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EFFICIENT MOBILE SINK LOCATION PLACEMENT BY RESIDUAL STATUS IN WSN TO ENHANCE THE NETWORK LIFETIME

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Abstract

A wireless sensor network (WSN) consists of autonomous nodes with sensors to sense and collect the status of the surrounding environment continuously. Characteristics of WSN are infrastructure-less, self-organizing, and fault tolerance. One of the applications of WSN is living and sleeping pattern reorganization in the home environment. Where the sink node is equipped with a sufficient amount of processing and battery capabilities, but sensor nodes are outfitted with the restricted battery as well as processing capabilities. The sensed information is transmitted to the sink node in a single or multi-hop communication manner. The energy depletion of any sensor node directly affects the sensing coverage and thereby on the network performance. Particularly the sensor node that is neighbour to the sink node faces the extra overload and drops the information due to insufficient buffer. Moreover, the neighbour of sink node exhaust soon due to the energy depletion. Thus the placing the sink node in a suitable position in WSN is a quite vital design issue, as the performance of the WSN is greatly affected by the proper placement of the sink node. The paper designs an efficient mechanism for deploying the sink node to a suitable position. The deployment is based on the sensor node's residual buffer and energy status. The performance of the proposed mechanism is evaluated by a network simulator and compared the results with recent existing mechanisms in an identical environment. The performance results indicate that the proposed work enhances the network lifetime and energy efficiency in WSN. Finally, it prevents packet drops in WSN by avoiding the nodes becoming the bottleneck.

Keywords: Buffer, Cluster-head, Energy-efficiency, Network performance, Node lifetime, Residual status, Routing, Sink node.

1. Introduction

Wireless sensor networks (WSNs) are the greatest technology and gains high attention from the researcher from the last few decades. WSN is composed of the number of wireless sensor nodes spread over the communication region for sensing and detecting the surrounding environment. Nodes are self-directed and used to collect the environmental states such as humidity, gravity, and temperature. The sensed data is transmitted to the outer world through the sink node. The communication in WSN is possible either by single-hop or multi-hop communication based on the distance between the sink node and the sensor nodes [1]. Characteristics of WSN are infrastructure-less, self-organizing, and fault tolerance.

One of the applications of WSN is living and sleeping pattern reorganization in the home environment. The home network is composed of network-enabled sensing devices known as sensor nodes. These nodes are operational with limited and irreplaceable batteries and computational capabilities. The sensor nodes present in the home network are different in different locations such as Camera, RFID, Bio-sensor, and Salam et al. [2]. Further resources of the sensor nodes are heterogeneous and constrained such as battery, memory, and processor. These nodes sense the surrounding environment and transmit the sensed data to the outside world through the sink. On the other hand, the sink node, which is static or mobile, is equipped with a sufficient amount of battery and processing capabilities. In the home network environment, the sink node is equipped with Robovac [3] to move from one place to another place.

In WSN, sensing coverage area by sensor nodes is an important factor to analyse and enhance the network performance as well as the network lifetime. The sensor nodes might expire due to the exhaust of energy during the mission, as they are equipped with limited irreplaceable batteries [4]. The situation directly impacts the sensing coverage thereby the performance of the WSN in terms of network lifetime. Thus, a suitable mechanism with energy efficiency is required to utilize the available node energy in an efficient way [5]. The placement of the sink node in WSN is also an important parameter to enhance the efficiency and lifetime of the network [6]. Particularly, the sensor node that is neighbour to the sink faces the extra overload and drops the information due to insufficient buffer. Moreover, the neighbour of the sink node exhausts soon due to the depletion of energy. This situation in any communication network is known as a bottleneck, the bottleneck may be a single point through which all traffic must flow [7], and it is related to the network layer. Bottleneck nodes drop the packet due to constrained resources, such as buffer space and energy [8]. Thus placing the sink node in a suitable position in WSN is a quite vital design issue, as it influences the performance of the network [9].

