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Energy Efficient and Delay Aware Optimization Reverse Routing Strategy for Forecasting Link Quality in Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) have a rapidly increasing number of applications due to the development of long-range low-powered wireless devices. Node decoupling for (NoRD) efficient power-supplying of nodes offers a evade network to avoid sleepy nodes (Chen and Pinkston in NoRD: Node-node decoupling for effective power-gating of on-chip nodes, in Intl, Symp, On Microarchitecture (MICRO), 2012). Though, it obtains a huge latency as well as restricted scalability. In addition, it enhances energy utilization. To defeat this problem, Energy Efficient and Delay Aware Optimization Reverse Routing Strategy (EEOS) is proposed for forecasting link quality in WSN. The main objective of this research is to design a Multi-hop Reverse Routing Technique in WSN. The reverse routing technique avoids the amount of retransmission. Forecasting link quality is used to measure the link quality by Estimating Communication Count (ECC), energy, and delay. This technique enhances routing, link stability, and energy efficiency and minimizes network congestion. It supports Quality of Service (QoS) necessities of energy control, traffic arrangement, and route allotment. In this scheme, the Signal-to-Interference and Noise Ratio (SINR) assists in measuring the quality of a wireless connection. In addition, the route link score is used to form the route from sender to receiver. The reverse routing also provides an efficient route. Simulation results prove that the EEOS minimizes both the delay and the energy utilization and increases the network throughput compared to the baseline protocol.

Keywords Energy efficiency · Wireless sensor network · Forecasting link quality · Signal to interference and noise ratio · Delay analysis · Reverse routing · Simulation analysis

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1 Introduction

A WSN comprises spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc., and to cooperatively pass their data through the network to a Base Station (BS), as shown in the Fig. 1.

WSN has appeared as interrelate prototype in state-of-the-art many-core structures. WSN acts as the main task in chip transactions. However, energy dissolution has a key intention restraint in compound System-on-Chips, sores training operation, battery life spans and consistency. The function is corrupted by energy utilization as well as latency. It is the significant parameter for the WSN function [2].

WSN necessitates being planned resourcefully to exploit system operation and diminish energy utilization in the network. Adjustable channel buffers and node pipeline bypassing are utilized to minimize the energy utilization and progress execution concurrently. Energy utilization can be diminished by abbreviating the volume of the node buffers. The network bypassing method, alternatively, permits flits to bypass the node pipeline and evade the node buffers overall [3]. A low-energy combined bus and error rectification coding is introduced to offer trustworthy and energy proficient interconnection for WSN knowledge. The small energy coding method is built with 2 phases, such as reproduce error correction coding and the low energy bus coding phase. Reproduce error rectification coding offers an additional dependable method to superior techs. The low energy coding applies additional energy decrease with a combined reproduce bus energy example for cross-talk evading [4]. WSN topology through fewer hops and lengthy channels is between the capable answers to undertake these problems. The extended-range connections must be intentional in an operation and energy proficient mode. Therefore, the major aim of this paper is to intend a better throughput and the least energy utilization and delay in the network [5].

Section 2 introduces the related work of energy-saving methodology on WSN. Section 3 depicts the Energy Efficient and Delay Aware Optimization Reverse Routing Strategy for Forecasting link quality in WSNs. The simulation performance of the EEOS approach demonstrates in Sect. 4. Section 5 concludes the paper.

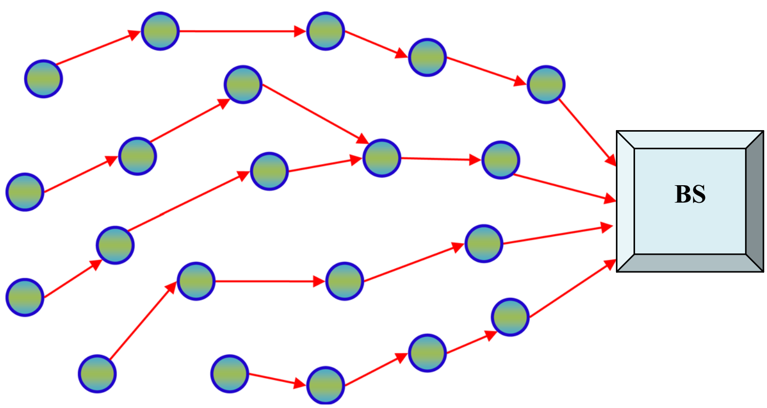

Fig. 1 Data transmission from sensor to BS

2 Related Work

An Artificial Bee Colony optimization technique incorporated with the smallest route designing approach for best routing. Routing-aware Heuristic-based Opportunistic method raised throughput gain and minimized the energy expenditure [6]. A Hybrid Routing enhances the rate of packet delivery. The Routing stages, for example, prioritization and classification, are conceded out on the animate in a disseminated online mode through qualified transmitters. These transmitters calculate their precedence charge by cross-layered routing parameters in a fuzzy mode. And work together through timer coordination by distinguished Back-off Exponent factors appointment for packet transmitting [7].

A Routing with data fusion that describes the spatial–temporal association between receptive data is ever-present. In this approach, the data fusion and usual route communications are accessible for choosing a next-hop transmitting node that could preserve the highest quantity of energy. A Cuckoo Search (CS) method is introduced to discover the best CS of every node. This approach enhances the network lifespan and minimizes the network delay [8]. A Forwarder selection method for selecting the best node depends on the connection's superiority, length of the route, and the node distance. It rejects irregular route disconnection and enhances the quality of the routes. The evaluation routing protocol aims to optimize the new generation's function [9].

