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Energy Efficient Cluster Based Network Coding Algorithm (EECSNC)

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Abstract

Wireless sensor network (WSN) is a network that sense and monitor the environment. It also enables interaction among persons or computer. The sensor nodes monitor, collect data and transmit to base station by multi hopping. In real world WSN plays a significant unlimited variety of applications. The objective of this is to minimize end to end delay and maximize the lifetime of the network. The proposed model develops an algorithm Energy Efficient Cluster Based Network Coding Algorithm (EECSNC) that introduces group of techniques for the efficient use of energy for nodes in clusters. The technique involved in clustering of nodes, cluster head selection, end to end delay minimization, data compression and sleep and wakeup of nodes according to the usage of reducing the battery consumption. This EECSNC gives the better network efficiency for lifetime when comparing to other methods of algorithms. The simulation is verified using NS2 simulation tool and results are graphed for verification.

Key Words:WSN, EECSNC, clustering, end to end delay, sleep wakeup scheduling, network coding.

1. Introduction

In technological development of recent years wireless sensor network provides an efficient designs for most of the real world applications due to low cost and ability to acquire data irrespective of environmental harshness [1]. Wireless sensor networks (WSN) are widely being used in various fields such as medicine and health care, machine surveillance and preventive maintenance, precision agriculture, disaster relief applications, military applications and so on [2].

This wireless sensor networks is a collection of sensor nodes arranged in a pre-specified or random in the way of location which has to monitor. All nodes in network are capable of sensing, data gathering process and communicating with other nodes. It ease the data collecting process of environment where it is deployed [1][2][7]. The sensed informations are transmitted to base station via many intermediate nodes. So energy of nodes is consumed while transmitting the data. The main limitation of WSN is its limited battery power, because sensor nodes are very small in size so its battery capacity is small [5]. In most of the cases battery recharging or replenishment is not possible, so efficient energy utilization is the first important factor in WSN. End to end delay is another problem to minimize the energy constraint and maximize the life time of nodes [3][4][6].

In proposed model, nodes in the cluster collect the data and send it to cluster head (CH) which in turn aggregate the data that is redundant and highly correlated from all cluster members and transmits to the base station using single hop or multi-hop transmission. The relay node and cluster head selection based on the residual power and inter cluster hopping will increase the lifetime of the network [8][9]. Cluster head is changed according to their residual energy value. Energy Efficient Cluster Based Network Coding Algorithm (EECSNC) method is developed for wireless sensor network efficiency. In this EECSNC, data is compressed using encoding and decoding technique for energy efficient transmission. To avoid unnecessary on time of node, sleep mode for nodes are introduced using time scheduling. By continuously monitoring the node’s energy, dead nodes are predicted before transmitting data. Energy efficiency will improve the life time of network and end to end delay is minimized.

2. Literature Survey

Juan Luo et al (2015), focuses on minimizing energy consumption and maximizing of network lifetime for data relay in one-dimensional (1-D) queue network. Energy Saving via Opportunistic Routing (ENS_OR) algorithm is designed to ensure minimum power of cost during data relay and protect the nodes with relatively low residual energy. The objective of this opportunistic routing theory and multi hop decision is to optimize the network energy efficiently. This is done using differences between the sensor nodes in distance to sink and residual energy [22].

Trong-Thua Huynh et al (2016) propose a new distributed clustering approach to determining the best cluster head for each cluster by considering both energy consumption and end-to-end delay requirements. Next, we propose a new energy-cost function and a new end-to-end delay function for use in an inter-cluster routing algorithm. We present a multi-hop routing algorithm for use in disseminating sensing data from cluster heads to a sink at the minimum cost of energy subject to an end-to-end delay constraint. Delay-constrained energy multi-hop (DCEM) for solving the problem by considering the delay-energy trade-off in multi-hop routing between cluster heads [16].

HariPrabhat Gupta et al (2015), proposes Energy-efficient Homogeneous Clustering (EHC) technique in WSNs, which selects the CHs to create a connected backbone network. Route Optimization Technique (ROT) in clustered WSNs among obstacles that forms an energy-efficient path between the CHs selected by EHC technique and the sink. ROT uses Dijkstra's shortest path algorithm. Energy-efficient clustered WSNs are to prolong the lifetime of WSN [17].

Yimei Kang et al (2014), proposes a hybrid node scheduling, that reduces consumption of energy and failure rate based on Energy Efficient Chain (EEC). It includes sleep scheduling for rotational monitoring regions of interest in time-driven modes and wakeup scheduling for tracking emergency events in event-driven modes. The data can be successfully delivered to the sink rather than the absolute lifetime of the network [21].

