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EECRT: Efficient Energy Conservation Routing Technique for WSN with Node Mobility

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Abstract: In recent years, the main research challenge is the issues in wireless sensor networks (WSN). Energy conservation and coverage of the sensor nodes considered as major metrics for the long time survival of sensor networks. In this paper work, proposed an efficient energy conservation routing technique for WSN with node mobility (movable sensor nodes). Furthermore, in this proposed routing technique, two algorithms developed. Namely, Selectively Turning ON/OFF the Sensors (STOS) and Ongoing Routing Table (ORT). Moreover, in STOS, the sensor nodes divided into several sets of scheduling modes (active, standby, hibernate) and let them to perform alternatively, by which conserves extra energy. Consequently, in ORT Ongoing (up to date) data maintained to update and know the detailed information regarding mobile sensor nodes including the factors such as hop count, residual energy (current energy level), threshold energy with the status of the sensor nodes. In connection with ORT, the next sensor node will identified for forwarding the information. Herein concentrated on dynamic network, where all the deployed sensor nodes are in-mobile except base station (BS) or sink node. Nevertheless, the absence or failure of BS, nearest mobile sensor node to the BS will act as BS. Provided, Simulation result shows that the proposed technique will be enough competent for maximizing the energy conservation.

Key words: Wireless・Sensor Networks (WSN)・Ongoing Routing Table (ORT)・Energy Conservation・Coverage・Mobile Sensor Node (MSN)

INTRODUCTION

Advances in wireless sensor networks becomes a major key technology for several applications such as Security surveillance, intelligent home, animal health and behavior monitoring, weather monitoring, forest fire detection, structure health monitoring and Industrial process control [1-3] etc. Consequently, the deployments of autonomous sensor nodes which may work co-operatively for completing a specific set of tasks are maximum in WSN. Furthermore, the energy conservation considered as major important parameter by reason of the sensor nodes having limited battery power, where it's used to sense, communicate and data process as shown in Figure 1. Nevertheless, from the sensor network, the sensed data by the mobile sensor node will transfer to a sink node (BS), where it will send to the ending user via server.

The subsequent units are the parts of the general wireless sensor network. Moreover, it consists of five major units. Namely, sensor unit, processor unit, transceiver unit, power supply unit and power generator unit. Herein, will concentrate on first four units in proposed work.

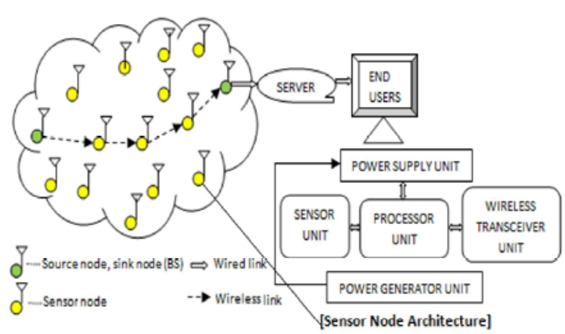

Fig. 1: General WSN

Sensor Unit: Sensor unit consists of several sensor nodes, also known as a mote which will employ to perform some sensing, processing, gathering information and communicating with further sensor nodes in the network.

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Processor Unit: Processor unit used to process data, perform particular tasks which comprises the functionality control of other components in the sensor network. Usually microcontroller prefer this processor unit, on account of its lower power consumption and ease of adaptation through other devices compared to further microprocessors, FPGAs, Digital signal processors and ASIC.

Transceiver Unit: A single device that is having the functionality of both transmitter and receiver over a wireless channel called as transceiver. Typically, WSN tend to use ISM band, free license frequencies (433MHz, 915MHz & 2.4GHz) for their communications.

Power Supply Unit: WSNs are tiny electronic devices. Consequently, they have a limited power source which is lesser than 0.5 to 2 Amps and 1.2 to 3.7 Volts.

To design a high-quality protocol for wireless sensor networks, mandatory to understand the metrics that relevant to the sensor applications. Finally, the following metrics used for evaluating the network.

Estimation Constraints: The WSN analyzed using several constraints. The following five metrics proposed to evaluate the entire network.