Wavelength Reused Hierarchical WSN structure is hierarchic for reprocessing the restricted amount of wavelengths. In this scheme, the entire cores are formed into numerous sub-systems, and the cores in a similar system are straightened, utilizing a λ-node to no jamming transaction. Also, it is proficient with multicast capability [10]. Approximation-Based Dynamic Traffic Regulation (ABDTR) is used to reduce traffic congestion with the integral error resiliency. ABDTR misses a portion of safe-to-estimate information, which might exacerbate system congestion earlier than they are interposed into the system. It also anticipates the missing data in the packet following arriving in the receiver node. Traffic loss charge adapts to the transfer and network states [11].

Serialization minimizes the compactness, thus the combination capacitor among neighbouring information bits. This modifies superior data ranks accordingly, building it probable to transmit numerous information bits on a solitary clock series. Energy diminution is contributed to reduced mating capacitance, though this is balanced by improved size and amount of repeaters to attain higher speed [12]. Mapping of Intellectual Property (IP) cores onto WSN structures is a fundamental action in WSN intentions. Energy, latency, and bandwidth are the basic metrics that require optimization in this design. A Particle Swarm Optimization-based methods for utility IP cores. It is used to examine the multi-objective WSN [13].

Buffer-less flow deals with this concern with absenting node buffers and covers disputation with discharging flits. It uses virtual channel as well as digression flow control. Destitute buffer bypassing for energy effectiveness when buffer-less terms characteristic of a novel routing method that minimizes the average delay [14].WSN trust in virtual channel flow permits efficient exploitation of connectivity bandwidth at the charge of additional energy and lengthy delay. Circuit-switching might convince the execution necessities with little energy spending and shorter delay. It permits to efficiently diminish the energy utilization of WSN without buffering and a higher sleep period for energy gating when holding like delay [15].

A crossbar structure diminishes energy expenditure by entirely dealing with a minimized amount of channels throughout the system. To allow proficient global dealing dissociate the allotment of media and buffers and introduce a photonic token-stream method for channel adjudication and recognition allocation. The flexibility precedes extra node difficulty as well as electrical energy expenditure. But, minimized amount of optical channels, the entire energy utilization is minimized, lacking defeat in execution[16]. Energy proficient spike-timing-dependent plasticity depends on coding the complicated calculation of the winner-take-all function and recurring neuronal functions in the time field treatment. This function changes depending on the forecast of spike breathing nerve cells [17]. The multi-core structure that incorporates numerous treating cores on a particular chip rapidly appropriates the calculating engines with working the correspondence in applications through short clock frequency for elevated energy effectiveness and throughput. The fresh structure, which grants a different core to transmit to all others by WSN rules, has a capable substitute for usual bus-based interlinks [18]. Most conventional schemes on the energy supervision for WSN depend on multi-core arrangements that dismiss the effects of transaction contestation on the opportunity, otherwise integrating evaluated system congestions into the examination for energy supervision. In addition, with the promotion of nano-photonic production and the expansion of silicon photonic devices, inter-crossed optical WSN has appeared as a novel resolution to convene the rising chip-level interlink disputes owing to its less delay, highest bandwidth as well as lowest energy utilization [19].

Modified Russian Peasant Multiplier based on the divide and conquer method is utilized for multiplication. Minimizing the chip size, enhancing the quickness, and minimizing the energy depletion are key critical issues in system strategy [20]. An opportunistic routing by the responsiveness of energy to accept a dynamic environment. While the sender transmits the information to a multicast group, the sender transmits the information via greater energy between vicinity, thus enhancing the lifespan [21].

A Least Square Quadratic Polynomial Regression-based method evaluates the link failure time by applying the signal strength. The forwarding and obtaining node's distance is computed from the data packets received signal strength. The formulation of the quadratic model and the time of link failure are measured to discover the moment at which the greatest transmission range will be attained for regard as the pair of transmitter-receivers. However, this approach can't detect the link failure accurately. Furthermore, it can't provide a better QoS alternative path [22]. The link reliability and performance optimization approach applies a cost function that linearly merges the node energy ratio, link reliability, and precise incorporation rate operations. This approach involves a reliable link routing policy and the contention window techniques adjustment. This method enhances the lifetime by minimizing the node energy utilization [23].

Energy-efficient Q-learning and approach that handle the congestion and it measures the node-link quality through Q-Learning. This approach minimized both the overhead and the time [24]. KullbackLeibler Sparse Auto Encoder Congestion-control method that minimized the congestion and increasing the received ratio [25]. QoS and Energy-Aware Cooperative Routing applying Reinforcement Learning based on node received signal strength and energy. Received Signal Strength based link quality evaluation is utilized for enhancing the quality. However, it makes an extra computational complexity [26]. An Optimal Path is proposed to reaches the packet delivery. This method increases the number of extra neighbors that are conserved data communication. However, it raises the energy utilization [27].

3 Energy Efficient and Delay Aware Optimization Reverse Routing Strategy for Forecasting link quality

WSNs have a rapidly increasing number of applications due to the development of long-range low-powered wireless devices under the IEEE standards. Routing is simply the process of sending data from a source after discovering the available nodes capable of forming a connection chain to a destination.