In WSN, the node that is neighbour to the sink faces the overhead and becomes the bottleneck due to its constrained resources such as battery and buffer [10]. Thus this paper aims to compute the residual status of the sensor nodes in WSN in terms of the battery and buffer. Further, the deployment of the sink node position is dynamic, and it is based on the computed residual status of the sensor nodes concerning buffer and energy [11]. The remainder of the paper is structured as follows; the 2nd part will discuss the possibility of the node becoming the bottleneck in WSN. The third part gives the proposed work of prevention bottleneck in WSN with diverse concepts. The fourth part will show the performance of the proposed work in contrast with existing work. To conclude, the paper is dealt with the conclusion part.

2. Literature Survey

Reliable communication is one of the important issues in WSN, as applications of WSN are sensitive. One of the parameters to achieve reliable communication in WSN is energy efficiency and network lifetime. Many researchers raise the issue of energy efficiency in WSN by designing different routing protocols to elaborate the network's lifetime. Energy-based routing techniques are the routing techniques that consider energy as the main constraint in the routing protocol designing [12]. They are further divided based on different sub-parameters like energy awareness, energy-efficient, and reliability [13]. These protocols route selecting parameter is based on greater energy node or less energy depletion path and/or less retransmission-count path, all of them are reserving the specific path for communication. The node, in a communication path, is accepting massive traffic due to its location, greater energy, and/or less transmission energy path, becomes a bottleneck, and drops the information due to insufficient resources will expire soon. This situation directly influences network performance in terms of energy efficiency and network lifetime. Thus Achieving energy-efficiency and extending network lifetime is an active research area in the wireless sensor network. One can achieve it by managing the data quantity, multi hops routing path in transmission. But the node nearer to the sink become a bottleneck and start to drop the packet and exhaust quickly due to the high load, as nodes in a network have limited energy and buffer capacity [14].

To overcome this problem one possibility is to change the node which is the neighbour node to sink and responsible to send the sensing information to the sink node via it. However, the nodes deployed in WSN are static and fixed to a particular location and we cannot change the position of sensing nodes. One possible solution is to make the sink node mobile from one place to another place in the network according to neighbour node properties concerning energy and load. Thus, the aim is to change the position of the sink to achieve energy efficiency and extend the network lifetime. In other words, it will provide mobility to the sink node. Aiming at this concern, we investigate the method that provides the sink node to mobile for achieving the network lifetime and energy efficiency by removing the problem of the neighbour node of the sink becoming a bottleneck node [15]. The proposed method uses the cluster-based approach to implement the hybrid sink mobile routing protocol, where the sink changes its position based on the node status concerning the load and energy of its neighbour. The model is designed based on the cluster-based technique. But, apart from the cluster-based approach, the distributed and centralized techniques can also be preferred for WSNs. The nodes are autonomous, and the communication is only between neighbouring nodes in the distribution approach, while, in the Centralized approach the network formation is controlled by a single device. On the other hand clustering in network solve the issue of scalability and avoid expensive long-distance communication and improve the availability of network resources by providing service locally and also a better solution for packet drop prevention.

Energy balancing in the network is an important issue to enhance the lifetime of the network (NL) and to get energy efficiency. In the current research, various designing protocols are tried forgetting the efficient location of the sink node throughout the network operation [16]. Due to the imbalanced energy exhaustion, the sensor node will die and hence makes major issues in single-hop WSNs. Hence, the position of the sink plays a vital role to balance the network energy. This type of design is suitable for homogeneous nodes. But besides that, the majority of home networks consist of heterogeneous nodes like biosensors cameras, Micaz, which differ from the other in terms of the original energy of the battery as well as energy consumption. For that reason, there is a need to introduce an algorithm with energy efficiency to balance the node energy and depletion time, which interns in improved performance and network coverage. Hence, the paper proposes the "Network Lifetime Enhancement in WSN Using Energy & Buffer Residual Status (EBRS) with Efficient Mobile Sink Location Placement" in WSN to enhance the performance in terms of lifetime and energy efficiency.

3. Proposed Model

In recent years, the attraction of the researcher is to improve the performance and lifetime of WSN through the development of the mobility-based mechanisms by dynamic replacement of the position of the mobile sink i.e., mobile sink sojourn locations [17]. Sojourn locations are the set of locations in the WSN to receive the sensed information from the sensor nodes. The selection of appropriate sojourn positions for the mobile sink in the WSN home network will reflect in network performance such as maximizing the lifetime of network, energy efficiency, scalability, and network coverage. Thus the placing of the sink node at a suitable position in WSN is a quite vital design issue and it influences the lifetime and performance of the network [18]. This section designs an efficient mechanism for deploying the sink node to a suitable position. The deployment is based on the residual status of the neighbour node to the sink in terms of buffer and energy.