Power Consumption: Due to the miniature in nature, the energy carried by the sensor nodes are less. When used in border surveillance and harsh environment applications, enormous number of sensors deployed. Consequently, it is unfeasible to replace the failed sensor. Therefore, reduction of power consumption is a major design which helps to maximize the network lifetime.

Fault Tolerance: Sensor nodes are easily prone to failures, due to the limited battery power, deployment of sensors in rugged environments. Hence, an alternative arrangement must make with additional energy, less traffic.

Scalability: For several applications such as disaster recovery and border surveillance massive amount of sensors nodes used for the deployment. Moreover, the designed network sensors should be scalable for different size of networks.

Coverage: Sensor nodes have limited sensing range (radio). Nevertheless, to scale up the sensor network, the coverage of the network might be excellent with low latency. Hence, herein WSN excellent coverage is a key parameter.

Connectivity: Though every sensor node is ready to connect with the base station via multi hops, therefore, to achieve better throughput the dropped packets in a network should be the minimum. While designing an efficient sensor network, it's worthwhile to possess the coverage metric.

To address the issues mentioned above, an efficient energy conservation scheduling technique proposed. Moreover this novel routing protocol which develops the STOS (Selectively Turn ON Sensors) and ORT (Ongoing Routing Table) algorithms based on threshold energy, residual energy and hop count.

The rest of this paper organized as follows. In section II related work presented. Section III outlined the proposed network model. In section IV proposed EECRT implemented in detail. Performance evaluation of the network model analyzed in section V. Finally concluding remarks with possible future work provided in section VI.

Related Work: In WSN many experts addressed Energy efficiency as novel protocol design for duty cycling [4], Radio sleep mode optimization protocols [5, 6] and efficient routing algorithms [7]. Static (fixed) sensor nodes design is common because dynamic (mobile) sensor nodes consume additional energy. Furthermore, from diverse analysis [8-10], Mobile sensor nodes designs are useful for the real time systems to deploy sensor nodes in the sensor network for performing the specific tasks. However, many deployment methods proposed to maximize the lifespan of a wireless sensor network [9, 10].

Though several existing work in WSNs rooted in energy efficiency proposed [11-14], it shows that numerous scheduling sets developed for the same node. Hence it reduces the potential network lifetime with poor tracking capability of sensor node. Moreover, an energy-efficient integrated LEACH algorithm proposed in [15]. Herein whose residual energy is greater than the threshold energy are in ON state and further sensor nodes are in OFF state. Nevertheless, sensor node coverage due to the nature of static network is limited. Consequently, under sensor network topology, sensor networks with moving element developed in [16-18].

To achieve balanced usage of energy, mobile BS and mobile sensors developed in several papers. The authors in [19] proposed Reliable scheduling in terms of the network lifetime, QoS separation, data delivery possibility, system competence, energy consumption and consistency[20].

In [21], the authors proposed a distributed geographic K-any cast routing (GKAR) technique which effectively reduces the entire period and the communication overhead while finding K destinations. Moreover, in [22] the authors describes a mixture of scheduling protocols for radiation monitoring applications which shows the competent performance contrast to previous protocols. Provided, in [23] the authors developed an algorithm named Maximum Connected Load-balancing Cover Tree (MCLCT) which enriches the connectivity with proper coverage tends to balance the energy consumption among all the nodes. Furthermore, Duty cycled WSNs achieve enhanced energy efficiency for data diffusion explained in [24]. Nevertheless, in [25], watchdog optimization conserves energy in an efficient manner with improved reliability in WSNs.

A key idea to conserve maximum energy is, to turn OFF the devices when they are not in use [11-13]. Furthermore, proposed technique scheduled the unused mobile sensor nodes (MSN), to be in hibernate mode and selectively turn ON/OFF the sensors (STOS) derived from routing path. Moreover, Ongoing Routing Table (ORT) will intimate the routing path where the sensors to route. Nevertheless, the coverage and connectivity of the mobile sensor nodes would be efficient, with less power consumption which helps to maximize the network life time.