Wang Ke (2016) proposes a novel energy aware hierarchical cluster-based (NEAHC) routing protocol with two goals to minimizing the total energy consumption and ensuring fairness of energy consumption between nodes. The energy consumption of communication between the CH and BS, relay node selection is not only based on residual energy but also fairness and finally next hop node selections are modeled [23].

Yanwen Wang et al (2015) modeled a Sleep Scheduling (SS) mechanism to manage energy of each node and are capable to prolong the lifetime of the entire network. In this paper a Software-Dened Network (SDN) is based on Sleep Scheduling algorithm SDN-ECCKN manages the energy of the network. There is no broadcasting between each two nodes, which are the main features of the traditional EC-CKN technique. The results of our SDN-ECCKN shows it advantages in an energy management, such as network lifetime, the number of live nodes and the number of solo nodes in the network [18].

Nikolaos A. Pantazis et al (2009) designed TDMA scheduling scheme mainly for energy efficiency and to reduce end to end transmission time from sensors to gateway. In order to construct an appropriate transmission that helps in achieving high levels of power conservation. Network connectivity is ensured by scheduling TDMA based wakeup intervals, which is used for propagating Wakeup messages, prior to data transmissions [24].

3. Proposed Model

EECSNC method is proposed in this paper to enhance the energy efficient cluster based on the network topology. The techniques for less energy consumption and minimization of end to end delay are detailed below.

1. Cluster Setup Technique

Clustering is one of the most efficient techniques in data forwarding and providing convenient framework for resource management. Nodes can be partitioned into a number of small groups called clusters for data aggregation. Each cluster has a coordinator, named as a cluster head and others are member nodes [8][9].

The cluster head aggregates the collected data and then send it to its base station. The cluster heads should be therefore changed several times during the lifetime of the sensor network in order to distribute the extra workload and energy consumption evenly. Thus hypothesis is that the geographical distribution of the cluster heads severely influences the overall energy consumption of the network, thus prolonging its lifetime [11][12].

The base station, in our case, is composed of a transceiver (also called a gateway node), base station software and a host computer [14]. In proposed model delay-constrained energy multi-hop (DCEM) approach is used for clustering.

Cluster Formation

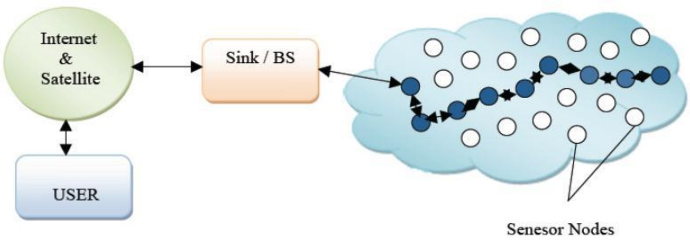

Figure 3.1: General Overview of Wireless Sensor Networks

Transmission energy depends on distance between nodes and number of bits while receiving energy depends on number of bits received. This can be calculated using following equations,

$$E_{transmitting} = (E_{elec} \times k) + (E_{amp} \times k \times d^2)$$
$$E_{receiving} = E_{elec} \times k$$

Where

E_{elec} is the energy being dissipated to run the transmitter

E_{amp} is the energy dissipation of the transmission amplifier

K is referred as length of the message in bits
d is referred as distance between transmitter and receiver

The sensor nodes sense and collect information in cluster and passes the collected information to its corresponding cluster head using distributed transmitted lines.

The cluster heads are selected based on mamdani's method fuzzy inference technique.

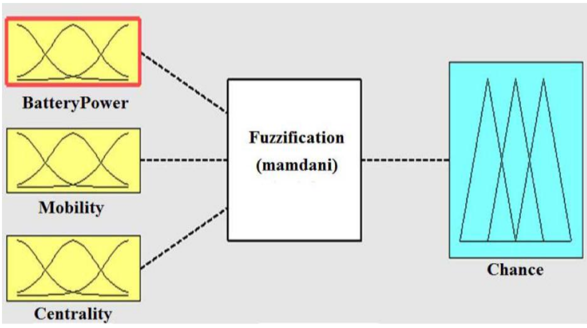

Figure 3.2: Mamdani's Method Fuzzy Inference Technique

If the location of base station is far from the field, communicating to the base station will consume a lot of cluster head's energy. If transmission time assigned to the CH becomes elapsed, the network starts searching for new CH.

After selection of cluster head, selected CH will send advertisement message to all nodes in cluster. While receiving message from cluster head, each node measure the distance from all the cluster heads. The distance is calculated based on Euclidean distance; thereby it forms the cluster head [14].

To avoid redundancy cluster head aggregates all information gathered. The cluster head must remain in active state, whether if sensor member nodes can go to sleep mode from time to time.