Figure 2 shows that the shortest route from the source (Forward Route indicated by green arrows) is different from the shortest route from the destination (Reverse Route indicated by red arrows). Multi-hop routing is a mandate for almost every large wireless network with randomly deployed nodes. Since the forward routes to the destinations are generally busy, thus a possibility of disconnecting the route and creating network congestion. This problem reduces the number of retransmissions, enhances energy utilization, and improves the network delay.

3.1 System Model

This scheme considers a WSN containing a set of nodes *R* associated with set *C* of connections. Let's assume each connection R_SR_R represents the sender and receiver. C_R denotes the rate of route communication; the channel time period is spitted into identical length time slots. To assure the necessary QoS, the C_R range for every session C_{Rmin}, C_{Rmax} represents the minimum maintained rate and top rate. This scheme's main aim is to minimize both the energy utilization and latency in the system.

In this approach, the WSN contains the number of sensor nodes that sense the surrounding information and transmit the recognized data to the base station. However, the link capability is very low intrusion sensor nodes are presented inside the network and compromise the normal sensor nodes, then destroy the whole network. Thus, intrusion

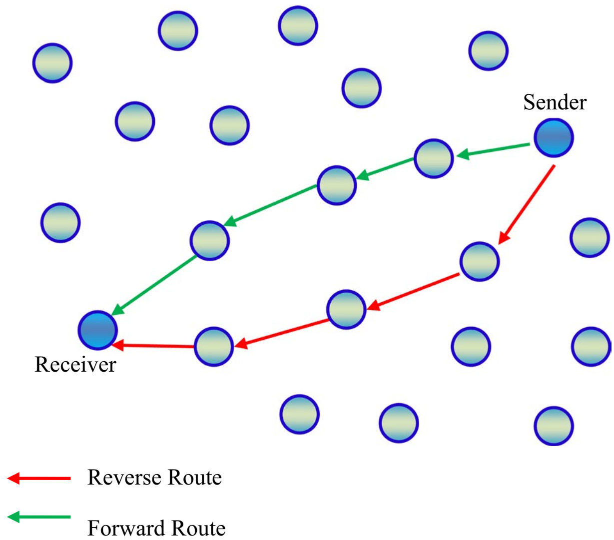

Fig. 2 Forward and reverse route among source to destination

sensor node detection is an essential factor. Here, Reinforcement Learning uses reverse routing for choosing the better forwarder.

Figure 3 shows the architecture of the EEOS approach. Every sensor node distributes it's predicting link quality value, computed by ECC, delay, and energy values at a specific time. The Forecasting Link Quality (FLQ) represents the connectivity strength among two nodes. The FLQ calculation is given below.

$$FLQ = \text{EE} + \text{ECC–Delay} \tag{1}$$

The forecasting link quality is stored in matrix M, and the following steps are executed in the repeating node classification method. The node Forecasting link quality value in this scheme represents 0 to 1.

3.2 ECC Model

An Estimated Communication Count (ECC) is applied to measure the link quality. This metric integrates the efficiency of link loss among the two directions of every connection and the interference between the succeeding path links. It is computed by the formula given below.

$$ECC = \frac{1}{\text{PTR*RTR}} \tag{2}$$

Packet Transfer Ratio (PTR), which represents the possibility of a packet, is effectively established, and the Reverse Transfer Ratio (RTR), which means the possibility that the Acknowledgement packet, is effectively established.

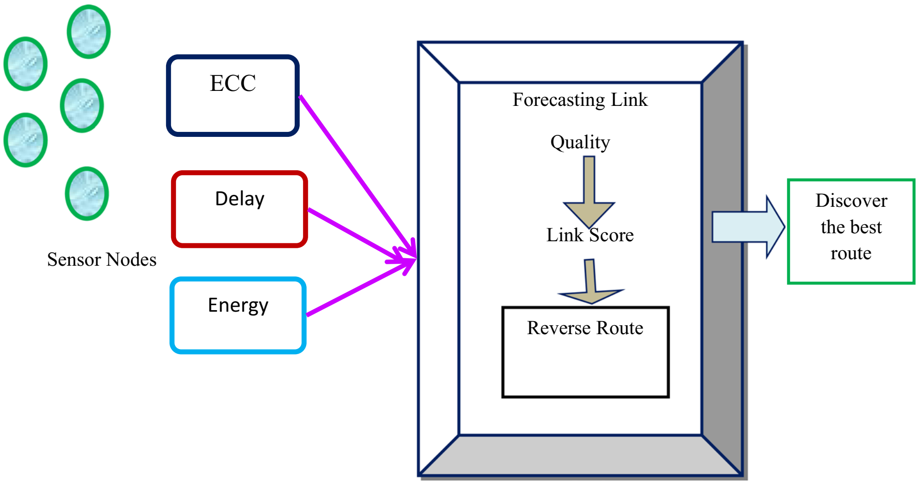

Fig. 3 Architecture of EEOS approach

3.3 Delay Model

The delay in communicating data from a sender node to a destination node affects the network traffic and transaction path. While congestion occurs, entire packets have to wait for a longer time at the node till another transaction releases resourcefulness. The clock chases delay time in every node. The delay time computation is given below.

$$\frac{D = \mathrm{ADX}C_{\mathrm{hop}} + P_{\mathrm{out}} - P}{C_{\mathrm{hop}} + 1} \tag{3}$$

Here, AD represents the average delay, C_{hop} represents the hop count, P_{out} Packet sending time, and P_{in} is the packet receiving time. If the computed delay value is lesser than the average delay value, that indicates less congestion.