Network Model: In the proposed network, for the radio propagation model simulations preferred using two-ray ground path loss model as shown in Figure 2. Moreover, the calculated total energy from the addition of line of sight (E_{LOS}) and the ground energy (E_{GND}) referred as follows;

$$E_{TOT} = E_{LOS} + E_{GND} \quad (1)$$

and

$$E_{TOT(d)} \approx \frac{2E_i\, d 2\pi\, h_{Tr} h_{Rr}}{\lambda d^2} \quad (2)$$

The two-ray model consists of both direct path and the ground reflection path [36,37].

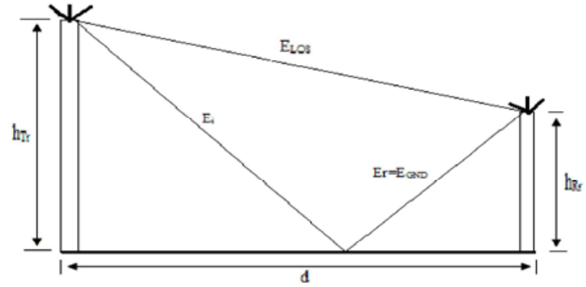

Fig 2: Radio propagation model for two- ray ground

The transmitting node and the receiving node separated using the distance'd'. If the distance'd' is less than the threshold energy(E_{th}) then the free-space propagation model used. Otherwise two-ray ground propagation model used. Consequently, for transmitting 'm'-bit message at a distance (d), the energy consumption is given by,

$$E_{Tr}(m, d) = E_{dev} m + \epsilon_{amp}\ m d^2 \quad (3)$$

Device energy, E_{dev} depends on factors such as modulation, filtering, coding of digital signal and signal spreading, whereas the amplifier energy $\in_{amp,}$ depends on the receiver distance and the bit-error rate.

Energy consumption for receiving 'm'-bit message is,

$$E_{Rr}(m) = E_{dev} m \quad (4)$$

Proposed Efficient Energy Conservation Routing Technique (Eecrt): To overcome the issues in previous methods, EECRT put forward with the subsequent steps:

(a) Using ORT (Ongoing Routing Table) have a close monitor on mobile sensor nodes with its residual energy (E_{res}) Whose E_{res} is greater than threshold energy E_{th}, to avoid unnecessary transitions between active and inactive nodes.
(b) Both hop count (HC=1(active); HC=2(standby); HC>2(hibernate)) and energy level (if Residual energy is greater than threshold energy (E_{res}>E_{th}) considered for selecting the next node for data transmission. With the intention that balanced distribution of energy consumption maintained throughout the network and can achieve low latency with enhanced network energy efficiency.
(c) By using mobile sensor nodes, enhanced coverage will achieve, with increased scalability for large-scale sensor networks

(d) Consequently, Random deployment of mobile sensor nodes with STOS (Selectively Turn ON/OFF the Sensors) algorithm used in data transmission. Furthermore, using this method based on the requirement (ref. with ORT) few sensor nodes will turn on, others are in standby or in hibernate mode. Hence, effective energy conservation obtained which prolongs the network lifetime.

(e) Absence/Failure of BS (sink node) altered as a result of few mobile sensor nodes (MSNs) which is closer to sink node, further improves the efficiency of the network with excellent connectivity.

Implementation of STOS:In this algorithm design, sensor nodes turned ON/OFF selectively according to the statistics of observed event. As a result, maximum energy conserved efficiently, to prolong the network lifetime. Table 1 shows the various power saving modes (PSM) scenario of proposed network. Namely: 1) Active mode (Whose nodes hop count 'HC=1') 2) Standby mode (Whose nodes 'HC=2') 3) Hibernate mode (whose nodes hop count 'HC>2').

Table 1: PSM Scenario for EECRT

Power Saving Modes	Processor Unit	Sensor Unit	Wireless Transceiver Unit	Indicated Color
Active	Active	Sense	Tr/Rr	Blue
Standby	Sleep	ON	OFF	Gray
Hibernate	Sleep	OFF	OFF	Black

The proposed algorithm STOS design procedure explained in detail, through EECRT design flow diagram shown in Figure 3.

