Enhanced Energy Storage and Management Scheme in MH-CRSNs with ACO Algorithm

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Abstract

Energy efficient scheme in cognitive radio sensor networks (CRSNs) has many advantages compared to traditional networks. In cognitive radio (CR) system, the efficiency of the routing algorithm directly affects the system performance. We propose an energy storage and management scheme for improving network throughput and energy efficiency. Energy harvesting is adopted in cognitive radio sensor networks with battery-free secondary users that perform multi-hop transmission to reduce the network congestion and data loss. The proposed scheme is designed based on partially observable Markov decision process (POMDP) framework. In the case of multi-hop energy harvesting, in order to minimize the delay and energy consumption, an optimization concept is introduced which is named as Ant Colony Optimization (ACO). By using this method, shortest path from source node to the sink node is obtained and delay as well as consumption of energy is reduced. The simulation results show that the proposed scheme operates energy-efficiently while properly protecting packet loss.

Keywords - *CRCN, Energy harvesting, POMDP, ACO, Energy storage and management.*

I. INTRODUCTION

Wireless sensor network (WSN) is a wireless self-organizing networks, formed by a large number of low-cost, small size sensor nodes with wireless communication capabilities. These sensor nodes can monitor, perceive and extract data from environment. Then this information data are sent to the base station through the wireless multi-hop transmission technique [11].

Today, remarkable growth in the applications that use unlicensed bands introduce coexistence problem. Hence, WSN requires extra potential to withstand the interference introduced by the other applications. Cognitive Radio (CR) technology provides a favourable solution to support the sensor nodes with opportunistic spectrum access (OSA) capacity. In a CRSN, a collection of wireless cognitive radio sensor nodes are arranged in a distributed manner, in order to recognize an event signal and collectively communicate their readings over available spectrum bands in a multi-hop fashion. Power consumption problem is evidently an evaluative issue for CRSN. Battery-controlled life-time of sensor nodes can be improved by reducing power consumption, also limits overall energy consumption by sensor network, since the uncontrolled energy consumption will cause the network to die prematurely and reduce the network lifetime.

So, the key point for WSN is selecting the appropriate WSN routing algorithm which has the capability to save node energy and improve the standard of network communication. One of the widely used methods for route optimization in WSNs is Ant colony optimization (ACO) algorithm.It is a bio inspired approach that solves the problem in a heuristic way like natural ants. In wireless networks, there is probability that an error may exist or may not exist. The error can be link failure, interference, and packet. So, Partially Observable Markov Decision Processes (POMDP) can be used to create errors and propose a system in order to mitigate the error.POMDP is a powerful decision making tool since it contribute general and meaningful structure for modelling practical systems.

The rest of the paper is organized as follows. In section II, related work is given. The proposed system which includes ACO Algorithm and POMDP Framework are introduced in section III. Simulation setup is explained in Section IV. Performance evaluation and results are included in section V. Finally, the paper is concluded in Section VI.

II. RELATED WORKS

Cognitive techniques are used in wireless networks to solve the limitations of conventional WSNs. When CR integrated with wireless sensors, it can overcome the many challenges in current WSNs. CR has the ability to know the unutilized spectrum in a license and unlicensed spectrum band, and utilize the unused spectrum opportunistically.

CR gives advantage to WSNs by increasing the communication reliability and improving the energy efficiency. In CR-WSNs, a wireless sensor node selects the most appropriate channel once an idle channel is identified and vacates the channel when the arrival of a licensed user on the channel is detected. It increase spectrum utilization, and fulfills the end-to-end goal, increase network efficiency and extend the lifetime of WSNs. The system has the capability of packet loss reduction, power waste reduction and has better communication quality [1].

The color sensitive graph coloring (CSGC) is a widely used method in dynamic spectrum assignment

[3]. Through changing the labeling method, CSGC is effective in all situations. But the stability of CSGC is poor. In order to overcome these shortages, a set of intelligent algorithms has been used, genetic algorithm [4], bacterial foraging optimization algorithm [5], bee colony optimization algorithm [6], and particle swarm optimization [7].

