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Analysis of Bio-inspired Scalable Routing Protocol for Cognitive Radio Sensor Networks

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Abstract: Wireless sensor network (WSN) is an autonomous system of number of sensor nodes deployed in the region and connected by the wireless links. The sensor nodes are battery powered node with some limited energy to utilize in network for various applications. The nodes are changing the position frequently and forward the packets from source to the destination. The routing is the main issue in wireless sensor networks. Thus there is need of designing the routing protocol for WSN. The next generation of wireless sensor network is the improvement in the hybridization techniques. The MAC and network layer is to be improved for the next generation wireless technology. The new idea behind the routing techniques is by sending the packets whenever the communication required with available spectrum holes. The next generation WSN is the CRSN (Cognitive radio sensor network) with cognitive capabilities. It is a possibly new routing philosophy that provides a scalable so lution to relatively large network in CRSN. An inspired from swarm colony optimization as artificial intelligence techniques likely to be ACO (Ant colony optimization) method used to find the shortest route with reliable routing in CRSN. In this paper an attempt has been made to compare the performance of routing methods for CRSN using biologically inspired methods. As per finding the differences in the protocol provides better solution for routing techniques with high density network. The performance differentials are analyzed using varying number of packets and pause time. The simulation is carried out using ns2 simulation tool. The results illustrate the importance of implementing the routing protocols in CRSN environment for large network.

Keywords: *Routing; scalability; ant colony optimization; cognitive radio sensor network; performance analysis.*

1. Introduction

Wireless sensor networks are emerging trends in the communication technology. Wireless sensor networks consists of large number of sensor nodes deployed in the specific region as an autonomous system with on-board system with wireless transceivers, a small processor and battery with specific allocation they are capable to communicate with each other.

The nodes are deployed over large dense network. They must interact with environment to sense the physical variable such as temperature. They communicate, route and forward packets for various application and reach to the base station as sink node. As per large network to route the packets it is difficult for sensor node because of non-rechargeable or infeasible battery of sensor nodes. WSN should be scalable and energy-efficient, reliable and adaptive to any failure and self-organized fulfill the entire requirements for good communication network.

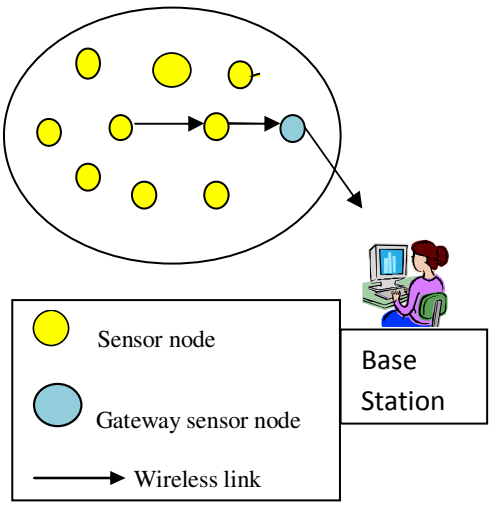

Fig. 1: Architecture of wireless sensor network

The hundred and thousands of sensor nodes are working and routing techniques having the job of identifying and discovering the number of routes to route the packets with given region. The some parameters affects in the performance of network such as delay in the network, node exhaust because of energy level of battery, routing overhead, packet delivery and much more. The main requirement of routing protocol is to optimize the network performance. The ad hoc network is the base line of the sensor network as infrastructure less and improvement in the network such as MANETS, WSN, and CRSN and so on. The based on these networks the requirement are not much differ for successful communication.

Routing in WSN or CRSN are the challenging job because of limited level of hardware and other resource available. The designing the routing protocols with some consideration such as minimum routing overhead, adaptive should be sustain more in the network. The sensor nodes operate on the different environment and therefore the routing may be done in centralized or distributed network. The designing approach of the routing protocol that the sensor nodes should be self-organized, adaptive to any failure and scalable and able to remain alive for long time.

The swarm intelligence (SI) is the artificial intelligence techniques that are behavior of social insects which solves the different complex problems in the society of research. The inspiration from the collective behavior to these insects' societies brings the solution for self-organization techniques, solves the fault-tolerance issues like choosing alternative path and collective behavior solves the problem of large network. The inspiration from these insects society for the research to solves the complex problem. There are many techniques of SI based such as ACO (Ant Colony Optimization), PSO (Particle swarm optimization), BCO (Bee Colony Optimization), solves the problem. The analogy between these bio-inspired methods and real routing problems motivate to design the routing protocol for solving different issues.