ORT Algorithm Design Description: In EECRT, each MSN (Mobile Sensor Node) maintains an ORT (Ongoing Routing Table) for their efficient data transmission. Nevertheless, the Design procedure of ORT Algorithm sequenced as follows;

- The ORT contains the ID of source node, ID and position of current node, % of available energy, path direction of the BS, Hop count, destination ID, distance between (shortest) MSN and path cost.
- Furthermore, all time, the ORT updates their current information.
- Consequently, reference with ORT all the MSN in the EECRT sensor network communicate effectively.
- Moreover, from anywhere, the status of sensor node will obtain and fetch the ORT updated information from the network, through base station and server.
- Herein, next hop neighbor (receiver) node probability for each sensor node calculated in ORT as follows;

$$P_N = P_{cost} \times \frac{HC_{current} - HC_{neighbour}}{HC_{current}} + P_d \times \Delta d \times E_{res}^{P} \quad (5)$$

Where P_N is the probability of next hop neighbor (receiver) node, $HC_{current}$ is the current node cost, P_d is the path direction towards BS, Δd is the distance between two sensor nodes.

- Finally, the path cost of the two sensors x and y defined;

$$C_{x,y} = \frac{d_{xy}^{3}}{E_{res}^{y}} \quad (6)$$

Where, $C_{x,y}$ is the path cost of transmitting a message from node x to node y directly, d_{xy} is the distance between node x and node y, E_{res}^{y} is the residual energy in the battery of node y.

The Table 2 shows the entire notations with descriptions of proposed EECRT[26-30].

Table 2: EECRT Notations and Descriptions

Notations	Descriptions
E_{TOT}	Total Energy
E_{GND}	Ground Energy
E_{LOS}	Line of Sight Energy
h_{Tr}	Transmitter height
H_{Rr}	Receiver height
E_{th}	Threshold Energy
E_{res}	Residual Energy
E_{dev}	Device energy
$\in$ amp	Amplifier energy
d	Distance between transmitting and receiving nodes
$E_{Tr}(m,d)$	Energy consumption for transmitting 'm'-bit message at a distance (d)
$E_{Rr}(m)$	Energy consumption for receiving 'm'-bit message
HC	Hop Count
SD	Distance between sensors
V_{supply}	Supply voltage

Performance Evaluation: To evaluate the performance of EECRT, Network Simulator 2 (NS2) used [31-33]. Moreover, this is an incredibly effective, fast-discrete event simulator for simulating hybrid (both static & mobile) networks in wireless communications. Nevertheless, it has detailed radio, propagation model and MAC layers.

Hence, the detail simulation parameters described in Table 3. Provided, to control the radio channel assignment directory and to monitor sleep-wake schedules, IEEE 802.11 DCF used for the MAC layer protocol [34, 35].

Experimental Setup: In this paper, the power consumption of mobile sensor nodes dynamically reduced which also improves the coverage, network lifetime and overall throughput of WSNs. Furthermore, figure 4 shows the random deployment of mobile sensor nodes.

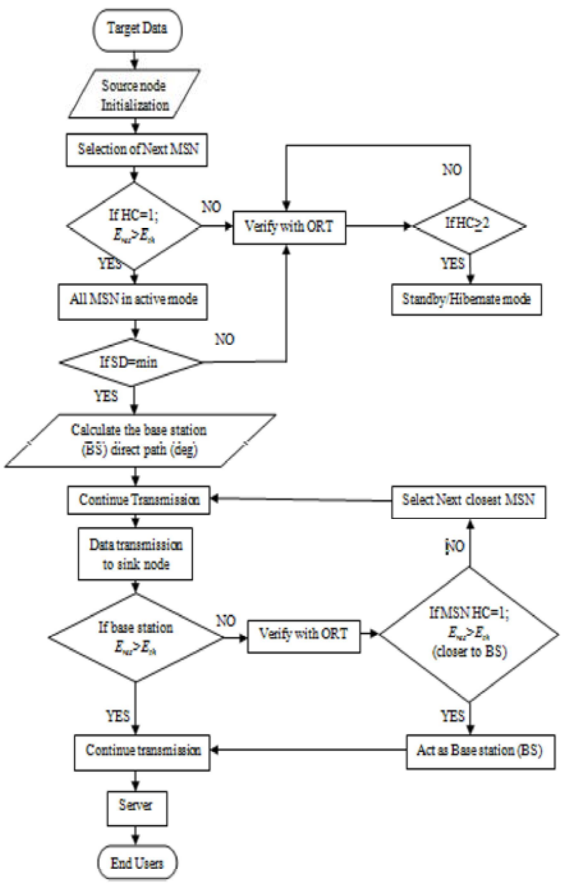

Fig. 3: EECRT design flow diagram

Herein, initially deployed 51 nodes. Provided, 50 nodes are mobile except the base station (sink). Nevertheless, the light green color illustrates the source node and the dark green denotes the base station (sink node).