The process of data sending and operation of re-clustering (if necessary) continues for many cycles until the death of all nodes. If size of cluster becomes smaller than pre-defined threshold, the cluster merges with the neighboring clusters. The number of cluster nodes decreases by death of nodes, it leads to decrease in number of clusters. Then the amount of information also decreases with fewer nodes left in physical area [15].

DCEM Algorithm

DCEM is a distributed clustering scheme [16] that operates in consecutive rounds, each round which is separated into two phases: Network organization and data transmission. The first stage task is to establish a cluster network topology and build a multi-hop route. The second stage task is to transmit data from source sensors to the sink node via cluster head-based multi-hop forwarding.

This algorithm starts with “Hello” broadcasting ADV message to the neighbor discovery phase, which is initiated by sink node. This message will provide the information of distance between sensor nodes and sink node. Each node waits for an amount of time $\tau = \frac{1}{E}$ before ADV message and compares it energy level with the energy level of the all other nodes. If a sensor node has less energy, it will cancel its timer and decide to be a cluster member. If two or more nodes have same energy level then it is said to be a trade-off for energy and delay (TED). The values of α and β lies in the range of [0,1] and α+β=0,then

$$TED_i = \left(\frac{E_i}{E_{total}}\right)^{\alpha} + \left(\frac{1}{d_{(i,s)}}\right)^{\beta}$$

Where

E_i Remaining energy of cluster head candidate i

E_{total} Cumulative energy of other cluster head candidates received from ADV messages

$d_{(i,s)}$ Distance from cluster head candidate i to the sink

After cluster setup procedure is finished, all cluster heads broadcast time division multiple access (TDMA) message to allocate time slots to their cluster members. The cluster head is selected by calculating the terms such as energy, end to end delay, hop-count, transmission energy and distance to sink.

Relay Node Selection

More cluster heads are elected to ensure that the cluster heads can form a connected network. Non-Cluster Head sensors (NCH) are referred as Gateway CH (GCH), if two or more neighboring initial CHs are not connected. Preference is given to the NCHs which have higher amount of residual energy and maximum number of neighboring CHs. NCH has maximum five neighboring ICHs. The randomized back-off delay is estimated to resolve the advertisement contention for selecting GCHs [17]. The randomized back-off delay for a NCH is denoted by

$$\text{delay}_{\boldsymbol{2i}} = \left(\frac{E_{init} - E_i}{E_{init}} + \frac{5 - |n_i|}{5} + R\right) \times |n_i| T$$

The cluster member node with high residual energy can be selected as a relay node or gateway node. The relay node is selected using route optimization technique in clustered WSNs among obstacles using Dijkstra’s shortest path algorithm.

2. End to End Delay

The delay of a packet experienced when traversing between node i to node j called link delay D(i,j). It is defined that link delay includes the queuing delay dQ per node, transmission delay dT and propagation delay dP, given as,

$$\mathrm{D(i,j)} = (\mathrm{dQ} + \mathrm{dT} + \mathrm{dP})$$

Here,

Transmission delay, dT = I/ ψ and

Propagation delay, dP = dij/ γ;

Where

I packet size (bits)

Ψ link bandwidth (bps)

dij length of physical link from cluster head I to cluster head j

γ propagation speed in medium(m/s)

The queuing delay dQ can be calculated using rules related to queue theory. The nodal queue is considered of the type M/M/1, in this type of queue, the input is of poisson type, the output is an exponential random variable and the amount of service is 1.

Queuing delay, dQ =n1/ μ – λ

Where,

μ service rate, which is exponential stochastic variable

λ rate of entry for new packet, which is poisson stochastic variable.

An end to end delay is denoted by $\mathrm{D}_{ete}(x, s)$, which is time elapsed between the departure of a collected data packet from a source x and its arrival at sink s. By definition end to end delay of route from cluster head x to sink node s, given by,

$$\mathrm{D}_{ete}(x,s) = \sum_{i,j\in\{x,U,s\}} D(i,j)$$

$$= \sum_{i,j\in\{x,U,s\}} \left(\left(\frac{1}{\mu - \lambda} \right) + \frac{1}{\Psi} + \frac{dij}{\gamma} \right)$$

Where,

Ψ, β and γ are constant, that are assumed to be same for all cluster head. $\gamma$is propagation speed in the medium(m/s) and U is set of intermediate nodes from cluster head x to sinks [16].