We consider the analogy of bio-inspired method as AntHocNet routing protocol for designing the routing protocol. The routing protocol is designed and analyzed for next generation sensor network as cognitive radio sensor network with its capabilities as spectrum sensing and spectrum decision utilize the available vacant bands as secondary users with multi-hops probabilistic approach.

The rest of the sections are organized as follows, section II describes the literature review, section III explains the Issues and challenges and proposed methods, section IV performance evaluation and discussion and section V concluded the paper.

2. Literature Review

I. F. Akylidiz et al. [1] done the survey of sensor networks. The authors are surveyed on each layer of protocol stack. The author also provides the design factors of wireless sensor networks. The goals such as creation of network infrastructure and efficiently shared the resources. Same as in network layer there is need of development of new protocol for fault-tolerance and scalability for wireless sensor networks. Low-Energy Adaptive clustering hierarchy (LEACH) routing protocol proposed by Heinzelman et al. [2]. In conventional routing protocols the first hierarchical routing protocol in wireless sensor networks. In setup phase the cluster formation is exists and in steady phase the data transmission to the base station. The two tier hierarchical methods are proposed by the author. Where in second tier the cluster head formation and how many times in each rounds. Muruganthan et al. [3] proposed the centralized low energy adaptive clustering routing protocol as (LEACH –C). Lindsey et al. [4] proposed the power efficient gathering in sensor information systems routing protocols, which is the improvement in the LEACH protocol. It requires the formation of a chain that is achieved in two steps those are construction phase and gathering data. E. Egea-Lopez et al. [5] proposed and state that increasing growth of WSN research and challenges issues related to performance. L. Alazzawi et al. [6] proposed the simulation of scalability issue for wireless sensor network routing protocols.

According to the author stated as scalability is an important issues for designing the routing protocols. The author stated that the good algorithm is to be adaptive and scalable for network topology changes. Ameer Amhad Abbasi et al. [7] done the survey on the clustering algorithm for wireless sensor networks. The survey state that the hundreds and thousands of nodes are scattered in the region and to solves the issues of scalability. Maurizio paone et al. [8] proposed the multi-sink swarm intelligence routing protocols for wireless sensor networks. They also proposed and solve the issues of fault-tolerance, self-organization and scalability issues. Christian H. W. Oey et al. [9] proposed the cognitive radio sensor networks as next generation technology of wireless sensor networks solving multiple issues based on energy efficient routing protocols. The spectrum bands are utilized for data sharing. The opportunistically they used unlicensed spectrum band. In this they proposed a new energy based cognitive radio aware routing protocol solves the multiple issues. Essam H Houssein et al. [10] proposed the Ant-

Hoc protocol for mobile ad hoc network as a new routing protocol compared with the existing protocol with AntNet and AODV and DSDV routing protocol. The simulation results shows that the Ant-Hoc routing protocol is best in all aspect of performance analysis based on QoS, routing load and connectivity. Mohammad Saleem et al. [11] proposed the Bee-inspired power aware routing protocol for wireless ad hoc sensor network. They consider the BEE colony optimization for their research work and find the research gaps to develop the protocol for reliable, power aware, scalable routing protocol with considering the different behavioral techniques of BEEs. They specially develop the protocol for routing overhead and route optimality based on packet delivery ratio and other parameters.

3. Design Issues and Proposed method

Wireless sensor network has different challenges and issues to overcome the constraints of WSN's and solve the design application issues. The challenges and design issues in WSN are limited energy consumptions, fault tolerance, scalability, productive cost, data aggregation, load balancing, congestion, security, self-organization. In this paper, we consider following issues to develop the algorithm for robustness in self-organizing, adaptive in fault-tolerance, and scalability issues.

Self-organization: A WSN is expected to remain operational for an extended period of time. Here the new node added in this network, may be the other nodes fail because of failures or exhaust their batteries becomes un-operational. A routing protocol must resilient to such dynamic & generally unpredictable variations sustain long term availability of network services.

Fault-tolerance: One of the sensor nodes may fail, the algorithm can reorganize itself so that it continues to function without any disruption. The nodes are in working condition. The routing protocols are adaptive to topological changes.

Scalability: Sensor node deployment in WSNs is application dependent and affects the performance of the routing protocol. The large number of nodes is deployed in the region having short communication range and high failure rates. The routing protocols have effectively acceptable for those challenges.