In WSN, the neighbor nodes to the sink drop packets from the buffer due to insufficient space [19]. Further, it expires due to the exhaust of the energy in multi-hop communication environments of WSN [20]. The sensor nodes that are neighbours to the mobile sink node get an extra load, as though its data is reached to the sink node. If the neighbor node to the sink gets the data, more than its handling capability then they drop the information due to its constrained buffer. Moreover, processing the information received from the other nodes consumes more energy and causes the depletion of their batteries in advance to the other nodes. This situation in a network, known as a bottleneck, directly impacts network performance concerning network coverage, lifetime, and energy efficiency. Thus the paper proposes a dynamic placement of the mobile sink node based on the sensor nodes residual buffer as well as energy status [21]. The computation of the residual status of sensor nodes and the dynamic placement mechanism of movable sink is explained in the following subsections, and we consider the living and sleeping pattern reorganization in the home **environment**.

3.1. Residual status energy model for sensor nodes

In literature, various congestion control mechanisms have been designed at the transport layer of the OSI model to prevent buffer overflow. These mechanisms are well performed for wired and wireless infrastructure-based networks. They cannot directly apply to the infrastructure-free network such as WSN to prevent the packet drop from the sensor nodes that are neighbour to the sink node due to the buffer overflow [22]. Thus an early congestion detection algorithm is required to detect the congestion at the sensor nodes that are neighbours to the sink node, and well suitable place for the early congestion detection algorithm is the network layer of the OSI model. The buffer overflow at the node buffer is due to the exceeding high traffic load that is associates with the data forwarding and medium access control. Thus the traffic load of the sensor nodes needs to be computed at the network layer and according to that, the mobile sink position must be determined [23]. The number of traffic queued at the sensor node buffer is determined with the help of the Random Early Detection (RED) gateway as follows:

$$\text{Averagenewqueue}(Q_{avrg}) = \text{(Weighted constant)} * \text{Instant Queue} + (1 - \text{Weighted constant}) * \text{Average old queue} \tag{1}$$

The threshold queue value of buffer size is kept in this approach is

$$Thresholdbuffer(Q_{Th}) = 75\% \ of \ buffer \ size \tag{2}$$

The position of the sink node is required to be changed if the queue size of the neighbour node buffer is less than the threshold value.

3.2. Residual status buffer model for sensor nodes

The nodes deployed in-home network equipped with irreplaceable constrained batteries. The exhausting energy of any sensor node is a negative impact on the network performance and lifetime. To increase the network lifetime and performance the packet communication must be done with the least amount of energy with the consideration of the node state. Thus, to manage the node energy, a node balancing process is used in the network. Furthermore, it also calculates the remaining energy of the node to compute the node's residual capacity to process the number of packets in its available energy. In WSN, the Exhausting energy of the sensor node occurs at the sensor nodes that are neighbours to the sink node, as they receive more traffic due to their location [24]. Thus the paper computes the residual packet capacity of the node in its available energy as follows:

Here, a multi-hop WSN is considered with several nodes equipped with E joules of energy, with a handling capacity of 'n′ number of packets. The required energy to process the packet P_i is determined by the following equation [25]:

$$E(P_i) = E_r + E_t + E_p \tag{3}$$

Furthermore, the Residual energy after processing of one packet is computed as follows

$$E_{res} = E - E(P_i) \tag{4}$$

The residual packet processing capacity of the sensor node in its available energy is computed by the following equation

$$CRP = \frac{E_{res}}{E(P_i)} \ \forall \ \mathrm{E_{res}} \geq \mathrm{E}(P_\mathrm{i}) \tag{5}$$

The threshold packet processing capacity of the sensor node is computed as follows

$$CRP_{Th} = \frac{(75\%)*E}{E(P_i)} \quad (6)$$

Here also the sink node location has got to be changed if the neighbour nodes packet processing capacity is less than the threshold value.