Calculation Link and Route Cost

The definition of cost function for a link between cluster head nodes i and j is,

$$cost_{ij} = \sum_{\ominus \in \{Rx,Fu,Tx\}} E_{\ominus}^{ij} + \rho \times cost\left(E_{Re}^{i}\right)$$
$$= \left(E_{Rx}^{i} + E_{Fu}^{i} + E_{Tx}^{ij}\right) + \rho \times cost(E_{Re}^{i})$$

Where,

E_{Rx}^{i} Energy that cluster head i spends receiving data from members

E_{Fu}^{i} Energy that cluster head I spend in fusing data from members

E_{Tx}^{ij} Energy spends transmitting data from cluster head i to cluster head j

ρ Nodal remaining factor

$cost(E_{Re}^{i})$ Cost function that takes into consideration the remaining energy of sensors for the energy balance among sensors. Therefore, this cost(E_{Re}^{i}) is the cost function based on the principle in which small changes in remaining energy of sensors can results in large changes in value of cost function [16]. Then exponential function f(x) = exp $(1/x^2)$ is the type of function that can satisfy this principle when replacing x by E_{Re}^{i}, then cost is

$$cost\left(E_{Re}^{i}\right) = exp^{\left(\frac{1}{(E_{Re}^{i})^2}\right)}$$

Inter Cluster Multihop Routing Algorithm

The problem is finding the lowest cost route for energy efficient from a cluster head node x to sink node s, such that the end to end delay cannot exceed a delay constrained Δ. The constrained minimization problem is,

$$\min_{R_k \epsilon R'(x,s)} cost(R_k)$$

Where,

R_k k th route

$R'(x,s)$ set of routes from cluster head node x to s

The end to end delay is bounded by Δ, given by,

$$\mathrm{D}_{ete}\,(R_k) \leq \Delta, R_k \, \epsilon R'(x,s)$$

For consideration of above problem, algorithm is shown in algorithm 1 to find k-least cost routes that meet the end to end delay constraint. This algorithm calculates the cost for each link (line 3) from cluster head I to sink node j based on the cost function. After that it calculates the number of probable routes from cluster head x to sink s using depth first search (DFS) algorithm (line 4). This algorithm uses the k- shortest path to find k-least cost route in line 5. After the determination of least-cost route R_k(initial k=1), it calculates the end to end delay and $D_{ete}(R_k)$ for route using equation. Then it checks whether end to end delay can satisfy specified threshold value Δ or not, if so (R_k) is chosen (SeR lines 9 and 10), and if not, (R_k) will be removed and added to NoSa (lines 7 and 13). Line 7 can remove least cost routes that do not satisfy the delay bound Δ [16].

Algorithm

1:SeR=⊖;

SeR is the selected route to disseminate data from cluster head x to the sink s.

2:NoSa=⊖;

NoSa is set of routes that does not satisfy the delay bound Δ.

3: Calculate$cost_{ij}$, ∀i, j ∈ C;

C is set of cluster head nodes, j can be sink.

4:CalculateK(x,s);

K(x,s) is number of probable routes from cluster head node x to the sink s.

5:Find k-least cost routes k-SR(x,s,k);

k-SR(x,s,k) are k least cost routes from cluster head x to sink s.

6:while(k≠K(x,s))do initial k =1.

7:R_k=k-SR(x,s,k)\NoSa;

R_k is the kth least-cost route.

8: Calculate $D_{ete}(R_k)$ from (equ);

9: if $D_{ete}(R_k) \leq \Delta$ then

10: SeR= R_k;

11: break;

12: else

13: NoSa = NoSa∪R_k;

14: k = k + 1;

15: end if

16: end while

17: Return SeR;

3. Sleep-Wake up Technique

The nodes in the same cluster can sense the same information and send to cluster head, at that time cluster head aggregate the data and reduce redundancy of data. This process will consume some amount of energy for same information transmitting work. To prevent this problem the sleep wakeup scheduling of nodes can be introduced. Nodes are initially in sleeping state after preset time it wakeup and form network [18]-[20].

Cyclical Node Sleeping schedule

This method involves two parts: an initialization and sleeping scheduling mechanisms [21].

Initialization Mechanism

Nodes in network usually in sleeping state, after completion of preset time t_0 node enters into initialization state and receives messages from other nodes. In initializing state, nodes in gridA_j, begin to send a probing messages to all other nodes in 0 < j < M. $t_{start}(i)$ is the time of ith node start sending probing message.

Sleeping Mechanism

In time driven method, only one node is in wake-up state and others are kept sleep, in order to extend life time of network. The scheduling wakeup nodes one after the other but it may sometimes leads to some area not been monitored. For this, a node cannot be switched to sleeping state when it collects data. The working time of a node is longer than collection of data, this data acquisition cycle is, $T_{collect}$, the idle time during each $T_{collect}$ is t_{idle}.

$$T_{collect} = t_{collect} + t_{idle}$$
$$T_{schedule}(j) = t_{work}(j) + t_{sleep}(j)$$

Enhancing Robustness to Partial Occlusion

For emergency incidents, the WSN deployed is to report the situation to BS. If absorbed value is not matching with threshold value it sends signal to alarm the BS as soon as possible. To avoid wrong grid node wakeup by mistake, assisting message has partition ID. Wakeup scheduling increases energy consumption than sleep scheduling. But it helps to get accurate information of region. After finding the redundant nodes, they were going to sleeping state [21].