3.1 Biological Inspired Method

A. Bio-inspired Methods

Swarm optimization methods are useful to design our next generation routing protocol. swarm prompted the design of very efficient optimization and algorithms. The state of art many algorithms is based on ACO (Ant Colony Optimizations) and BCO (Bee Colony Optimizations) techniques useful to solve combinatorial optimization & NP-hard problems. We consider the ACO techniques to improve the efficient communication techniques.

1) Ant Colony Optimization

Researchers are find out the bio-inspired methods such as biological ants in the real world are able to utilize swarm Intelligence as artificial intelligence to find the solutions for different problems. Ant Colony Optimization (ACO) has been developed to mimic the behavior of real ants to provide heuristic solutions for optimization problems. The ACO is proposed by Macro Dorigo in 1992 in [12] his Ph.D. dissertation. While searching the food the ants while its journey they deposited a chemical are called pheromones. Pheromones attract other ants and follow the a path to the food source that other ants can follow. The other ants walk along the path, more pheromone is laid & path will increase & required time is less. There is another possibility of pheromone evaporation for that purpose reduces the change for other ants to consider the path Michael Brand et al.[13]. This characteristic of ants is adapted on ant colony optimization algorithms to solve real problems. ACO meta-heuristics approached models the real ants. In ACO a number of artificial ants build solutions to optimization problems. The path optimization between nest & food is achieved by ant colonies by exploiting the pheromone quantity dropped by ants. The analogy between the ACO characteristics and requirements are with the WSN and CRSN network. In WSN the path is chosen and data are transmitted through the labels on head of data packets, whereas in ACO the path is chosen based on pheromone left by ants in the path. Whereas there is forward ants and backward ants handling the responsibilities of forwarding information to exploring paths and collect the information from source to destination and backward ants to updating the information passing by nodes Kashif Saleem et al., [14].

2) ACO based Algorithms

Kwang et al. [15]In the network routing Ant Net routing using ACO techniques provides better results. Comparing all routing algorithms with ACO provides that ants are small can be piggybacked in data packets & frequently, transmission of ants may be possible in order to update the information to solve link failure. It proposed a ACO algorithm which aims at minimizing complexity in the nodes. This proposed is optimal for a less number of nodes in the cluster & also not suitable for ad hoc networks.

Mishra et al [16] The fault tolerant routing protocols using greedy ACO chooses a single path. The several algorithms were designed for the optimized routing process in wireless sensor network.

3.2 Research Method

In the proposed work we try to design the method for scalability issues. The wireless sensor networks works on sensors with limited battery power. The energy level of each sensor goes down with utilization of nodes in active condition. Those nodes are remaining ideal it store the maximum energy based on the method applied on the individual node with designed protocol. The state-of-the-art of the network to designed the routing protocol which route the packets with some conditions of saving energy, time, space that affect on sustainability of network lifetime of sensor nodes in the network. Though we consider the sensing task likely to be provide the spectrum availability for different frequency bands either 914MHz or 2.4GHz[22]. Those bands are unused causes the spectrum holes. The spectrum holes are utilized by the other waiting secondary user when primary user are not in active mode. Such sharing of spectrum are play important role for fully utilization of frequency spectrum bands. The same analogy play the role in swam intelligence, they try to utilize the available space and carry forward the work continuously with dropping pheromone trail so that other worker ants used the same route for finding the food source and came back to their nest, the concepts are used for the communication network.

Thus the concentration applied on the combination of cognitive technology and wireless sensor network causes the next generation communication network called as cognitive radio sensor network.

In previous paper we try to design the self-organized network and fault-tolerance network that are based on the same techniques. The scalability issues are also the important issues for sustainability of the network when the sensor nodes are increased in number. The sensor nodes are deployed in the specific unattended fashion for sensing the data and the data which sense forward to the base station. The neighbor discovery algorithm plays role for advertisement of neighboring nodes so that with finding the interested and shortest path nodes to forward the data to the base station. The node density is large in the network that scale the network, to occupy the all sensor nodes in CRSN, the nodes are forming the cluster with neighbor discovery, those nodes are nearer it forms the cluster and cluster nodes are forming the cluster head(CH) based on certain threshold energy level of nodes. The cluster nodes are find the multiple channels, select it and communicate with other cluster head nodes. They aggregate all the data and forward to the base station. The base station as sink node are static and also the multiple sink nodes are considered to forward the data packets to the sink node for proper balance network and to reduce less energy consumption. These concepts solve the scalability issue for CRSN or WSN network.

