Energy Efficient Routing Design for Target Tracking in Wireless Sensor Network

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Abstract-The wireless sensor networks (WSNs) provides an advance way for connection of various applications. Most of the applications use the wireless sensor network to transmit the information from the device to the main base station. The main operation of the wireless sensor network is to first sense the data using the sensor, then collect the data and finally transmit to the required base station. The data is transmitted in a timely manner such that the other wireless sensor network transmitting the information should not have any problem. During the transmission of the data the main objective of the wireless sensor network device is to provide reliability to the information which is being sent with less latency and to reduce the energy consumption in order to increase the lifespan of the wireless sensor network. Therefore, this paper presents an Energy Efficient Routing for the Target Tracking (EER-TT) in the wireless sensor network which provides reliability, less latency and reduces the energy consumption during the transmission of the information to the base station. Proposed model also provides a cluster selection method for the routing of the wireless sensor network devices. The results attained show that our model EER-TT shows better results when compared with the existing routing-based models.

Key-words: - Target tracking, Routing, Cluster head selection, Network performance, Energy efficiency, Reliability.

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1 Introduction

Using the wireless sensor network devices provides many benefits because they are small in size, cost is less and the wireless mode of communication helps to communicate to any sensor device easily. The benefits of the wireless sensor networks make the devices more robust. Due to these benefits of the wireless sensor networks, it is used in target tracking application [1]. Moreover, many applications nowadays use target tracking application to track the devices, see the location or to track a target. Hence, wireless sensor network devices provide various solutions for the target tracking applications.

Many of the studies have been going on in the field of target tracking applications and the scholars attained a result that by using the wireless sensor network the tracking task can be done efficiently. But the scholars also found some limitations such as during the transmission of the data the accuracy of the target tracking is reduced [2]. To resolve these issues [3] presented a method which provides a higher accuracy for the target tracking and reduces the consumption of energy during the transmission. Another method was proposed by [4] in which they have used an automata algorithm which tries to find the minimum number of nodes which can reduce the time to transmit the data and provide better Quality-of-service (QoS) requirements which in turn also reduces the energy consumption. Moreover, most of the new wireless sensor network devices use the target tracking prediction method to track the target or to find the location of the target [5]. In [6], they have proposed a method which uses the signal intensity of the node to track the node and provide a better cluster head selection method. During the selection process, the cluster head is identified and selected using the communication range of the cluster head, the amount of information it can carry, and the amount it can fuse to the base station. One of the most important problem that has not been resolved in the wireless senor network for the target tracking applications is to increase the lifespan of the device. In order to increase this, the latency of the wireless sensor device has to be reduced. To resolve this issue, [16] used the evolutionary computing method, in [17], they have used a cluster formation method which reduces the computational overhead. In [18], they developed a routing method in which the packets are sent from the node to the gateway hub utilizing less energy and less packet loss during the transmission. This method did not address the problem of the data transmission latency. Hence, to reduce the network data transmission latency various models have been developed in [7], [22], [23], and [24]. In [8] they have presented a fuzzy method for the selection of the cluster head and in [9] used the multipath-based transmission method. In both [8] and [9] they have attained better results when they have varied with the existing models. Moreover, these models did not consider the environmental conditions for the target tracking applications [10], [11]. This led to the improper scheduling of packet loss and consumed more energy and reduced the overall performance of the target tracking applications [12], [13], [14].

From all these research work, we have built a model, Energy Efficient Routing method for the target tracking applications (EER-TT) for the wireless sensor network. In this model the wireless sensor networks are first placed in various regions of the fixed network area. Then the distance of each of the wireless sensor network which are adjacent to each other is calculated. After this process, the EER-TT model is presented which provides a selection method for the cluster head which provides reliability for the transmission of the data, reduces the energy consumption and increases the network coverage. This method also reduces the communication overhead and the data communication latency and increase the lifespan of the wireless sensor network device.

2 Energy Efficient Routing Design for Target Tracking in Wireless Sensor Network

In this section, the Energy Efficient Routing Design for Target Tracking Applications in the wireless sensor network has been discussed. In this model, the wireless sensor network devices are implanted with the tracking sensor which is provided with a battery to provide power and also to carry out all the sensing operations that a tracking sensor has to perform. Moreover, the wireless sensor network devices are mostly placed in various locations such that it can sense different regions and transmit the data of each region to the edge device for the further data calculation and evaluation. The whole process is given in Fig.1.