3.4 Energy Model

Energy Efficient (EE) routing algorithm is significant to ensure that the data can be transmitted in a link quality path and solve the energy balance issue. Thus, EE routing is an essential factor. For each connection C on each time slot, t is E_t^c represented as

$$E_t^c = \begin{cases} 0 \ \textit{otherwise} \\ 1 \ \textit{if connection to forward on time slot t} \end{cases} \tag{4}$$

For each connection C on each time slot t is E_t^c represented as

$$E_t^c = \begin{cases} 0 & \textit{if } E_t^c = 0 \\ [0, E_{\max}] & \textit{if } E_t^c = 1 \end{cases} \tag{5}$$

If connection C is granted to forward through the time slot, that E_t^c incessantly alters the energy interval among 0 to $E_{\max}$ or else zero. In each time slot, route receiving and leaving connections is allowed to forward. To qualify this constriction, comprise $\sum_{C \in R_c(i) \cup L_c(i)} E_t^c \le 1$. Here, R_C denotes the receiving connection, and L_C denotes the leaving connection of node i, respectively. The quality of a connection is based on the signal-to-interference and noise ratio (SINR). For each connection C on time slot t, the SINR will be computed using the formula below.

$$SINR_t^c = \frac{h_c E_t^c}{vB + H(T,T)E_t^c} \tag{6}$$

Here, h_C represents the broadcast gain of connection C, v denotes the density of thermal noise, B denotes the bandwidth of the channel, H(T,R) denotes the propagation gain of the sender and receiver connection C. Then computes the capability of every connection using Shannon capability model as $B \log_2(1 + SINR_t^c)$.

In the system, a sender node forwards data to its receiver node that makes a session. Due to the restricted communication energy of a node, it might be required to forward data via multiple middle routes to alleviate communication across a long distance. To offer enhanced routing consistency and flexibility by applying multi-path routing and flow dividing. Each node can divide received traffic into sub-flows that are forwarded to various adjacent nodes. Let ${FR_{s,t}}^{C}$ indicates the flow rate of the session s on connection C at time slot t. If node i is the sender of session s, next

$$\sum\nolimits_{C\in R_c(i)} FR_t^c = C_R T \in IS(i) \tag{7}$$

Here, $IS(i)$ is the set of sessions in which the sender node is i. While both positions of formula 8 are multiplied by the time period of the time slot, the left region gives the whole quantity of traffic (in bits) yielded by the sender node, and the right region establishes the middling session range multiplied by the arrangement instance period. Obviously, both amounts should be equivalent. If node i is an in-between node of session$s$, after that, it will be

$$\sum\nolimits_{C\in R_c(i)} FR_{s,t}^c = \sum\nolimits_{C\in L_c(i)} FR_{s,t}^c \tag{8}$$

The above formula involves which, for each session, the remaining quantity of receiving and leaving traffic should be equivalent at every communicate node. Formulas 7 and 8 declare the flow equilibrium at the receiver node of a session. Therefore, exclude flow maintenance restraints of the receiver node for every session. In addition, the whole quantity of traffic at each time slot since different sessions on a specific connection cannot exceed the connection's capability. Hence, the next restraint $\sum\limits_{s\in S} FR_{s,t}^c \le B\log_2(1 + SINR_t^c)$ ultimately, to maintain QoS necessities, presume C_R of every session s should convince $C_{R^{\min}} \le C_R \le C_{R^{\max}} \quad \forall s \in S$. Here, S represents the overall session rate. This scheme helps to enhance the energy efficiency that is definite as the overall session rate fractioned with the energy exhausted by entire nodes through the arrangement time.

It is equivalent to the quantity of data forwarded by the entire sender and receiver rates fractioned with the energy exhausted by the nodes. Accordingly, the task is revealed as

$$EE = \frac{\sum\limits_{s\in S} C_R}{\sum_{c=1}^{C} \sum_{t=1}^{T} E_t^c} \tag{9}$$

3.5 Score Computation

The score consists of two phases score of the link as well as a score of the route. The individual link score denotes the link score among two neighbour nodes. Furthermore, the route score indicates the routing path of the link scores. Check the forward route link score value and reverse route score value. Usually, the forward route is always busy; thus, we use the reverse route in the WSN. The score of link and route computation is given below.

$$LS_{i,j} = F\mathrm{LQ}_{\mathrm{i,j}} \tag{10}$$

$$RLS_{i,k} = \max\{F\mathrm{LQ}_{\mathrm{i,j}} + F\mathrm{LQ}_{\mathrm{j,k}} + F\mathrm{LQ}_{\mathrm{k,l}}\} \tag{11}$$

The source node has the maximum route score path selected as a data transmission route. As a result, improve the better route formation. In WSN, every node informs its link score to its neighbour; thus, the source discovers the best route.