3.3. Mobile sink model for its dynamic placement

The home sensor network consists of the mobile sink node with sufficient energy and processing capabilities. The sink node was initially deployed in the network randomly with the known location. The paper assumes that the network consists of the location finding mechanism to determine the position of the sensor nodes and the sink node [26]. During the communication phase, all the sensor nodes in the WSN compute the residual buffer status and packet processing capacity by Eqs. (1) and (5) respectively. The computed information is transmitted to the mobile sink node. Then the sink node verifies its neighbour nodes residual buffer status and packet processing capacity and compares the values with threshold values, which are computed by Eqs. (2) and (6) respectively. If the computed rate is more than the threshold value then the position of the sink does not change. Otherwise, the sink node position is changed to that sensor node that is nearer and satisfies the threshold status of buffer and packet processing capacity, in the network. The distance between the sink node and the sensor node is computed by the following Eq. (7). The algorithm for the dynamic replacement of the mobile sink node is explained in Algorithm-1.

$$D_i \sum_{i=1}^{n} \sqrt{(X_i - X_s)^2 + (Y_i - Y_s)^2} \quad (7)$$

where,

D_i = Distance between an ith node and mobile sink node

n = number of sensor nodes

(X_i, Y_i) = Location of the i^{th} node, and

(X_s, Y_s) = Location of the sink node

Algorithm-1:- Dynamic replacement of the mobile sink node in the WSN home network

1. Procedure for dynamic replacement of the sink node $(n, CRP, CRP_{Th}, Q_{avrg}, Q_{Thre}, D_i)$
2. Get the location of the n sensor nodes along with the CRP and Q_{avrg}
3. Check the status of the neighbour sensor node of the sink node by

   $if\ (CRP \geq CRP_{Th})\&\&(Q_{avrg} \geq Q_{Thre})$
   {
   The sink node position does not change
   }

   Else
   {
   - Determine the number of sensor nodes that satisfy the threshold status of the buffer and packet processing capacity and also compute the distance between sink nodes and the sensor nodes.
   - Determine the nearest location sensor node, which satisfies the threshold status of the buffer and packet processing capacity

- Displace the sink node to the current position to the neighbour position to the nearer and which satisfies the threshold status of the buffer and packet processing capacity

}

4. Results and Discussion

Performance evaluation of the proposed mechanism is carried out with the help of a network simulator and compared the performance with existing mechanisms such as Nikolaos [27], and ESMML [28], EEMSR [29], in the same network environment with different performance metrics. Table 1 gives the parameters used for the simulation process. The simulation environment consists of 400 numbers of static sensor nodes and a mobile sink node with the RWP (Random Waypoint Mobility) mobility model. Sensor nodes are equipped with a battery of 100 joules of energy and a 250 m radio transmission range. The nodes contain Ethernet with IEEE 802.11 MAC card. Simulation duration is kept as the 1200s. Finally, the sensing node generates a packet size of 512 bytes as a CBR traffic signal. Performance results are the average of 3 scenario performances in the simulation part. All threshold values could be set at network initialization time. Hence, these values can be changed depending on the network's sensitivity and its application [30]. The proposed models EBRS, EBRS-MS, are compared with ESMML [28], EEMSR [29], and NIKOLAS [27].

Table 1: Network model parameters.

Parameters	Standards
Simulation Time	1200 s
Deployed Nodes	100 – 400
Used Layer	Logical Link
Protocol Used (MAC)	802.11
Mobility Type	Random waypoint
Network Layer Used	Distance Vector
Communication Methodology	Two-Ray Ground
Queuing Technique	Drop-Tail priority
Battery Power	100joules
Traffic Model	Constant Bit Rate
Total Application Area	1000m x1000m

The performance evaluation metrics are throughput, packet delivery, network lifetime, and the remaining energy [30], and their results are shown in the Figs. 1-4. Figure 1 show that the average throughput concerning simulation time and it indicates that the existing protocol throughput is very less compared to the proposed work, as the proposed work prevents the packet drop due to constrained resources.