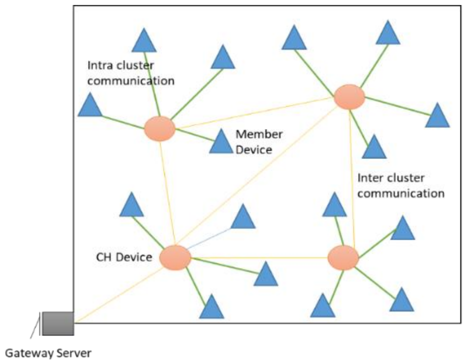

Fig. 1: Framework for our proposed model for target tracking in wireless sensor networks.

2.1 Selection of Cluster Heads for the Wireless Sensor Networks

In this model, first the distance between the overlapping wireless sensor network devices is computed using the wireless sensor network device distance p which is in the region $0 \leq p \leq 2p$. The distance O_F of the overlapping wireless sensor network is calculated using the following equation

$$O_F = 2p^2\left[\theta - \frac{p}{2p}\sqrt{1-\left(\frac{p}{2p}\right)^2}\right], \quad (1)$$

In the Equation (1), the θ is evaluated using the given equation

$$\theta = \cos^{-1}(p/2p). \quad (2)$$

The wireless sensor devices which are normally overlapping is attained using the given equation

$$\omega = O_F/\pi p^2 \quad (3)$$

In above equation the parameter ω is in range between 0 and 1 which can be described as $0 \leq r \leq 1$. Here the r is used to depict the mean ratio of the WSN device cluster head with respect to the particular time. The evaluation of r is done using the given equation

$$r = p/2p, \quad (4)$$

In improving cluster head selection, the distance is normalized probabilistically. Therefore, the normalized coverage is measured as follows

$$r(d) = \propto \times \omega(d), \quad (5)$$

In Eq. (5), the $\propto$ is used to describe the average size of the cluster head. Hence, the improved threshold value $H(d)$ to select a correct cluster head for a given wireless sensor network device d is given using the following equation

$$H(d) = \begin{cases} \frac{r(d)}{1 - r(d) \times [\varphi mod(1/r(d))]}, if\ d \in \bar{S}; \\ 0, \quad Otherwise. \end{cases} \quad (6)$$

In Equation (6), φ is used to denote the current session time (round) and is in the range $0 \leq \varphi < \infty$. $\bar{S}$ is used to denote the value of wireless sensor network device which has not been a cluster head for a long period of time. d is used to denote the cluster head for a current working session $1/r(d)$. Using this method, each of the wireless sensor network device is elected as a cluster head for a given instance of time having different probabilities. After the selection of the cluster head an efficient routing path $L_{\mathcal{M}}$ is established which uses less energy and has less latency using the following equation

$$L_{\mathcal{M}} = \min(\mathcal{E}_v + \mathcal{G}_l). \quad (7)$$

In Equation (7), the $\mathcal{E}_v$ denotes the remaining energy of the wireless sensor network device. $\mathcal{G}_l$ denotes the anticipated hop size. In this work the Equation (7) is minimized that both energy consumption and number of hops required for transmission is reduced. This provides reliability with improved energy efficiency for the wireless sensor network. The result attained by the Energy Efficient Routing Design for Target Tracking in Wireless Sensor Network have been discussed in the result and discussions section.

3 Results and Discussions

In this section the attained results during the experimentation have been discussed. For the execution of the Energy Efficient Routing Design for Target Tracking in Wireless Sensor Network, the Intel quad processor having 8 GB of RAM has been used. Along with theses specifications, Windows 10 has been used with the SENSORIA simulator [19] has been considered for the execution of the code. The code has been scripted in C# and C++ programming language. The target tracking application using H-infinity filter [15] is used for validating model. In [25] the dataset for complex target maneuvering is taken from [26]. The Table 1 shows the parameter used for conducting simulation.