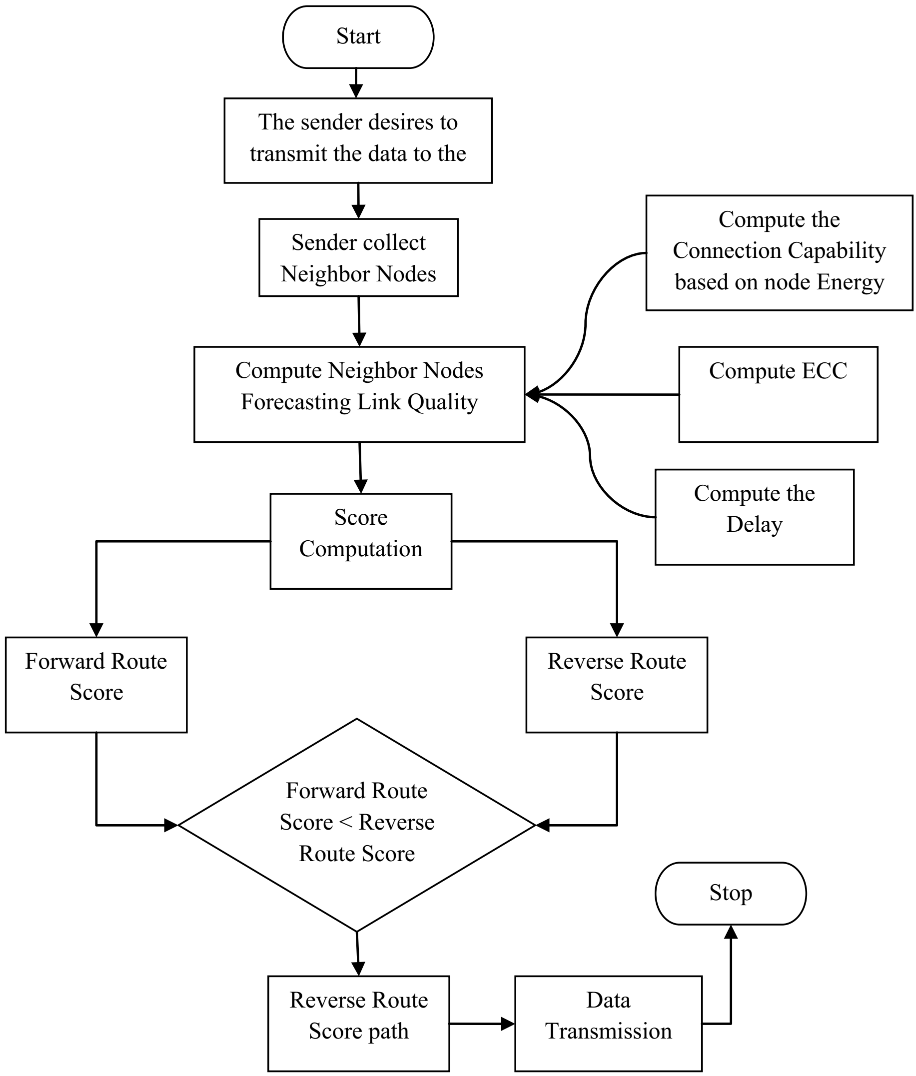

Fig. 4 Flow diagram of EEOS approach

Figure 4 shows the flow diagram of the EEOS Approach. In this approach, the delay model is used to minimize average delay, and the energy model is used to reduce energy utilization.

4 Simulation Evaluation

Network Simulator (NS-2.35) is intended for research in WSNs. Table 1 discusses the EEOS and NORD simulation factors. The EEOS has 100 sensor nodes arranged in the region of 900 × 800 m. Constant Bit Rate (CBR) and Variable Bit Rate (VBR) is employed

Table 1 EEOS and NORD simulation factors

QoS Factors	Rate
Sensor Nodes Count	100 Sensor Nodes
Sensor Node Antenna	Omni antenna
Sensor Node Radio Propagation	Two ray ground
Sensor Nodes Traffic	CBR, VBR
Topology Area of Sensor Nodes	900 × 800
Sensor Node Time of Simulation	100 s
Sensor Node Range of Communication	250 m
Sensor Node Channel Type	Wireless channel
Sensor Node MAC	802.11
Sensor Node Packet Size	512 bytes

for handling the traffic models. User Datagram Protocol (UDP) and Transmission Control Protocol (TCP) are applied for transactions among the nodes.

4.1 CBR with sensor nodes count

Simulation analysis for EEOS and NORD approaches are compared based on sensor nodes count. Here, CBR traffic is used for data transmission. The performance evaluation metrics are examined for the network performance, such as Packet Achieved Ratio (PAR), Packet Loss Ratio (PLR), delay, throughput, and Residual Energy (RE).

4.1.1 PAR

PAR is well-defined as the number of packets achieved at the receiver sensor per unit time. PAR is evaluated by the formula 12. Where n represents the sensor nodes count. Table 2 displays the PAR values of EEOS and NORD approaches based on sensor nodes count.

$$PAR = \frac{\sum_0^n \text{Packets Achieved}}{\text{Time}} \tag{12}$$

The EEOS and NORD approaches of PAR is planned in Fig. 5. It displays that the EEOS has 25.26% greater PAR than NORD. Since the EEOS approach uses reverse routing based on route score. But, the NORD approach increases the link failure in the network.