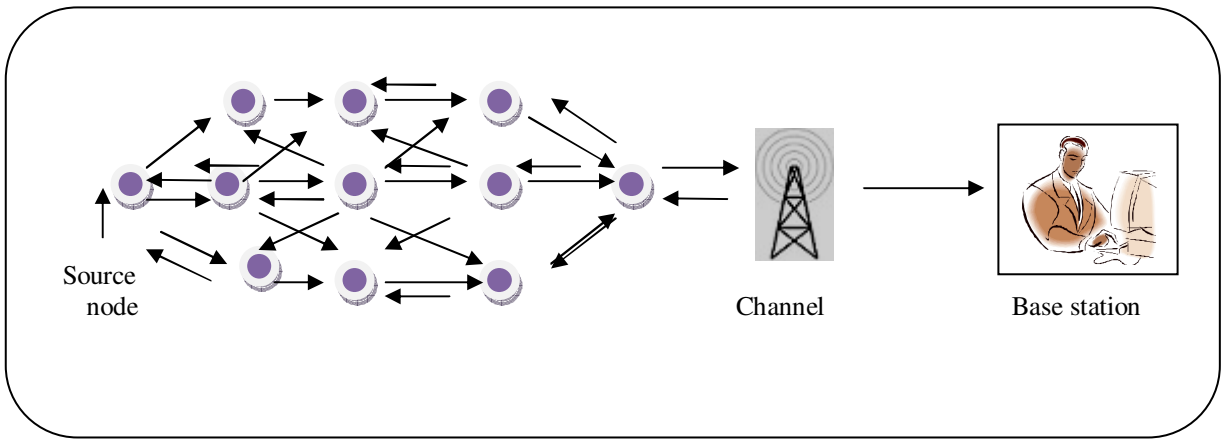

Fig. 2. Neighbor Discovery

The neighbor discovery algorithm creates nodes adjacency matrix with multi-hops probabilistic approach for either 1 or 0. According to the above fig. the individual nodes selects the route on-demand and

probabilistically transfer with multi-hops fashion reach to the base station through different channel. Thus there are Markov chain model plays the role for probabilistic approach.

Markov Chain is a class of characterizing stochastically the process by Markov property. The meaning is the next process takes depends on the current state and not on the previous state. To prove this for discrete time as given as follows and stated by [17]. Here P is the probability of selecting the behavior of next-hope sensor node and X_t is the condition probability.

$$P[X_t+1=x \mid X_0=x_0,.....X_t]=P[X_t+1=x \mid X_t=x_t] \quad (1)$$

This process called as a Markov Chain model. This way multiple nodes transfer the data with Markov model.

Neighbor Discovery with multipath construction

I/p: n number of nodes are deployed in region randomly.
O/p: Optimum path selection with multi-hops construction

Sink nodes advertise the hello message periodically
For each path (i, j) do
Perform the spectrum sensing;
End for
finding the number of hops to its neighbor node (Nd, ID, List of Nd);
Compute the probability of choosing multi-hop{ 0,1}
Probability of choosing path {0,1} through channel;
Like ants choose the path randomly
either channel is busy or idle;
If [channel is busy (ON)]
Primary user (active) is used;
else if [channel is Idle(OFF)]
Secondary user (active) is used;
Ants used available space (shortest route)
Depends on channel sensing neighbor discovery works,
For selection of channel the next hop neighbor node with handoff for PU to SU*(Channel list, radio frequency, transmission range)* **Ants find the optimum neighbor with avoiding obstacles.**
End for
End if
End

Clustering Approach

I/O: N numbers of nodes are deployed in region with multi-hops fashion
O/P: forming cluster & CH with channel selection reach with optimum path to the sink node.

After sensor nodes spectrum sensing and spectrum sharing
for
N number of nodes are after deployment for cluster.
If (nodes nearer to each other)then
Forming cluster
Else
Move to other nearer neighbor nodes
End if
End for
For
After nearer neighbor form cluster with cognitive capabilities
CH selection procedure starts to reduce energy level
If (node > threshold energy level)then
Forming cluster Head(CH)
Else remain in cluster
End if
End for
CH finds the available channel (channel allocation)
If(channel = busy)then
Select channel else
Other channel
End if
Destination node forward the packets to the base station with optimum path selection.