Table 1. Parameters considered for the analysis of performance and reliability for both the proposed model EELLR-TT and the existing model LEACH

Parameter	Value
Simulation area	$100 meters \times 100 meters$
Base stations	1
Number of devices	$400\ to\ 800$
Transmission range	$10\ meters$
Sensing range	$5\ meters$
Initial energy	$0.01\ Joules$
Radio energy consumption	$50\ nj/bit$
Data packets length	$1000\ bits$
Bandwidth	$10000\ bit/sec$
Idle energy consumption	$50\ nj/bit$
Signal amplification energy consumption	$100pJ/bit/m2$

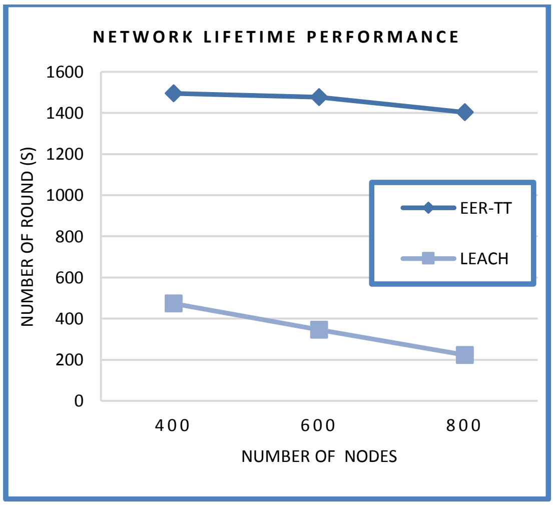

Fig. 2: Lifetime of the wireless sensor network varied with number of nodes.

3.1 Performance of Network Lifetime

In this section the results for the performance of the network lifetime of the nodes has been evaluated using some of the parameter set. The performance has been evaluated by considering a fixed network area where the wireless sensor network devices have been deployed in a fixed region of that area. The results have been shown graphically in the Fig.2. Proposed model shows an improvement of $68.37\%, 76.65\%,$ and 84.12% for $400, 600,$ and 800 wireless sensor network nodes respectively when compared with the existing LEACH model.

The overall network lifetime performance shows an improvement of 78.29% when compared with the LEACH routing-based model.

3.2 Performance of Communication Overhead

In this section the results for the performance of the communication overhead of the nodes has been evaluated using some of the parameter set. The performance has been evaluated by considering a fixed network area where the wireless sensor network devices have been deployed in a fixed region of that area. The results have been shown graphically in the Fig.3. Proposed model shows a reduction of 16.81%, 9.01% and 34.39% for 400, 600, and 800 wireless sensor network nodes respectively when compared with the existing LEACH model. The overall network lifetime performance shows an improvement of 25.19% when compared with the LEACH routing-based model.

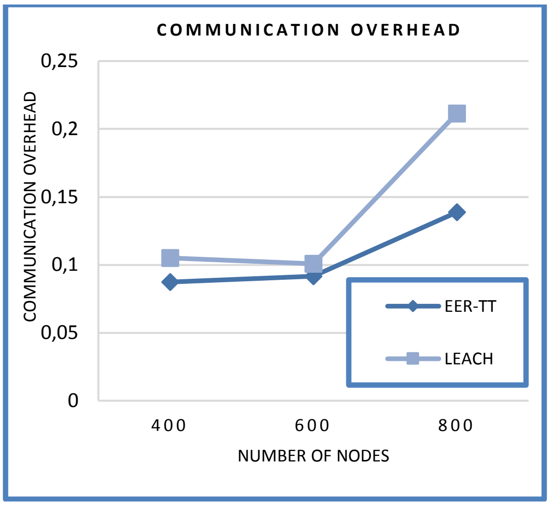

Fig. 3: Performance of Network Communication Overhead varied with number of nodes.

3.3 Performance of Data processing Latency

In this section the results for the performance of the data processing latency of the nodes has been evaluated using some of the parameter set. The performance has been evaluated by considering a fixed network area where the wireless sensor network devices have been deployed in a fixed region of that area. The results have been shown graphically in the Fig.4. Proposed model shows a reduction of 57.76%, 52.34%, 59.46%, for 400, 600, and 800 wireless sensor network nodes respectively when compared with the existing LEACH model. The overall data processing latency shows an improvement of 52.83% when compared with the LEACH routing-based model.

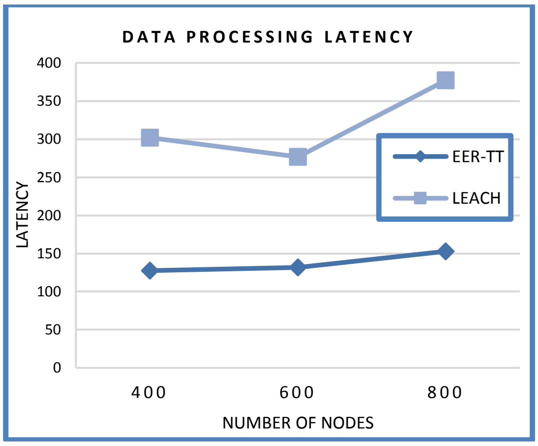

Fig. 4: Performance of Network Data Processing Latency varied with number of nodes.