Table 2 PAR values of EEOS and NORD for sensor nodes count

Sensor Nodes	PAR of NORD	PAR of EEOS
0	1	1
25	0.92	0.97
50	0.88	0.99
75	0.81	0.96
100	0.71	0.95

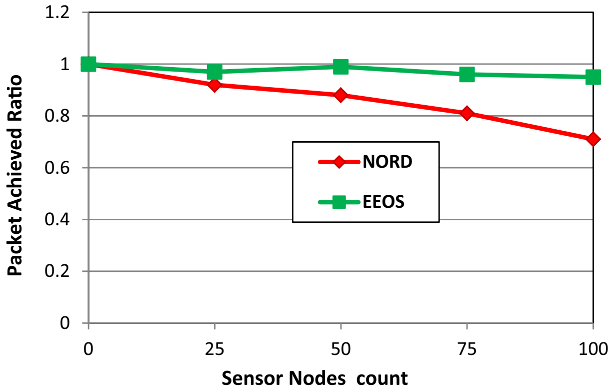

Fig. 5 PAR of EEOS and NORD for sensor node count

4.1.2 PLR

PLR is well-defined as the sum of packet losses per unit time. PLR is evaluated by the formula 13. Here, n represents the nodes count. Table 3 illustrates the PLR values of EEOS, and NORD approaches based on Sensor nodes count.

$$PLR = \frac{\sum_0^n \text{Packets Loss}}{\text{Time}} \tag{13}$$

Figure 6 explains the EEOS and NORD approaches of PLR values received for sensor nodes count. The NORD approach has the highest packet loss ratio from this figure

Table 3 PLR values of EEOS and NORD for sensor nodes count

Sensor Nodes	PLR of NORD	PLR of EEOS
0	0	0
25	0.05	0.01
50	0.09	0.035
75	0.15	0.09
100	0.23	0.16

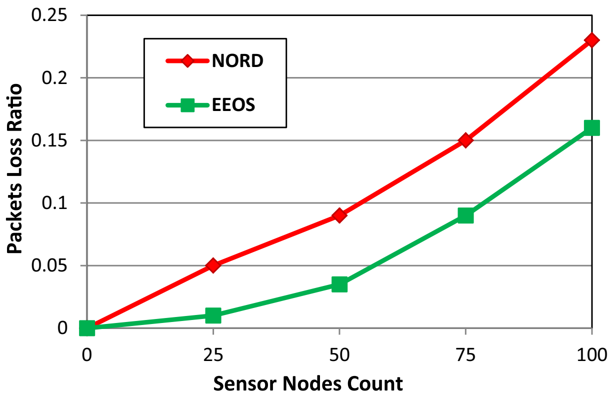

Fig. 6 PLR of EEOS and NORD for sensor nodes count

Table 4 Delay values of EEOS and NORD for sensor nodes count

Sensor Nodes	Delay of NORD (sec)	Delay of EEOS (sec)
0	0	0
25	0.2859	0.1525
50	0.5924	0.2354
75	0.7958	0.37
100	0.941	0.643

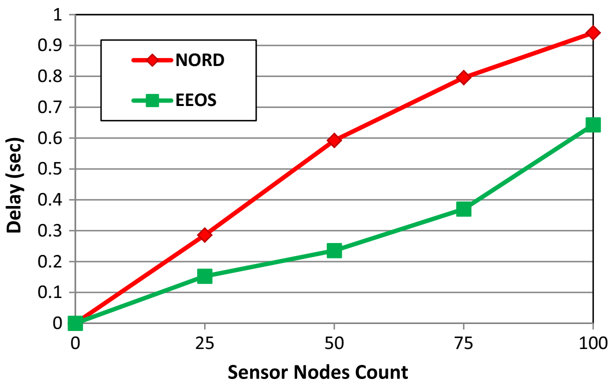

Fig. 7 Delay of EEOS and NORD for sensor nodes count

because it uses the frequent link failure forward route. Figure 6 specifies that the PLR of EEOS is 30.43% lesser than NORD.

4.1.3 Delay

It is well-defined as the time variation among sensor node packets achieved and packets transmitted. It is evaluated by the formula 14. Here, n represents the nodes count. Table 4 demonstrates the delay values of EEOS, and NORD approaches based on sensor nodes count.

$$Delay = \sum_{0}^{n} PacketAchieved\ Time - Packet\ Transmit\ Time \tag{14}$$

Figure 7 indicates EEOS and NORD approaches delay values achieved for sensor nodes count. During data transmission, the EEOS approach chooses the route by better-forecasted link quality route; as a result, the EEOS approach has a 31.66% lesser delay than the NORD approach.

Table 5 Throughput values of EEOS and NORD for sensor nodes count

Sensor Nodes	Throughput ratio of NORD	Throughput ratio of EEOS
0	1	1
25	0.95	0.996
50	0.88	0.981
75	0.8	0.984
100	0.7	0.962

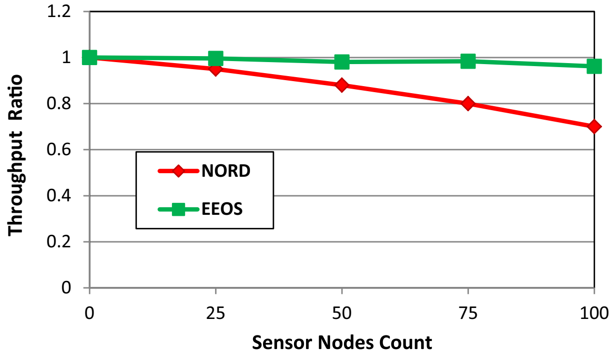

Fig. 8 Throughput values of EEOS and NORD for sensor nodes count

4.1.4 Throughput

It denotes the total number of packets successfully achieved across the network per unit time. It is received applying formula 15. Here, n represents the nodes count. Table 5 indicates EEOS and NORD approaches' throughput values based on sensor nodes count.

$$\text{Throughput} = \frac{\sum_0^n \text{Packets Achieved(n)} * \text{size of Packet}}{Time} \tag{15}$$

Figure 8 denotes EEOS and NORD approaches throughput values obtained for sensor nodes count. It can be noticed from the Figure that EEOS is higher than 27.23% compared to the NORD approach since the EEOS approach computes the forecasted link quality by the node delay, connection capability based on node energy, and node ECC.