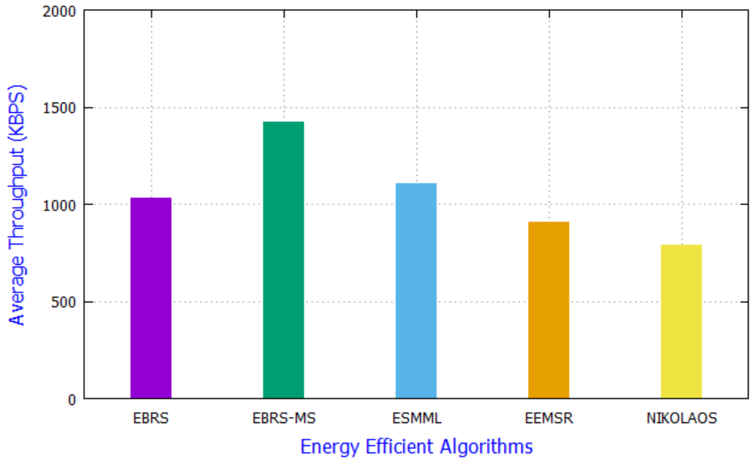

Fig. 1. Average comparison of throughputs for different approaches.

The packet delivery is defined as the packets forwarded between the source nodes to the sink. It can be computed within changeable nodes and time for simulation. As shown in Fig. 2 proposed work outperforms in contrast with the existing work. Figure 2 shows the average packet delivery fraction comparison of existing and proposed works. The results indicating that the proposed work prevents packet drops in the network by avoiding nodes to become the bottleneck.

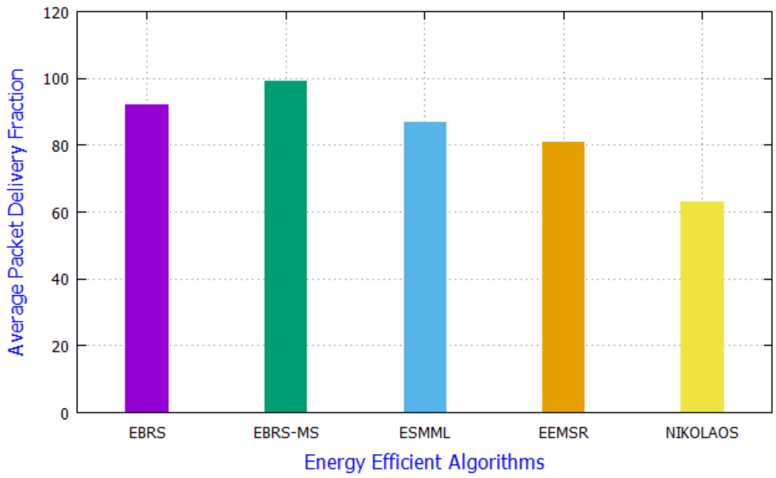

Fig. 2. Output performance of average packet delivery for different approaches.

The metric network lifetime is very important in wireless sensor networks to analyse protocol performance. The lifetime of the nodes is computed with the number of nodes employing their left overpower. Figure 3 shows the network lifetime of proposed and existing mechanisms. Results are indicating that the proposed work extends the network lifetime of WSN, as the proposed work contributes to select the best congestion less node.

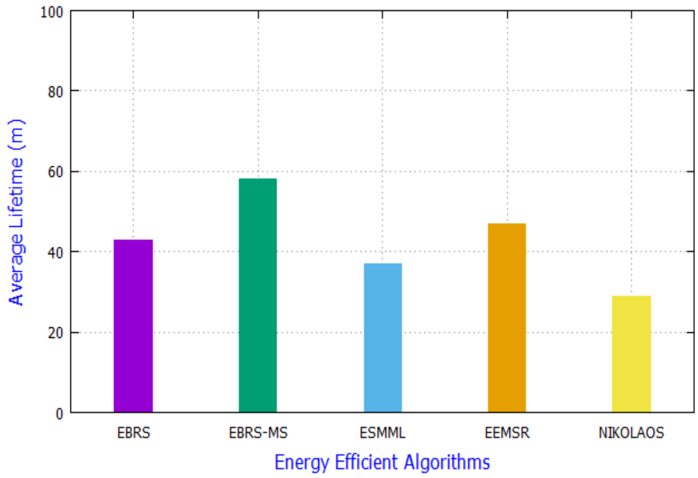

Fig. 3. Network's lifetime **c**omparison **between proposed and existing work based on random mobility sink.**

The remaining energy of the network gives the node residual energy during the communication process in the network. The network remaining energy is computed through the number of nodes as well as simulation time. Figure 4 shows that the remaining energy in the case of the existing protocol is very less, as in this approach the nodes are communicating with the cluster head with the constrained resources.