These algorithms have a good optimization ability and fast convergence speed. But in most cases, they only aimed at maximizing the networks' utilization and do not care about the fairness between the users [2].

Performance analysis of four routing protocols, ACO, AODV, DSDV, and DSR in wireless sensor network was done. Simulation results show that ACO is not only energy efficient, but also has the highest packet delivery ratio and the shortest first packet arrival time [8].

Ant colony optimization is a metaheuristic in which a colony of artificial ants cooperates in finding to solutions to difficult discrete optimization problems [9]. The key advantages of ACO are its low computational load, less complexity and fast running time.

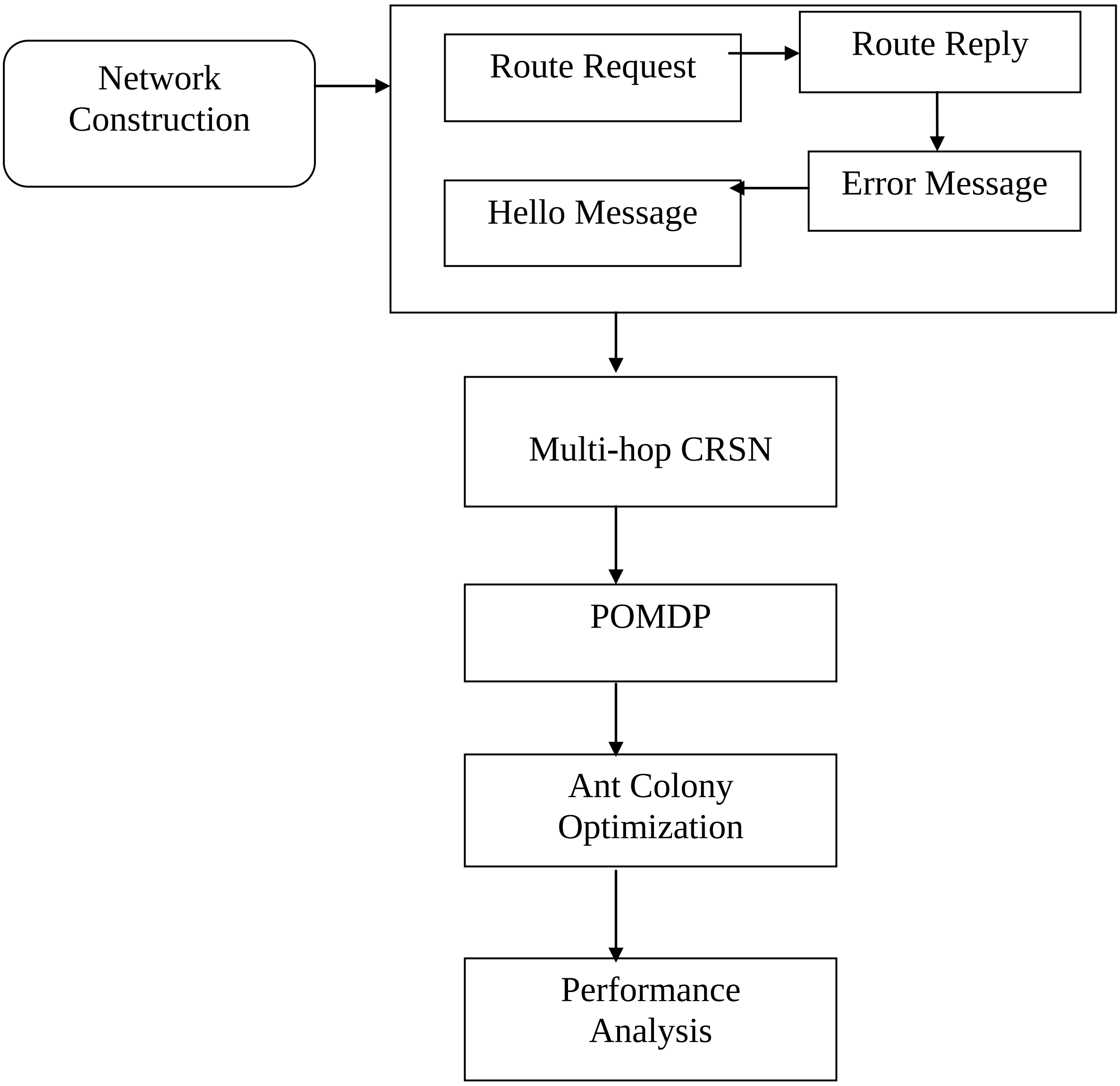

Fig. 1. Flow diagram

III. PROPOSED SYSTEM

In this system model of CRSN, several primary users and secondary users co-exist and they share spectrum channels for the purpose of data transmission. In this experiment, 50 mobile nodes are distributed into the system and they are powered by energy harvesting technique. Information is sent to the base station through wireless multi-hop transmission technique. But the drawback of Multi hop concept is that there is no method to find shortest path from source to destination, so, end to end delay and energy consumption will be high. ACO algorithm is used for route optimization and it will result in reduced network delay and energy consumption, thereby improves energy efficiency and end to end throughput. In wireless networks, there is probability that an error may exist or may not exist. The error can be link failure, interference, and packet loss. So, Partially Observable Markov Decision Processes (POMDP) can be used to create errors and propose a system in order to mitigate the error. Fig. 1 gives the flow diagram of the proposed method.

A. Multi-hopping Network

- In the network, during the process of data transmission the source node sends the data and the sink node which is the destination collects the data.
- During the process of data transmission, the message reaches the destination with the help of the intermediate hop nodes.
- If the number of intermediate hop nodes is large in number, that process is called as multi-hopping.

Due to the process of multi-hopping the network congestion and data loss are reduced. But energy consumption and network delay will be high.

B. Partially Observable Markov Decision Process