4.1.5 RE

It is well-defined as the whole energy drained by every sensor node divided by the number of data packets that are ideally disseminated to the receiver or BS. Figure 9 illustrates the EEOS, and NORD approaches RE values for sensor nodes count. Table 6 displays EEOS and NORD approaches' RE values based on sensor nodes count.

The EEOS approach enhances routing and link stability, energy efficiency and minimizes network congestion. Hence, the EEOS approach minimized the unwanted energy utilization in the network. Figure 9 specifies that around 2.07 Joule of energy is saved for EEOS than the NORD approach.

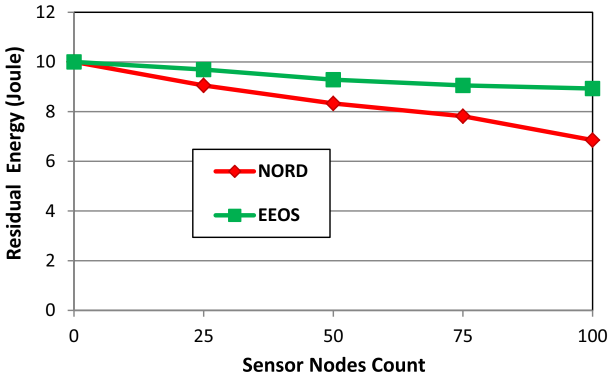

Fig. 9 RE of EEOS and NORD for sensor nodes count

Table 6 RE values of EEOS and NORD for sensor nodes count

Sensor Nodes	RE of NORD (joule)	RE of EEOS (joule)
0	10	10
25	9.053561	9.692374
50	8.32763	9.283218
75	7.81729	9.053826
100	6.854672	8.92894

4.2 VBR with the Traffic Load

Analysis for NORD and EEOS approaches is executed based on traffic load, and the VBR traffic model is used for data transmission. The figures of the same parameters are indicated below. To examine the effect of various traffic flows, the flow size is changed from 0.1 Mb to 0.6 Mb. The performance evaluation metrics are examined for the network performance, such as PLR delay, throughput, and RE.

4.3 PLR

PLR is estimated similarly to simulation time using Formula 13 for Traffic Load. EEOS and NORD approach PLR for Traffic Load is plotted in Fig. 10. Table 7 indicates the PLR values of EEOS and NORD approaches based on Traffic Load in the WSN.

The figure shows the PLR values obtained during the simulation analysis based on the traffic load parameter using the VBR traffic model. It indicates the PLR of the EEOS when compared with NORD for Traffic Load. The PLR of NORD is 33.16% greater than the EEOS mechanism.

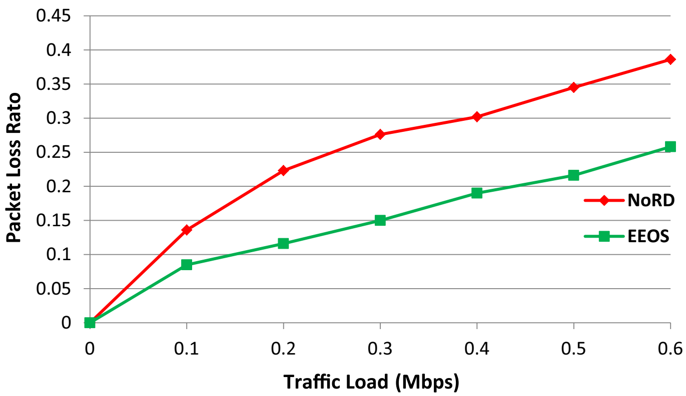

Fig. 10 PLR of EEOS and NORD for traffic load

Table 7 PLR values of EEOS and NORD for Traffic Load

Traffic Load (Mbps)	PLR of NORD	PLR of EEOS
0	0	0
0.1	0.136	0.085
0.2	0.223	0.116
0.3	0.276	0.15
0.4	0.302	0.19
0.5	0.345	0.216
0.6	0.386	0.258

Table 8 Delay values of EEOS and NORD for Traffic Load

Traffic load (Mbps)	Delay of NORD (sec)	Delay of EEOS (sec)
0	0	0
0.1	0.1804	0.0569
0.2	0.2835	0.1423
0.3	0.3871	0.2280
0.4	0.4834	0.3082
0.5	0.5535	0.3835
0.6	0.6592	0.4432

4.3.1 Delay

Table 8 demonstrates the delay values of EEOS and NORD approaches based on the traffic load in the WSN. It is measured as the variation in the time of packet received and sent for all sensor nodes as in Formula 14.

