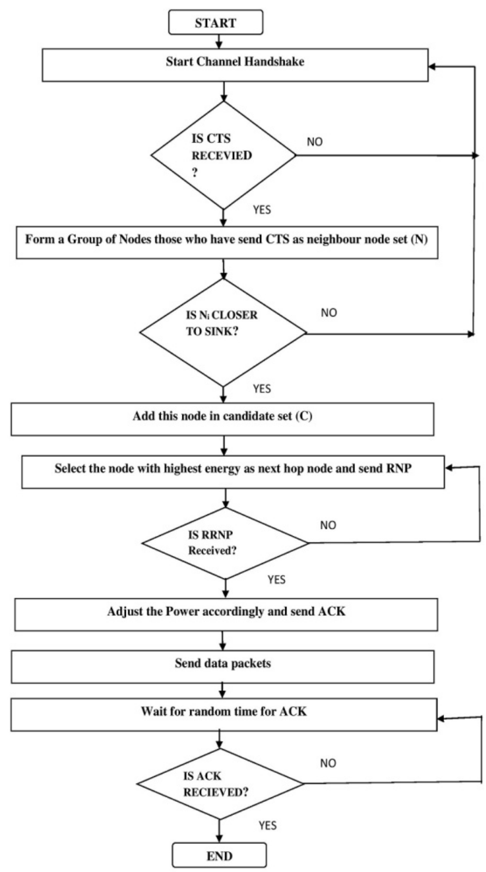
This calculated power is then send to the sender node through RRNP packet. Upon receiving RRNP packet minimum power level is extracted from it and given transmission power is adopted accordingly. Once this process is complete, actual DATA transmission begins. For every DATA packet sent sender waits for ACK from receiver node before sending next packet. If the link is loss in between the transmission, MAC layer informs NET layer about it. NET layer will store the data in its buffer until MAC layer does handover to another channel and will not let upper layer to know about it in order to avoid unnecessary congestion control. Once new free channel is sensed data transmission will be resumed from where it was broken. If it is not possible to connect with previous relay node on new acquired channel network layer will select new next hop node from candidate set.
Sensor nodes, which are idle, help to collect updating information about network. This process also finds out new node entries and death of existing nodes.

Psuedocode

Start
While (channel==free){
Send RTS;
If (CTS received) {
Check $C_{dst, dst}$ of receiver node i;
If(($C_{dst, dst}$)$_i$< ($C_{dst, dst}$)$_j$) {
Add i in candidate set C;
}
Select highest energy node k among C;
Send RNP to k;
If(RRNP received){
Change transmission power accordingly;
}
Send DATA;
Wait for ACK;
If (ACK not received) {
Resend DATA;
}
}}

EXPERIMENT AND ANALYSIS

For simulation we have used OMNeT++ as the simulation tool. In OMNeT++ to simulate the cognitive radio networks we used crSimulator framework designed by[13]. This framework gives several approaches for MAC layer and have all the required modules built for designing a cognitive radio node. In this scenario we have created a network consists of 50 secondary sensor nodes and 3 primary licensed users. Other simulation parameters are listed in Table I.

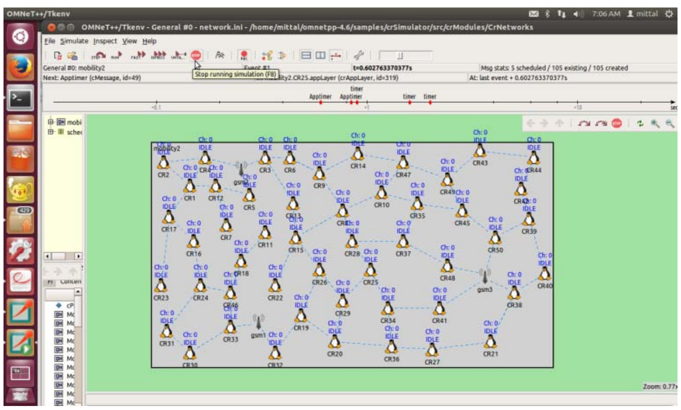


Flowchart of RDORP

Table I. SIMULATION PARAMETERS

SIMULATION PARAMETER	VALUES
RANGE OF FREQUENCY BANDS	900MHZ
CHANNEL BANDWIDTH	2MHZ
DATA PACKET SIZE	100 BYTES
TRANSMISSION RATE	270 kbps
TRAFFIC TYPE	CBR
PU ARRIVAL & DEPARTURE RATE	0.9 msec& 0.6 msec
MOBILITY MODEL(FOR NODES)	STATIC

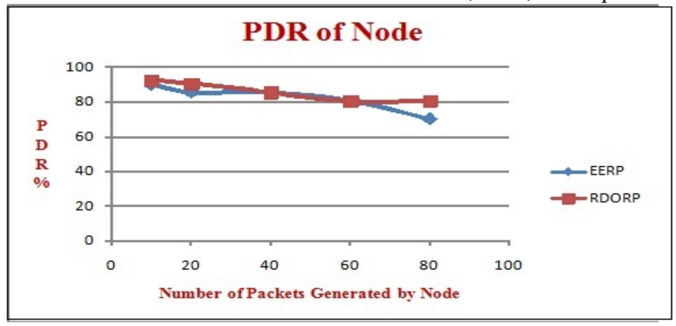
We have compared our proposed protocol with Energy Efficient Reliable Routing Protocol [6] in terms of packet delivery ratio, energy efficiency.



Network Topography

Packet Delivery Ratio

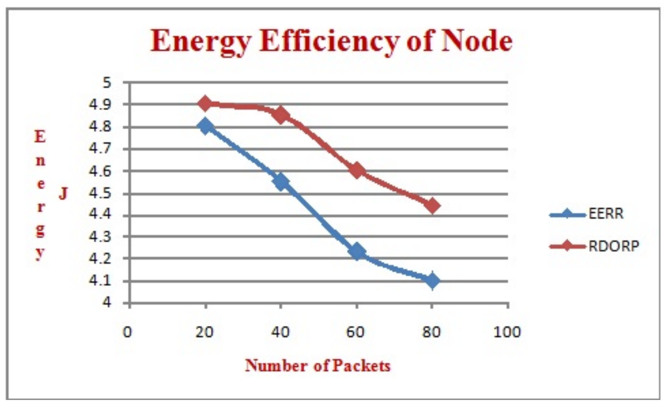
PDR is known as the ratio of number of packets send by source node to the number of packet received by destination node. Higher the value of PDR better the protocol performance is. In our simulation sender nodes send varying number of packets to destination node.



Comparision based on PDR

Energy Efficiency

It is the metric which is related to the energy consumption of nodes and network lifetime. Energy Consumption is inversely proportional to the network lifetime. Energy consumption of node depends on number of transmission thus total traffic in the network is responsible for deciding its total lifetime.



Comaprision based on energy

CONCLUSION

PU transmissions change the availability of wireless resources in CRSNs and are responsible for reliability and energy consumption of SU nodes. In this paper, a cross layer routing scheme is proposed which jointly considers reliability and energy efficiency. Firstly, next hop nodes are considered based on two metrics that are remaining energy and distance between sender and receiver. Further, transmission power is adopted according to the distance and channel characteristics by using Shannon's Channel Capacity theorem. The simulation results demonstrate that our proposed protocol achieves better energy efficiency while having satisfying performances in reliability.

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