Partially observable Markov decision processes (POMDPs) are commonly used to model stochastic environments with hidden states. They provide general and expressive frameworks for modelling practical systems [10].

In wireless networks, there is probability that an error may exist or may not exist. For real time applications, we have to create error or interference and we will propose a method in order to mitigate this error. The error can be link failure, interference, and packet loss. So, Partially Observable Markov Decision Processes (POMDP) can be used to create error values for all the data transmission.

C. ACO Algorithm

In AdhocOn Demand Distance Vector (AODV) Protocol, routes are located on demand i.e. when there is a requirement for a new route, it is discovered. The source node sends Route Request packets to all the nodes. All the other nodes except the destination node transmit the Route Request packets. When a Route Request packet is received, the destination node sends a Route Reply packet in response, and it will travel in a backward direction of the corresponding Route Request packet. At every node, the Route reply packet collects the traveling cost in that path. When the source node receives all the Route Reply packets, it decides which route to take based on the accumulated cost on each of the Route Reply packets. The AODV routing is not suitable for large scale wireless sensor networks since discovering the routes becomes expensive. In worst case scenario, all the nodes in the network may need to send the Route Request packet to discover new routes and optimize the performance of the network with changing network conditions. Thus, it would not satisfy the criteria of cost which requires the protocol to send as less number of packets as possible.

Ant colony optimization is an algorithm and its operation is similar to that of real ant colony behaviour. When ants search for foods, they will leave a substance called pheromones on the path and other ants will select the path according to this pheromone concentration. Pheromones have a property that it will evaporate over time, so, pheromones are quickly collected in the shortest path. After some time, a shortest path is created. When an obstacle is detected on the path, the ants spread into two directions at an equalprobability initially. After some time, due to the accumulation of pheromones, ants will select the shortest path.

The proposed ant based routing algorithm has several properties which makes it ideal for the above specified requirements.