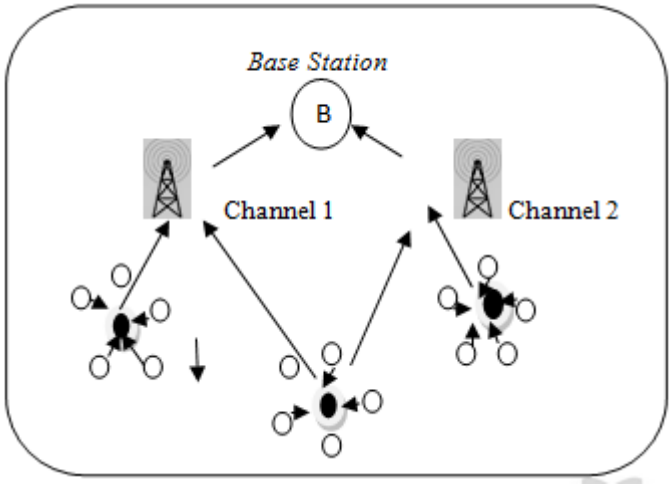

Fig. 3. Clustering Approach of CRSN

4. Result and Discussion

In this paper we have considered for QoS (Quality of Services) analyzed with the three parameters, the average end-to-end delay, average throughput, and packet delivery fraction. The performance parameters average throughput is obtained as the ratio of total number of bits received by a layer of destination node and total number of simulated time slots (sending time of the first packet minus receiving time of last packet by destination node).

Average Throughput $= \frac{N}{Rt - St}$, where the N = Total number of packets received by destination node, Rt and St are the receiving time of last packet and sending time of the first packet.

Average End-to-End Delay = The ratio of total number of receiving packet by destination node and receiving time of ith packet by destination minus sending timeof ith packet of source.

Packet Delivery Factorial = The ratio of receiving the number of packets by destination node and sending the number of packets by source node.

Energy Evaluation

The total energy is used by the individual sensor nodes in the network. The transmission and receiver energy cost for k number of bits for the distance of d meters are Et x(k, d), Er x(k) respectively as mention in equations of (1) and (2)

$$Et\ x(k, d) = Eelec. \times k + Eamp. \times k \times d\gamma \quad (1)$$

$$Er\ x(k) = Eelec. \times k \quad (2)$$

The Eelec. is the energy cost for transmitting and receiving multiple signal. Eamp is the energy amplifier consumed energy for reliable transmission as on [5].
Now,

$$Eamp. = \varepsilon fs \quad (3)$$

Where εfs is the energy cost of amplifier to transmit one bit at an open space for one hop same as for multiple-hops is εmp

Where the εmp given as follows.
Consider the pass loss components γ = {2, 4}. Now the distance d0 is the distance between the transmitter and receiver. The distance is given as

$$d_0 = \sqrt{\frac{\varepsilon fs}{\varepsilon mp}} \quad (4)$$

The Et x(k, d) =

$$\begin{cases} Eelec. \times k + Eamp. \times k \times d2 \ if\ d \leq d0 \\ Eelec. \times k + Eamp. \times k \times d4 \ if\ d > d0 \end{cases} \quad (5)$$

The sensor node is in sleep mode are denoted as *Esleep*

$$Esleep = Elow \times t \quad (6)$$

The *Elow* is energy consumption of any node during sleep mode of one second, where as the *t* is total time spend in *t* second.
So, the total energy spend is

$$Etotal = Et\ x\ (k, d) + Erx\ (k) + Esleep(t) \quad (7)$$

4.1 Simulation parameters

we consider the 100 number of sensor nodes with uniform random distribution, with the variation in parameters as packet size (100, 200, 300, 400, 500) with an initial energy of each node is 100 Joule, data transmission rate is 2 kbps, radio transmission rate 200 m, bandwidth of each channel 2 Mbps, sensing time 0.025 sec., operating time 0.6 sec, hand-off time 0.001 sec., with transport protocol TCP Reno, Number of TCP connection is 13, CBR of 256 kbps, routing protocol is analyzed with AODV and DSR routing protocol with cognitive capability. Number of channels is 11 in number, MAC as cognitive MAC and the simulation runs with 150 seconds in time. Here we select minimum interface channels with false alarm probability zero. The following are the output of four parameters, Average End-to-End Delay, Average Throughput, Packet delivery fraction, energy remains among the four parameter analysis to solve the scalability issue.