Moreover, Source node may differ based on Target sensing but the destination (BS or sink) node is fixed. Consequently, the sink node (BS) should be designed with super power and its memory compared with other sensor nodes of the network. As a result, the mobile

Table 3: EECRT Simulation Parameters

Channel Type	Wireless
MAC layer type	802.11 DCF
Radio-propagation model	Two-Ray ground
Interface Queue type	Drop tail/ Pri Queue
Antenna Model	Omni Antenna
No of sensor nodes	51
Payload Size	512
Deployment of sensor nodes	Random
Type of sensor node	Mobile
Type of BS(sink node)	Static
Radio Range	30m

sensor nodes move (some nodes up and down & few are side to side) for a particular distance with prescribed angle, based on the information maintained through ORT[36-38].

In rare occasion due to the absence/failure of sink node (BS), whose node is closer (hop count=1) to the sink node will act as a sink node. Furthermore, figure 4 shows the experimental setup of proposed EECRT. Provided, the next sensor node will select in accounts with data transmission between source and sink node which receives the information derived from the hop count and the information carried by ORT. Nevertheless, in figure 2 transmitting node indicated by means of red color. Moreover, the sky blue color nodes are in active mode whose hop count distance is 1. When the hop count is 2 then the node are in the standby mode which is shown in grey color, when hop count is >2 then nodes are in hibernate mode represented in term of black color.

In addition, the yellow color nodes are free sensor nodes which do not engage in any broadcasting activities. Consequently, after completion of the data transmission the particular transmitted node (red) again goes to another mode (for example black-hibernate) reference with hop count derived from ORT. Moreover, wide line between two nodes shows the present path, slim line represents the future path and the dashed line indicates the past path of this proposed network.

Performance Analysis: Simulation result shows the total network performance analysis of EECRT. Furthermore, Figure1 shows the analysis of coverage performance of various techniques under same conditions. The coverage of proposed technique is superior to other methods. Consequently, figure 2 shows the detailed analysis of computation time simulated by means of 51 nodes. Herein EECRT, solving geometric calculation and implementation will simplify comparing with other existing methods.

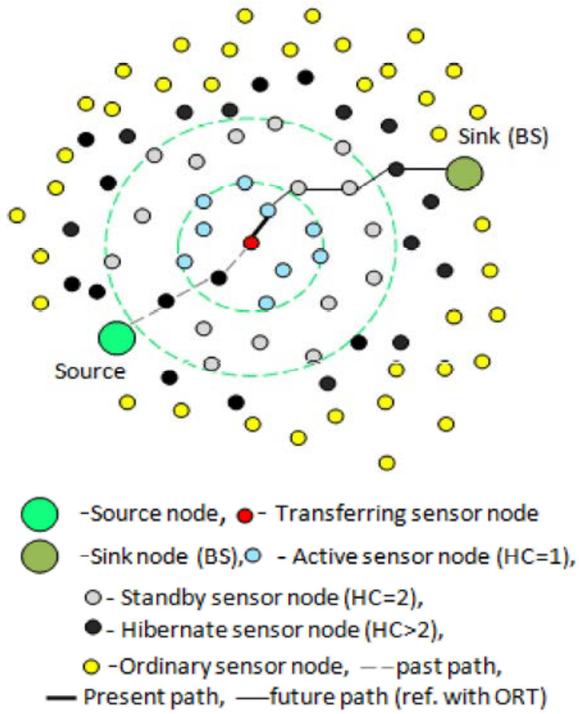

Fig 4: Experimental Setup of proposed EECRT

Moreover, figure 3 shows the energy conservation comparison of EECRT with the existing one. In accordance with the hop count, STOS (Selectively Turn ON Sensors) achieves optimum energy conservation with maximum life time and throughout. Finally the network uniform energy consumption maintained at about 26 mill joules.