4. Data Coding Technique

In WSN, the collected data from all sensor nodes are aggregated and framed then send to the sink node for transmission. The large amount of data causes high energy consumption so it will reduce the lifetime of the network. To protect energy consumption of nodes data compression is introduced. Network coding is a technique which allows the intermediate nodes to encode data packets received from its neighbouring nodes in a network [25][26].

Encoding Operation

A node, that wants to transmit encoded packets, chooses a sequence of coefficients q = (q1, q2...qn), called encoding vector. A set of packets G_i(1,2,3,4,…..n) can be compressed or encoded into a single packet at intermediate node. These coded data is transmitted and decoded at receiver side by using encoding vector. The encoded output packet is given as,

$$Y = \sum_{t=1}^{n} q_i G_i, \quad q_i \epsilon GF(2^8)$$

Decoding Operation:

A receiver retrieved original packets from coded packets by using linear equations. The encoding vector is received by receiver sensor nodes with encoded data packets. The symbols Y^j and q_i denote the information symbol and the coding vector for the j th received packet respectively. A node solves the following set of linear equations with m equations and n unknowns for decoding operation.

$$Y^j = \sum_{t=1}^{n} q_i{}^j G_i, \quad j = 1,2, \ldots . m$$

At least n linearly independent coded packets must be received by the recipients for proper decode of the original packets. The only unknown, G_i contains the original packets that are transmitted in the network. The n number of original packets can be retrieved by solving the linear system in above equation after getting n linearly independent packets.

Algorithm 1

Process of data packets at node inside the network coding layer require: Data Packet transmission and reception starts, received Data Packets inserted into the Recv Data Queue ()

Ensure: Encoded DataPacket transmitted or discarded
1. Pick a DataPacket Pi from RecvDataQueue (Pi)
2. If DataPacket Pi ∈ForwardDataPacketSet(Pi) exit;
3. If Node n ∈EncoderNodeSet () continue;
4. If native (Pi) then
5. CN =ExorEncoding ();
6. Node n transmits CN (coded Data Packets) to Sink
7. Insert the processed DataPacket Pi to ForwardDataPacketSet ();
8. Else
9 Discard (Pi);
10 end if
11. Else
12. Node n acts as relay and transmits the DataPacket Pi to the Sink;
13. End if
14. endif
15. If (RecvDataQueue()= empty)
16. goto step 1;
17. else exit;
18. endif

Algorithm 2

ExorEncoding() : Encoding algorithm

Require: A received queue RecvdataQueue() and a sensed queue SenstheQueue()is maintained at an encoder node

Ensure: Generation of network coded packet CN

1. If SenstheQueue() is not empty then continue;
2. Pick a packet Pi from head of the RecvdataQueue();
3. Pick a packet Pj from head of the SenstheQueue();
4. CN = Pi ⊕Pj ;
5. else
6. Pick next packet Pi+1 from the RecvdataQueue();
7. CN = Pi ⊕ Pi+1;
10. endif;
11. return CN

4. Result and Discussion

The proposed model is simulated using ns2 simulation tool. The version used is ns2.34 and this tool is mainly applicable for the simulations of MANET, VANET, and WSN and so forth. The proposed frame is evaluated to study the efficiency of cluster based on the network. The cluster based network model in ns2 simulator has sink node, cluster head and member nodes as shown in figure 3,

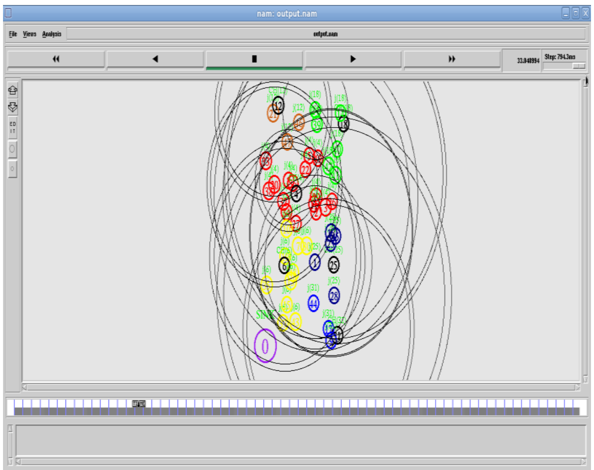

Figure 4.1: Cluster Structure In Ns2 Simulator

The energy, overhead, packet loss, PDR, throughput, average delay and network lifetime are studied for EECSNC and ENS-OR models. The graph of these metric terms is shown below.