- The algorithm has the capability to dynamically reconfigure itself with changing network topology. This is done by making use of certain number of data packets as ants which require the destination node to send an acknowledgement back to the source node.
- The Ant based algorithm can support multi path routing as each node has certain number of neighbours with specified pheromone concentration levels and the next hop is chosen based on the concentration of pheromone.
- Hence it allows the node to choose different routes each time.

The operation of the Artificial Ant protocol consists of three tasks. They are as follows:

- Periodic neighbourhood discovery.
- Packet forwarding/reception.
- Retaining end-to-end reliability of finding the destination(s).

IV. SIMULATION SETUP

Simulations are carried out in NS2. NS (version 2) is mainly used for simulating local area networks and wide area networks.

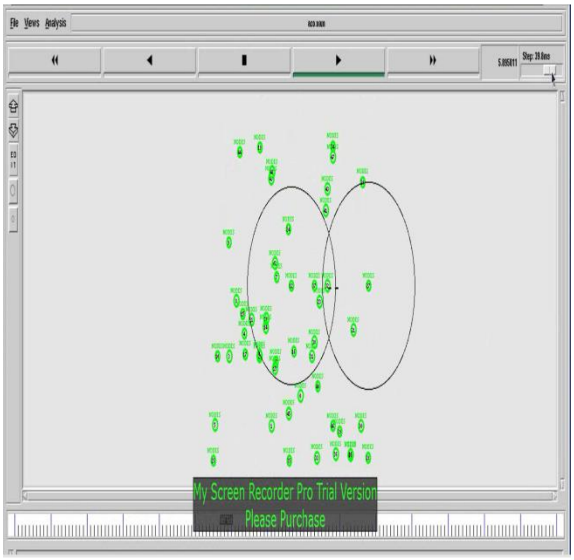

Fig. 2. Graphical representation of simulation window

The simulation scenario is the wireless sensor network. Nodes are responsible for data transmission and they are distributed within a region of 500cm × 500cm topography. The total number of nodes is 50. The initial energy of nodes is set to a particular value. Table I gives the parameter settings for the simulation.

TABLE I

PARAMETER SETTINGS

Parameters	Values
Number of nodes	50
Topography	500× 500 /m
Simulation time	15ms
Channel type	Channel/Wireless Channel
Radio propagation model	Propagation/Two Ray Ground
Antenna type	Antenna/Omni Antenna
Link layer type	LL
Interface queue type	Queue/DropTail/PriQueue
Max packet in ifq	200
Network interface type	Phy/WirelessPhy
Routing protocol	ACO

Initial energy of the nodes is 90J. Transmit and receive powers of 50 nodesare 0.3W and 0.6W respectively. Energy model is created based on these values. For Markov model, there are 2 stages and 2 variable states for each stage, one is ubstate and it is used for sending the data and second state is bstate for receiving the data. These states are created for all the channels and for each node in the channel. For stage 1, 27% error is created for ubstate and 12% error is created for bstate. Similarly, for stage 2, 0.4% error is created for both ubstate and bstate and similarly for data reception.

V. PERFORMANCE EVALUATION

Fig. 3, Fig. 4 and Fig. 5 demonstrate the performance evaluation of CRSNs (red colour), MH-CRSNs (Green colour) and ACO reinforced CRSNs (blue colour). Following graphs illustrates the simulation results corresponding to 50 mobile nodes and for the convenience, 2 nodes are selected as source nodes and they will transmit the data packets to the same destination node. During data transmission, the mobile nodes will change their positions in order to find the shortest path from source node to destination node.

Fig. 3 compares the received packets at the destination. 916 packets are transmitted and 850 packets out of these 916 transmitted packets are received at the destination. ACO shows the best performance among the other 2 scenarios.