MSN Coverage: Coverage defined as the ratio of the area position of few sensing region to the overall monitored surroundings [38]

$$Coverage(C) = \frac{\bigcup_{n=1,\dots,M} A_n}{A} \quad (7)$$

Where An stands for coverage area by n^{th} node and M measures the total number of sensor nodes and A is the monitored surrounding area. Furthermore, figure 5 give you an idea about the graphical representation of MSN coverage.

Lifetime Calculation: One of the main objectives of our proposed work is to prolong the lifetime of network. Hence, assume that the network is properly working for the successful completion of the data transmission. Nevertheless, the network lifetime defined from [32] as follows;

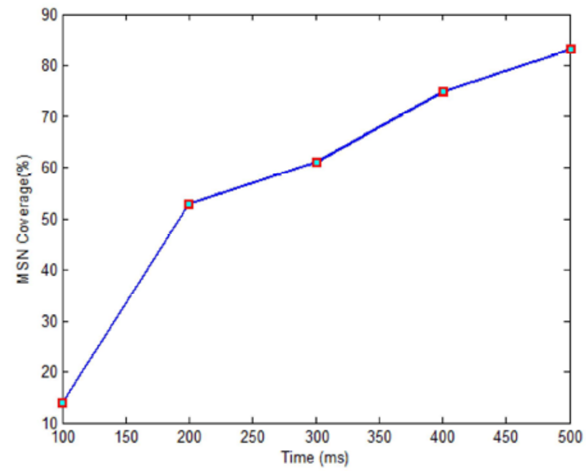

Fig 5: MSN coverage

$$LT_N = \min_{j \le N_m} LT_j \quad (8)$$

Where LT_j is the j^{th}MSN lifetime and N_m is the MSN number. In accordance with this definition MSN have different energy consumption depending on their power saving modes. However, EECRT balances the energy throughput of MSN. Hence, as of the definition, the MSN lifetime described as follows;

$$LT_j = \frac{\bar{E}_m - E_{th}}{P_m} \quad (9)$$

Where $\bar{E}_m$ is the residual energy (E_{res}) of the of the MSN with its arithmetic mean. P_m is the average power consumption of MSN (Mobile Sensor Nodes). E_{th} is the threshold Energy of MSN. If $E_{res}>E_{th}$ then, only hop count counted. Subsequently, derived from the hop count, the power saving modes (psm) established. Furthermore, figure 6 shows the graphical representation of MSN lifetime.

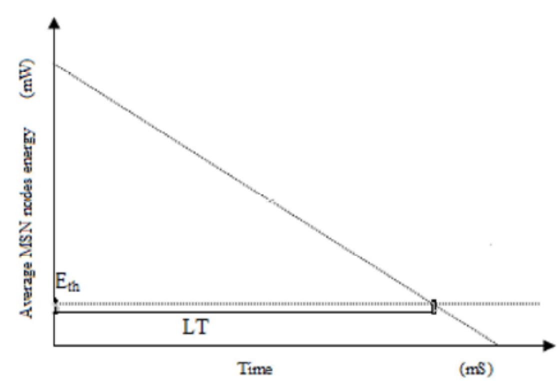

Fig 6: Graphical representation of WSN lifetime

Mobile Network Performance: The mobility of all sensor nodes depends on random walk mobility model [20]. Furthermore, Random deployment of sensor node movements mainly determined by means of the following factors; 1) Speed [minimum speed, maximum speed], 2) Angle of direction [0,2π]. Moreover, every possible mobility of sensor nodes continuous with the duration of 10 seconds interval.

Finally at each interval different speeds with different direction are chosen. Consider that the Probability of active state is ρ and the probability of hibernate state is 1-ρ. Nevertheless, by using EECRT the survival of sensor nodes maximized through a factor close to 1/ ρ.

Simulation results show the detailed analysis of mobile network performance. Moreover, the throughput, packet delivery ratio and packet delay calculated. Hence, the throughput calculated as follows,

$$Throughput = \frac{512 \times 8 \times Total\ Number\ of\ packets}{Time\ duration} \quad (10)$$

Where 512 bytes is the packet length of the each sensor node, each byte carries 8bit information.