3.4 Performance of Routing Overhead

In this section the results for the performance of the routing overhead of the nodes has been evaluated using some of the parameter set. The performance has been evaluated by considering a fixed network area where the wireless sensor network devices have been deployed in a fixed region of that area. The results have been shown graphically in the Figure 5. Our model shows a reduction of 56.48%, 51.45%, 57.69%, for 400, 600, and 800 wireless sensor network nodes respectively when compared with the existing LEACH model. The overall routing overhead shows an improvement of 55.21% when compared with the LEACH routing-based model.

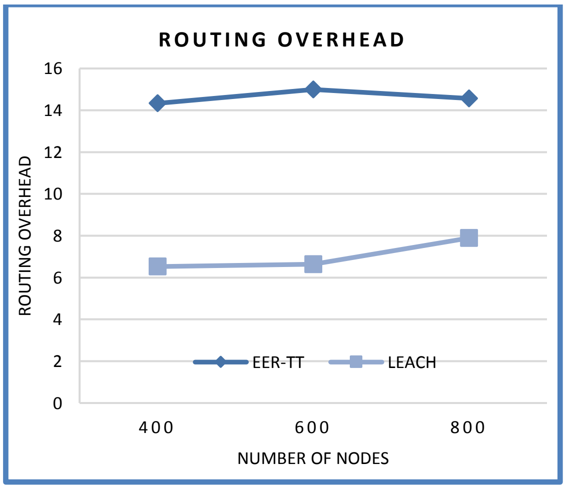

Fig. 5: Performance of routing overhead varied with number of nodes.

3.5 Comparison of the Proposed EER-TT Method and other Existing Methods

In this section, we have compared EER-TT model with the existing models. The results attained by EER-TT model show that it has outperformed all the existing models that either have used the fuzzy-based routing method or swarm optimization method such as PFuzzy ACO (Particle-Fuzzy Ant Colony Optimization) [8], MDT-FCSO (Multipath Data Transmission Fuzzy Cat Swarm Optimization) [9], and EER [20]. The comparison results have been given in the Fig.6 which has been described below.

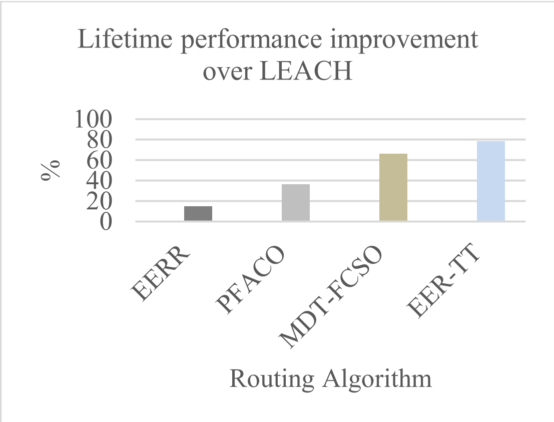

Fig. 6: Proposed EER-TT model compared with the existing routing models.

4 Conclusion

This paper presents an Energy Efficient Routing Design for Target Tracking (EER-TT) in Wireless Sensor Network. The main aim of the wireless sensor network in the target tracking application is to reduce the consumption of energy. Many existing methods have been proposed to reduce the consumption of energy in the wireless senor network but have failed to provide reliability. Most of the futuristic applications for the target tracking require less energy consumption and reliability such that if any failure occurs it should be able to transmit the data through some node or an of the wireless sensor network. Many techniques have failed to provide the latency also in the wireless sensor networks. Some of the existing techniques have used the fuzzy-based methods and swarm optimization method to resolve these issues by transmitting the data using a multipath but failed due to the varying nature of the wireless sensor network. Hence, due to these problems many packets are lost. Our EER-TT model provides less consumption of energy, less latency, more reliability and computation overhead. Our model has been compared with the existing system and the results show that our model has better performance when compared with the existing routing-based methods.

For the future development of our model, we would consider to measure the packets which have been lost during the transmission and also to develop a multi-objective routing method in order to improve the latency in the inter-cluster data communication. We would also try to evaluate the routing performance of the target tracking applications by considering various kind of filters.

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