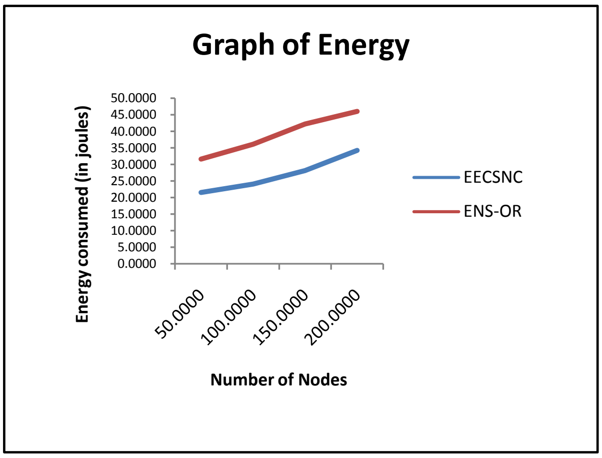

Figure 4.2:Comparison on Energy Consumption

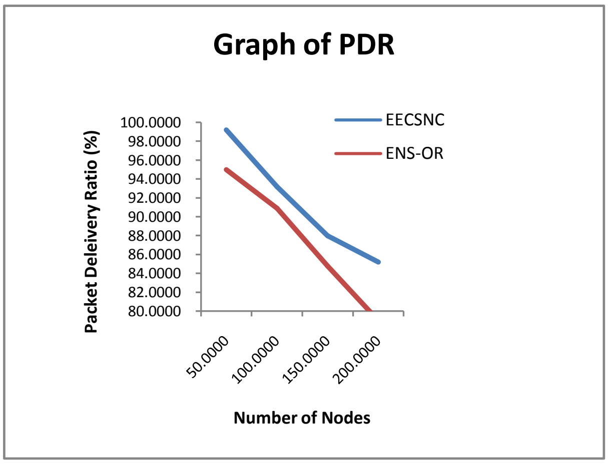

Figure 4.3: Comparison on Packet Delivery Ratio

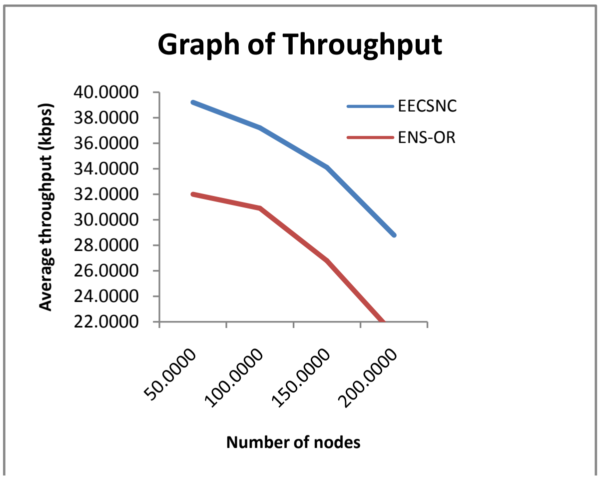

Figure 4.4: Comparison on Average Throughput

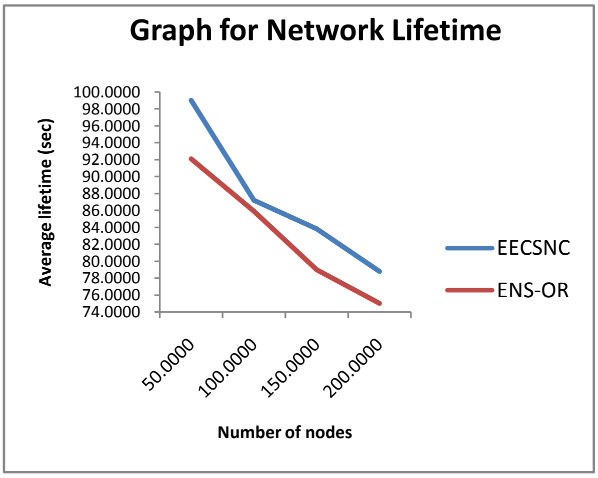

Figure 4.5: Comparison on Average Network Lifetime

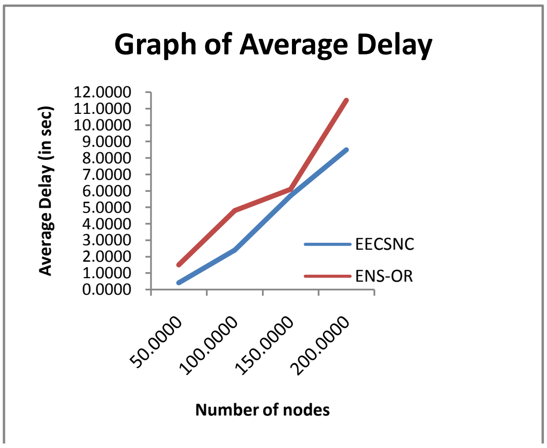

Figure 4.6: Comparison on Average Delay

The comparison of existing ENS-OR and proposed EECSNC output values are tabulated as,