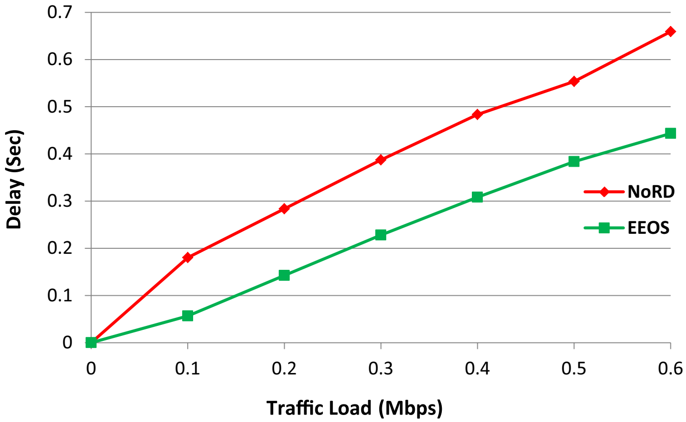

Fig. 11 Delay of EEOS and NORD for traffic load

Figure 11 illustrates EEOS and NORD approaches delay values for Traffic Load. It can be agreed due to the delay with the NORD 32.75% higher than EEOS; as a result, the EEOS approach minimized the network congestion in the WSN.

4.3.2 Throughput

It is estimated to apply Formula 15 for both EEOS, and NORD approaches. Figure 12 displays the EEOS and NORD throughput to detect the deviation. Table 9 indicates the throughput values of EEOS and NORD approaches based on the traffic load in the WSN.

Values for both EEOS and NORD functioning in a Traffic Load are given in Fig. 5, 9. From this figure, EEOS has a 33.76% enhancement over NORD for a Traffic Load. EEOS approach built the route by reverse route. Hence, it minimized the unwanted retransmission in the network.

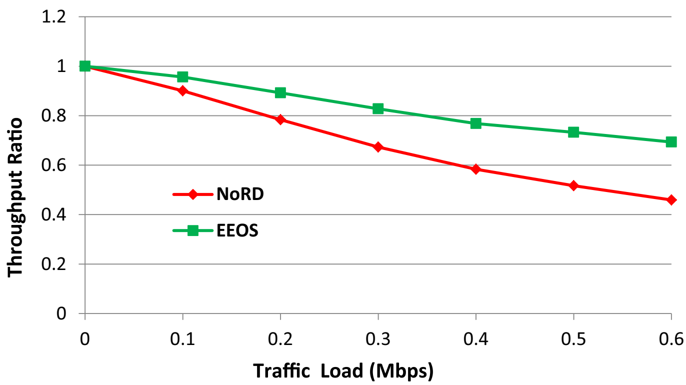

Fig. 12 Throughput EEOS and NORD for traffic load

Table 9 Throughput values of EEOS and NORD for Traffic load

Traffic Load (Mbps)	Throughput ratio of NORD	Throughput ratio of EEOS
0	0	0
0.1	0.9004	0.9565
0.2	0.7835	0.8923
0.3	0.6731	0.8280
0.4	0.5841	0.7682
0.5	0.5167	0.7328
0.6	0.4592	0.6932

4.3.3 RE

It is well-defined as the whole energy is drained by every sensor node divided by the number of data packets ideally disseminated to the receiver or BS. Table 10 indicates the RE values of EEOS and NORD approaches based on the traffic load in the WSN.

The figure illustrates EEOS and NORD approaches RE values received by network traffic load. Figure 13 denotes that EEOS, around 0.543 Joule of energy, is saved when compared with NORD; the EEOS approach preserves the sensor node resources in the WSN.

5 Conclusion

WSN is developing quickly, and it is a part of daily life. Huge utilization of this network has ensued in the growth of several routing approaches for WSN. A WSN comprises spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc., and cooperatively pass their data through the BS. Since the forward routes to the destinations are generally busy, thus investigate the possibility of reverse routing from the destination end. Reverse routing is designed for large low-powered WSNs. Energy Efficiency Optimization Scheme followed by SINR is used for WSN. The EEOS scheme allocates tasks on QoS necessities of energy control, traffic arrangement, and route allotment. Forecasting link quality is used to measure the link quality by ECC, energy, and delay. The route score forms a better link quality route from sender to receiver. This scheme

Table 10 RE values of EEOS and NORD for Traffic load

Traffic Load (Mbps)	RE of NORD (Joule)	RE of EEOS (Joule)
0	10	10
0.1	9.681	9.981
0.2	9.431	9.870
0.3	9.201	9.690
0.4	8.971	9.581
0.5	8.844	9.446
0.6	8.802	9.345

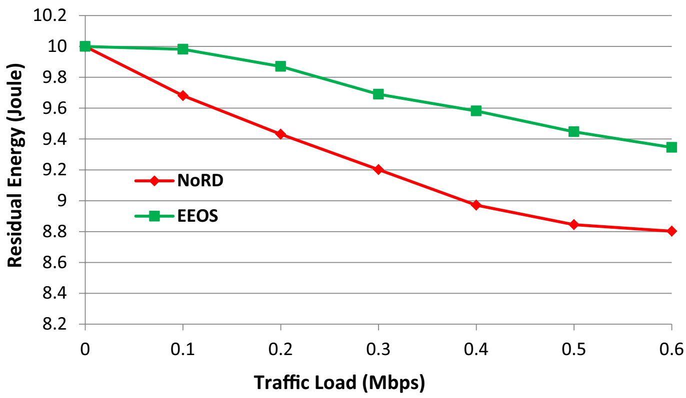

Fig. 13 RE of EEOS and NORD for traffic load

uses the reverse route; as a result, it minimizes the network delay and reduces network congestion. The simulation results demonstrated that the proposed EEOS methodology increased residual energy and throughput. In addition, the EEOS approach reduced the network delay in the WSN.

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Code Availability Source Code.

Declarations

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