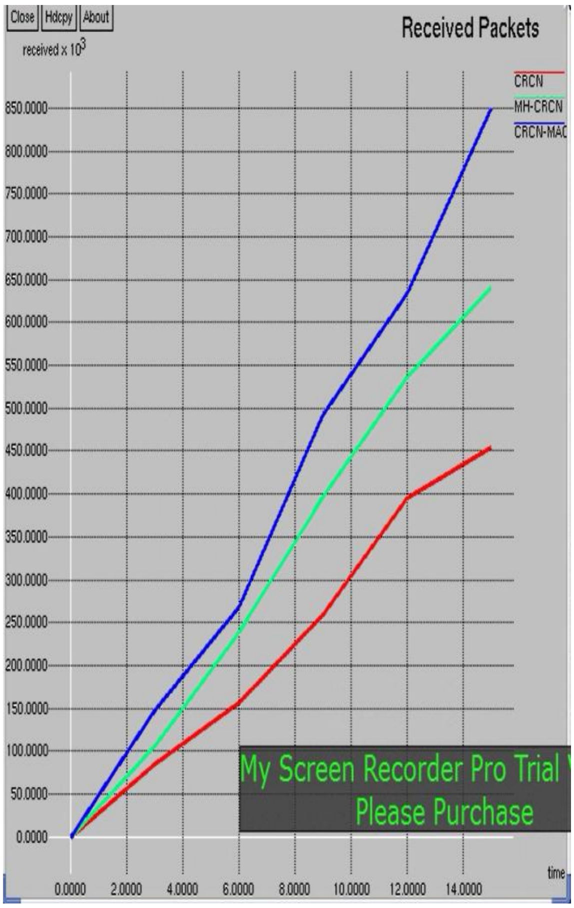

Fig. 3. Comparison of received packets

Fig. 4 compares the packet delivery ratios of 3 cases. ACO has the best performance among the other 2 cases, and the corresponding percentage of PDR is 93%. So from the perspective of PDR, ACO is more stable than the other two cases.

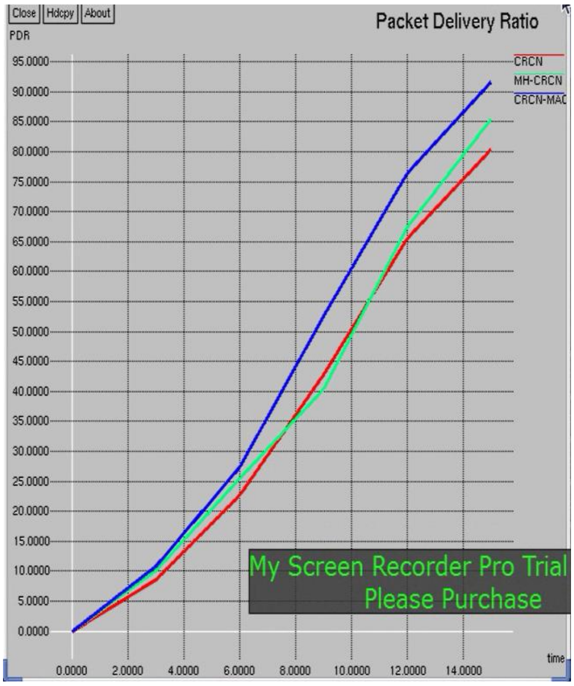

Fig. 4. Comparison of PDR

Total remaining energy is illustrated in Fig. 5.