Number of Nodes	Energy consumed (joules)		packet loss (%)		Network lifetime (sec)		PDR (%)		Throughput (kbps)		Average Delay (sec)		Overhead (bits)	
	EECSNC	ENS-OR	EECSNC	ENS-OR	EECSNC	ENS-OR	EECSNC	ENS-OR	EECSNC	ENS-OR	EECSNC	ENS-OR	EECSNC	ENS-OR
50	21.5	31.6	4.8	9.0	99.0	92.1	99.2	95.0	39.2	32.0	0.4	1.5	2.5	5.7
100	24.0	36.1	13.9	15.2	87.2	85.9	93.2	90.9	37.2	30.9	2.4	4.8	8.5	10.4
150	28.1	42.2	17.8	21.2	83.8	79.0	88.0	84.8	34.1	26.8	5.7	6.1	12.5	14.4
200	34.2	46.0	22.8	24.8	78.8	75.0	85.2	79.0	28.8	21.0	8.5	11.5	15.3	18.4

Figure 4.7: Comparison Chart

5. Conclusion

WSN based on clustering, sleep wakeup techniques, end to end delay calculation and data network coding for data compression is simulated. The proposed EECSNC model is compared with existing ENS-OR methodology. The result of the ns2 simulator shows that the EECSNC is more efficient than the existing method. The conclusion of approach in clustering, cluster head selection, sleep wakeup scheduling and coding of data will improve the network life time and reduce the end to end delays which are objective of proposed methodology.

References

[1] Swati Sharma, Dr. Pradeep Mittal, Wireless Sensor Networks: Architecture, Protocols, International Journal of Advanced Research in Computer Science and Software Engineering 3 (1) (2013), 303-308.

[2] Shio Kumar Singh, Singh M.P., Singh D.K., Routing Protocols in Wireless Sensor Networks A Survey, International Journal of Computer Science & Engineering Survey 1 (2) (2010), 63-83.

[3] Zahra Rezaei, ShimaMobininejad, Energy Saving in Wireless Sensor Networks, International Journal of Computer Science & Engineering Survey 3 (1) (2012), 23-37.

[4] MohitSaini, Rakesh Kumar Saini, Solution of Energy-Efficiency of sensor nodes in Wireless sensor Networks, International Journal of Advanced Research in Computer Science and Software Engineering 3 (5) (2013), 353-357.

[5] Rajan Kumar, Naveen Prakash, Energy Efficient Approach for Wireless Sensor Network, International Journal of Advanced Research in Computer Science and Software Engineering 3 (6) (2013), 287-294.

[6] NattarKannan K., Paramasivan B., Enhancing Energy Efficiency in Wireless Sensor Networks Using Optimal Gradient Routing Protocol, International Journal of Computer and Communication Engineering 3 (6) (2014), 408-412.

[7] Abdullah I., Alhasanat, Ahmad Ali Alhasanat, Khitam M. Alatoun, AwsAlQaisi, Data Gathering in Wireless Sensor Networks Using Intermediate Nodes, International Journal of Computer Networks & Communications 7 (1) (2015), 113-124.

[8] Amjad K., Abu- Baker, Energy Efficient Routing in Cluster-Based Wireless Sensor Networks: Optimization and Analysis, Jordan Journal of Electrical Engineering 2 (2) (2016), 146-159.

[9] AnupPawar, Divya K.V., Secure and Efficient Data Transmission in Cluster based Wireless Sensor Network, International Journal of Computer Science and Mobile Computing 4 (8) (2015), 132-142.

[10] Jin-Shyan Lee, Wei-Liang Cheng, Fuzzy-Logic-Based Clustering Approach for Wireless Sensor Networks Using Energy Predication, IEEE Sensors Journal 12 (9) (2012), 2891-2897.

[11] Kiran Maraiya, Kamal Kant, Nitin Gupta, Efficient Cluster Head Selection Scheme for Data Aggregation in Wireless Sensor Network, International Journal of Computer Applications 23 (9) (2011), 10-18.

[12] Manjusha M.S., Kannammal K.E., Efficient Cluster Head Selection Method For Wireless Sensor Network, International Journal of Computational Engineering Research 4 (2) (2014), 43-49.