Table 1: Number of nodes Vs Packet Deivery Fraction

			No. of Packets				
			100	200	300	400	500
		Protocols	Packet Delivery Fraction				
No.of Nodes	25	AODV(cogns)	0.9048	0.8881	0.9079	0.9037	0.9122
		DSR(cogns)	0.902	0.9099	0.9085	0.932	0.9228
	50	AODV(cogns)	0.8715	0.8788	0.8929	0.7153	0.8909
		DSR(cogns)	0.8964	0.8966	0.9034	0.9072	0.9175
	75	AODV(cogns)	0.8686	0.8702	0.8688	0.8429	0.7652
		DSR(cogns)	0.8989	0.8969	0.8915	0.9239	0.9272
	100	AODV(cogns)	0.8642	0.8748	0.8537	0.8724	0.8677
		DSR(cogns)	0.8867	0.8989	0.8919	0.901	0.9003

Table 2: Number of nodes Vs Throughput(kbps)

			No. of Packets				
			100	200	300	400	500
		Protocols	Throughput(kbps)				
No.of Nodes	25	AODV(cogns)	419782	285322	213678	221912	185257
		DSR(cogns)	726580	616326	410549	428994	299714
	50	AODV(cogns)	59997	51672	69431	57630	53120
		DSR(cogns)	2296418	1244118	1317820	819264	914833
	75	AODV(cogns)	42687	46622	33805	12547	1988
		DSR(cogns)	2606447	1871396	1594339	1278078	1382085
	100	AODV(cogns)	88863	67674	44845	46913	54783
		DSR(cogns)	5015599	4475121	3.10448	2820726	2224431

Table 3: Number of nodes Vs End to End Delay(ms)

			No. of Packets				
			100	200	300	400	500
		Protocols	End To End Delay(ms)				
No.of Nodes	25	AODV(cogns)	21.59	23.65	26.92	29.49	31.48
		DSR(cogns)	21.64	24.89	27.29	40.93	32.16
	50	AODV(cogns)	30	34.73	33.91	36	54.15
		DSR(cogns)	23.56	27.37	28.65	34.71	52.15
	75	AODV(cogns)	45.9	28.97	45.71	35.14	48
		DSR(cogns)	21.83	26.96	28.73	44.89	44.3
	100	AODV(cogns)	38.68	37.42	41.28	55.96	49.88
		DSR(cogns)	21.29	32.68	29.85	34.48	36.05

The above table 1, table 2, table 3 shows that the analysis of two different protocols with cognitive capabilites. The In table 1 it observes that the averagly the DSR with cogns has high packet delivery fraction, high Throughput and low delay as compare to AODV with cogns. The primary user when in no use that spectrum holes are fulfill by the secondary user applying various algorithm. The consideration of two different protocols with cognitive capabilities shows various results proved by the above experimental simulation results with energy level also high of DSR(cogns) tha n AODV(cogns).It gradually increases when the nodes are increases from 25 to 100 number of nodes as shown in figure 4.

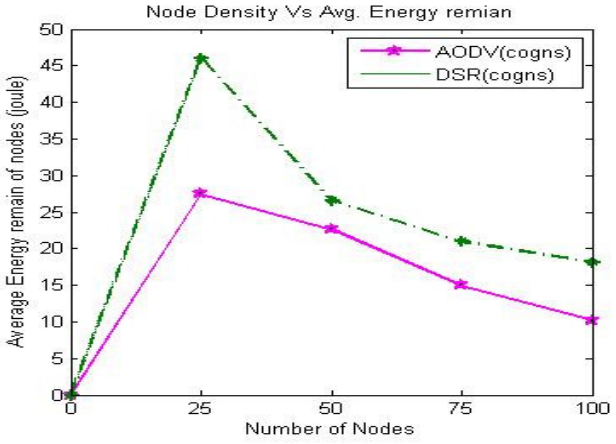

Fig. 4.Number of nodes vs Average Energy of nodes

5. Conclusion

In this paper the objective is to improve the scalability issue. To improve the scalability we consider the 25 to 100 sensor nodes for our experiment as node density. As observed that the increasing number of nodes may cause the reducing the performance of individual nodes in the network. The cognitive radio sensor networks which are the increasing network for the next generation wireless network also perform better in packet delivery ratio, throughput, and end2end delay with proper energy consumption of individual nodes, as per total energy by above equation. Here we consider the two routing protocol AODV and DSR with cognitive capabilities as AODV (cogns) and DSR (cogns) and observed that the DSR(cogns) perform better as compare to AODV(cogns) in parameter such as Throughput. They solve the complex NP-hard combinatorial optimization problem based on different application. The hands-off techniques from primary user to secondary user with available spectrum holes in the network occupied the secondary user for some duration of time and changing the route from primary user to secondary with efficiently. It solves and optimized different issues and challenges, which is the need of today era and solves the telecommunication problems.

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