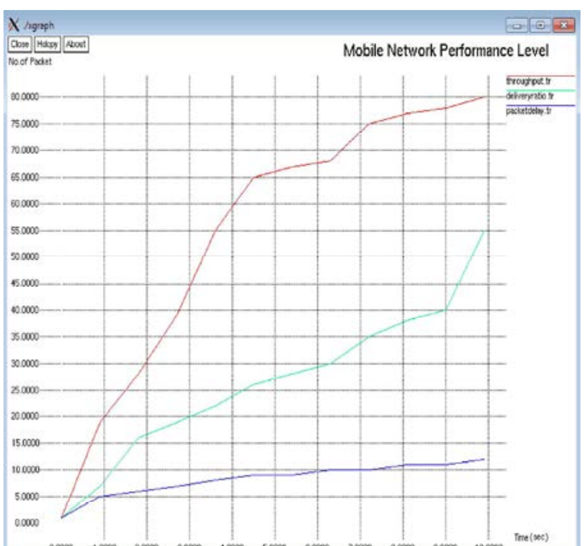

Fig 7: Mobile network performance

The packet delivery ratio can be calculated as below,

$$P_{DR} = \frac{P_{Rr}}{P_{Tr}} \quad (11)$$

Where P_{Rr} is the total number of packets received and P_{Tr} is the total number of packets transmitted throughout the network.

The average delay calculated as below,

$$D_{Avg} = 1 + (HC_{Avg} - 1) \times t_w \quad (12)$$

Where D_{Avg} is the average delay of MSN, HC_{Avg} is the average hop count travelled by all sensor nodes in the network, t_w is the time width Z

Network Energy Level: The total network energy consumption of proposed EECRT is shown in Figure 8. Herein EECRT initially, 50 mobile sensor nodes consumes 26mJ energy. Finally, this energy calculated with help of the formula mentioned in equation (1).

Comparison and Analysis: Figure 9 shows the comparison of the energy conservation of BLR, Grid method and EECRT routing techniques (protocols). Furthermore, in figure 9, the x-axis gives the number of deployed mobile sensor nodes in the network. Moreover, it shows the number of mobile nodes in our prescribed network. Subsequently, the y-axis represents the conserved energy of network relatively marked in percentage.

Fig. 8: Network energy level

In figure 10 and figure 11, we compare the network packet loss and energy usage of three protocols while varying the number of packets per second with delayed slots. However, our EECRT protocol is able to provide less packet loss and energy usage with the increase in the number of packets transferred with delayed slots as shown in the figure 11 and 12. Nevertheless, from this bring to a