[13] Santar Pal Singh, Sharma S.C., Cluster Based Routing Algorithms for Wireless Sensor Networks, International Journal of Engineering & Technology Innovations 1 (4) (2014), 1-8.

[14] Yogesh Kumar Fulara, Some Aspects Of Wireless Sensor Networks, International Journal on AdHoc Networking Systems 5 (1) (2015), 15-24.

[15] Mohamed Eshaftri, Ahmed Y. Al-Dubai, ImedRomdhani, MuneerBeniYassien, A New Energy Efficient Cluster based Protocol for Wireless Sensor Networks, Proceedings of the Federated Conference on Computer Science and Information Systems 5 (2015), 1209–1214.

[16] Trong-Thua Huynh, Anh-Vu Dinh-Duc, Cong-Hung Tran, Delay-Constrained Energy-Efficient Cluster-based Multi-Hop Routing in Wireless Sensor Networks, Journal Of Communications And Networks 18 (4) (2016), 580-588.

[17] HariPrabhat Gupta, Rao S.V., Amit Kumar Yadav, TanimaDutta, Geographic Routing in Clustered Wireless Sensor Networks Among Obstacles, IEEE Sensors Journal 15 (5) (2015), 2984-2992.

[18] Yanwen Wang, Hainan Chen, Xiaoling Wu, Lei Shu, An energy-efficient SDN based sleep scheduling algorithm for WSNs, Journal of Network and Computer Applications (2015), 1-18.

[19] Pradeebaa G., Nandita Lavanis, Network Lifetime Improvement Using Routing Algorithm with Sleep Mode in Wireless Sensor, IEEE conference on WiSPNET (2016), 1572-1575.

[20] Naveen K.P., Anurag Kumar, Relay Selection for Geographical Forwarding in Sleep-Wake Cycling Wireless Sensor Networks, IEEE Transactions On Mobile Computing 12 (3) (2013), 475-488.

[21] Yimei Kang, Bin Hu, Yi Ding, Jingdong Tan, A Hybrid Node Scheduling Approach Based on Energy Efficient Chain Routing for WSN, Advances in Mechanical Engineering (2014), 1-12.

[22] Juan Luo, Jinyu Hu, Di Wu, Renfa Li, Opportunistic Routing Algorithm for Relay Node Selection in Wireless Sensor Networks, IEEE Transactions On Industrial Informatics 11 (1) (2015), 112-121.

[23] Wang Ke, OuYangrui, Ji Hong, Zhang Heli, Li Xi, Energy aware hierarchical cluster-based routing protocol for WSNs, The

Journal of China Universities of Posts and Telecommunications 23 (4) (2016), 46-52.

[24] Nikolaos A. Pantazis, Dimitrios J. Vergados, Dimitrios D. Vergados, Christos Douligeris, Energy efficiency in wireless sensor networks using sleep mode TDMA scheduling, Ad Hoc Networks 7 (2009), 322–343.

[25] Ranganathan Vidhyapriya, Ponnusamy Vanathi, Energy Efficient Data Compression in Wireless Sensor Networks, The International Arab Journal of Information Technology 6 (3) (2009), 297- 303.

[26] Sughasiny M., Reliability Enhancement in Wireless Sensor Network using EARQ Protocol, International Journal of Advanced Research in Computer Science and Software Engineering 5 (12) (2015), 446-454.

[27] RAJESH, M. "A SYSTEMATIC REVIEW OF CLOUD SECURITY CHALLENGES IN HIGHER EDUCATION." The Online Journal of Distance Education and e- Learning 5.4 (2017): 1.

[28] Rajesh, M., and J. M. Gnanasekar. "Protected Routing in Wireless Sensor Networks: A study on Aimed at Circulation." Computer Engineering and Intelligent Systems 6.8: 24-26.

[29] Rajesh, M., and J. M. Gnanasekar. "Congestion control in heterogeneous WANET using FRCC." Journal of Chemical and Pharmaceutical Sciences ISSN 974 (2015): 2115.

[30] Rajesh, M., and J. M. Gnanasekar. "Hop-by-hop Channel-Alert Routing to Congestion Control in Wireless Sensor Networks." Control Theory and Informatics 5.4 (2015): 1-11.

[31] Rajesh, M., and J. M. Gnanasekar. "Multiple-Client Information Administration via Forceful Database Prototype Design (FDPD)." IJRESTS 1.1 (2015): 1-6.

[32] Rajesh, M. "Control Plan transmit to Congestion Control for AdHoc Networks." Universal Journal of Management & Information Technology (UJMIT) 1 (2016): 8-11.

[33] Rajesh, M., and J. M. Gnanasekar. "Consistently neighbor detection for MANET." Communication and Electronics Systems (ICCES), International Conference on. IEEE, 2016.