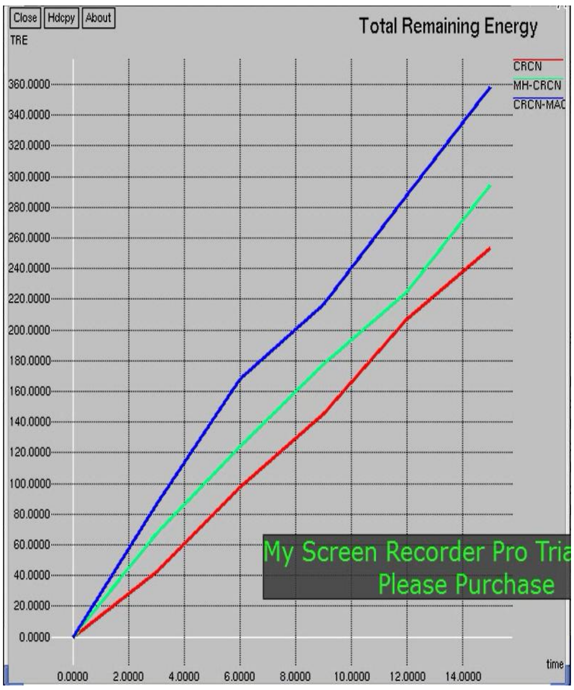

Fig. 5. Comparison of total remaining energy

Network delay and throughput are shown in Fig. 6 and Fig. 7 respectively.

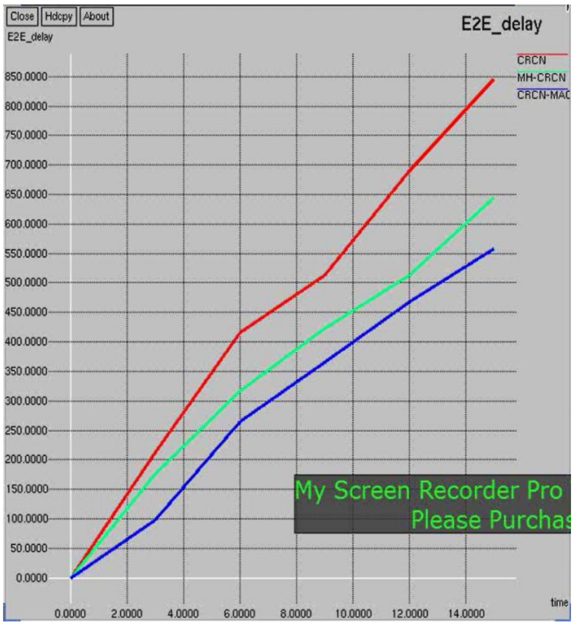

Fig. 6. Comparison of end to end delay

Fig. 7. Comparison of throughput

Simulation results are summarized in Table II

TABLE II
SIMULATION RESULTS

Parameter	value
Average end to end delay	427.29 ms
Throughput	22.20 Kbps
Energy spent	17.1146 J
Residual energy	82.8854 J
Transmitted packets	914
Received packets	850
Packet delivery ratio	93%

Main reasons for the superiority of the proposed algorithm over the other algorithms are summarized as follows:

- First of all, in the network, during data transmission, the source node sends the data and the destination node collects the data. Message reaches the destination with the help of the intermediate hop nodes. If the number of intermediate hop nodes is large, that process is called as multi-hopping. Due to the process of multi-hopping the network congestion and data loss are reduced. But energy consumption and network delay will be high. So ACO will find the shortest path from source to destination node and overcome the difficulties.
- Other algorithms examine the transmission distance to the next node i and don't consider the distance from the node i to the Sink, but this distance will reflects in the network energy consumption. Within the range of communications, closer to the destination node, the energy consumption of the network node will be smaller.

VI. CONCLUSIONS

By comparing with the traditional ad hoc network, the sensor network such as cognitive radio sensor network with multi hopping concept proposes a higher requirement for network energy consumption. In this paper, aiming at some features of the cognitive radio sensor network, the ant colony optimization routing algorithm based on partially observable Markov decision process is proposed. The simulation results indicate that by comparing with MH-CRSNs, the method proposed in the paper obviously minimizes the average energy consumption and extends the functioning period of the sensor node. From the performance analysis of various parameters it can be concluded that this scheme is efficient in reducing the energy consumption and increasing the throughput of the network. It also gives better Packet delivery ratio, increased throughput and reduced overall network delay. During the performance analysis, the parameters like average remaining energy, packet delivery ratio, received packets, end to end delay, and throughput are calculated.

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