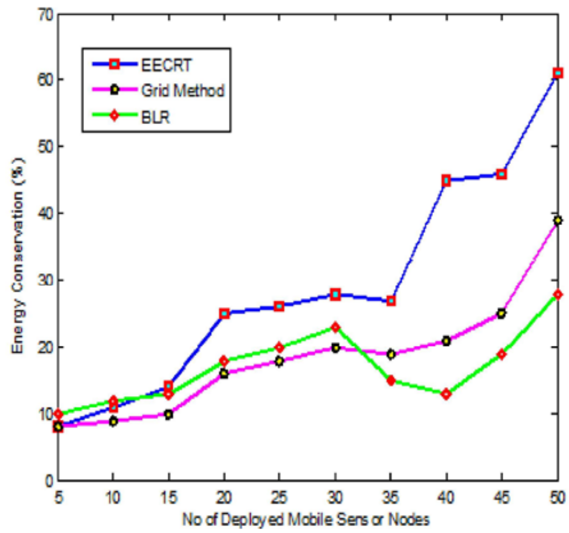

Fig. 9: Comparison of energy conservation

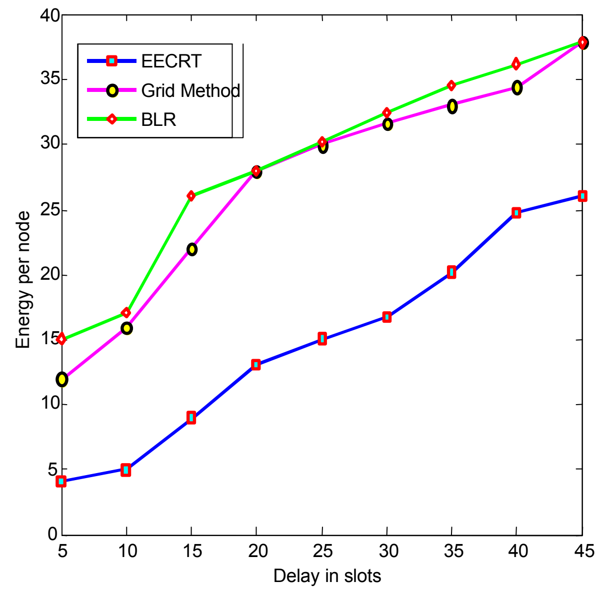

Fig 11: Comparison of energy per node with delay in slots

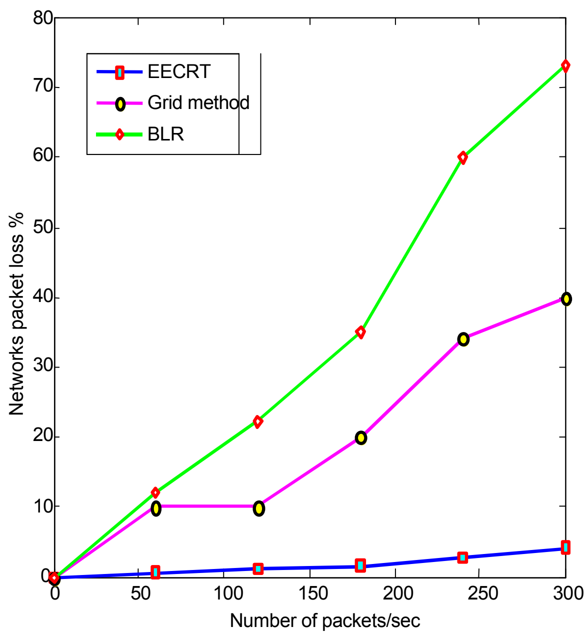

Fig. 10: Comparison of Network packet loss

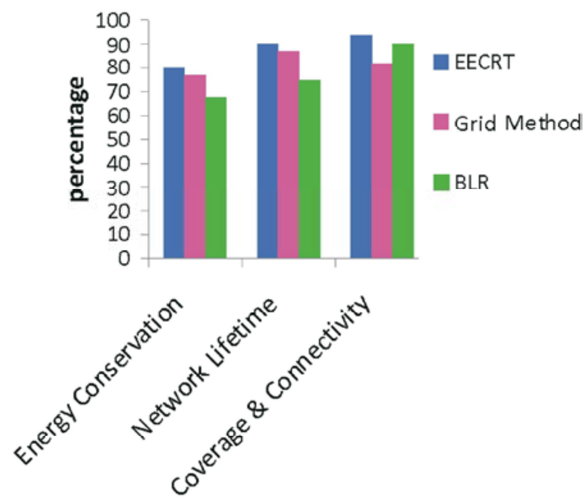

Fig 12: Comparison of different routing protocol

close that in proposed EECRT, the packet loss and the energy usage improved considerably than the other two protocols.

Figure 12 shows the network parameter comparison for different routing protocols Grid method, BLR with proposed technique EECRT. Consequently, it describes the BLR and Grid method that has a trade-off among network lifetime, coverage & connectivity. Finally, from figure 12, it seems that proposed technique outperforms the previous techniques.

CONCLUSION

In this paper, proposed an efficient energy conservation technique for WSN with node mobility. Consequently, two algorithms STOS and ORT developed for maximizing network lifetime, Energy conservation, throughput, enhanced coverage and connectivity (effective usage of MSN with ORT) of the sensor networks. Consequently, in STOS, a sensor node one who is in active state should consume energy or else put into standby or hibernate mode by considering hop count and energy level of sensor nodes. Nevertheless, conserve optimum energy with increased network lifetime. Proposed simulation result provides an excellent coverage and connectivity, reduced latency with highest throughput. Moreover, it significantly increases the network energy conservation and scale well with the density of the network.

In future proposed technique will extend with special intelligence which may work under harsh and rugged environments.

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