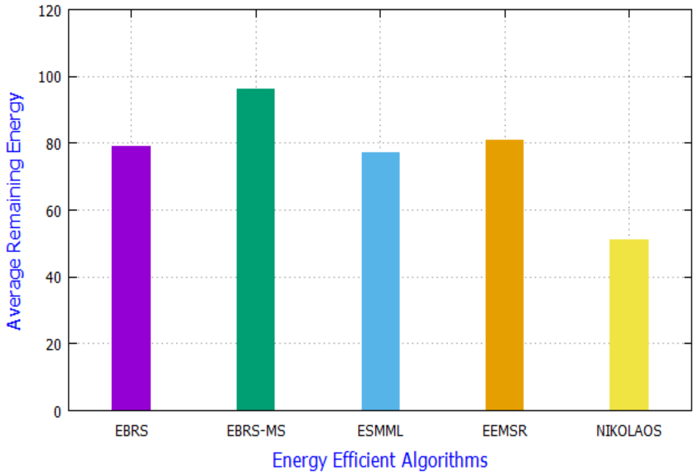

Fig. 4. Comparison of average remaining energy performance **for different approaches.**

The paper compares the proposed work EBSR, and EBSR-MS with the existing energy-based sink mobile routing protocol designed for wireless sensor network i.e., Exploiting Sink Mobility for Maximizing Lifetime [28], An Energy-Efficient Mobile Sink Routing [29], and Nikolaos [27] These routing protocols are based on the residual energy of the neighbour node of the sink node and mobility of the sink nodes. These protocols have proposed a mechanism for using a mobile sink to enhance the lifetime of the network. The protocol achieves the goal by linear optimization to regulate those nodes should be visited by the sink and for how long to maximize the time till the first node in the network dies because of energy depletion. The protocols directly aim at maximizing network lifetime instead of reducing total energy consumption during data communication, which is what was done in previous solutions. On the other hand proposed work is majorly based on the factors of node status regarding buffer and energy. Further, the proposed work aim is to prevent the node to become the bottleneck. Figures 1-4 give performance comparisons of proposed and existing approaches in terms of packet delivery, throughput, lifetime, and energy efficiency. Collectively, the proposed model has shown better results. Hence, we can conclude that our work outperforms while comparing with the recent work.

5. Conclusions and Future Scope

Achieving efficient power and extending the network's lifetime is an active research area in WSN. Thus, WSN needs a routing protocol to address this packet dropping issue. It can be done by managing the data quantity and multi-hops routing path in the transmission region. But the node nearer to the sink node will become the bottleneck and drops the data packets as well as it will exhaust very quickly due to the high load, as the nodes have limited energy and buffer in the network. To overcome these issues, one possible solution is to make the sink node mobile, to move from one place to another place according to neighbour node properties concerning energy and load. Thus, the aim is to change the position of the sink node for getting an energy-efficient and extended lifetime network or to provide mobility to the sink node. Aiming at this concern, in this work, a protocol with energy-efficiency in the wireless network is designed through mobility consideration. The proposed method uses the cluster-based approach for implementing the sink mobile routing protocol, where the node near to sink changes its location depends on the status of the node based on their residual status of buffer and power. It improves the performance of the WSN and reduces packet loss by removing the congested and constrained nodes from the communication path. Moreover, it elaborates the network's lifetime by making a movable sink node based on the load status of its neighbour node. Proposed work is designed based on the factors of node status regarding buffer and energy to prevent the node to become the bottleneck. However, regulate the traffic is also controlled by the efficient MAC mechanism. Thus in our future work, we include the efficient MAC mechanism to regulate the congestion at the node buffer.

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