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Review Article

A SURVIVAL STUDY ON DATA GATHERING AND TARGET TRACKING TECHNIQUES FOR ENERGY EFFICIENT ROUTING IN WSN

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Abstract
Wireless Sensor Network comprises thousands of small sensor nodes in a physical environment for monitoring and reporting the events. Wireless sensor networks (WSNs) are forecasted for gathering the data like physical or environmental properties from geographical area. Data gathering is based on the wireless communications between the sensor node and the sink node. Target tracking and multiple data collection are significant application in wireless sensor network. In Wireless Sensor Network, sensor nodes are used to sense the target object with minimum energy and collect data from different locations. However in existing techniques during routing, data gathering and target tracking, the energy consumption was not reduced and network lifetime was not improved. Our key objective is to reduce the energy consumption and data gathering efficiency during the data gathering and target tracking process in WSN. In this work, a survey is carried out with existing techniques for attaining higher energy efficient routing and maximal data gathering efficiency with minimal target tracking time in WSN.

Keywords: Wireless Sensor Network, Data gathering, Routing, Target tracking, Geographical area, energy consumption

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INTRODUCTION

Wireless sensor networks (WSNs) include many number of sensor nodes in network area. Every sensor node has capability to collect, process and forward the sensed data packets to one or more sink nodes through their wireless transceiver in multihop way. In WSN, routing is the process of selecting the path in a network across multiple networks. Routing is an essential one due to its utilization of computationally-constrained and resource-constrained micro-sensors. Routing process transfers the data packets from source to the destination. Data collection is the process of gathering the information on targeted node in systematic manner. Target tracking is an essential application in WSN where the sensor nodes monitor and report the positions of moving objects to the application's user with a minimum latency.

This paper is structured as follows: Section II discusses review on various energy efficient data gathering and target tracking techniques in wireless sensor network, Section III portrays the study and analysis of the existing routing and data gathering techniques in WSN, Section IV describes the possible comparison between them. In Section V, the discussion and limitations of existing techniques are studied and Section VI concludes the paper. The key area of research is to improve the performance of energy consumption and data gathering efficiency in WSN using machine learning techniques and ensemble techniques.

LITERATURE REVIEW

A heuristic termed weighted rendezvous planning (WRP) was introduced in [1] where every sensor node was allocated with weight similar to its hop distance from tour. However, the reliability in terms of time was not improved using weighted rendezvous planning. A mobile collector termed SenCar gathers the data from sensors and equalized the energy consumption in network. An adaptive anchor selection algorithm in [2] balancing between data collection and latency. A two-step method was designed for mobile data collection. But, the energy consumption remained unaddressed. A new distributed energy-efficient mobile sink routing protocol called Ring Routing was introduced in [3] for time-sensitive applications to reduce the routing overhead while preserving the benefits of mobile sinks. Though the routing overhead was reduced, the energy consumption was not reduced in efficient manner.

A new technique called mobile node rotation was introduced in [4] for low-cost mobile sensor nodes to address the power consumption and increased the WSN lifetime. Though the network lifetime was improved, the reliability was not increased. An energy-efficient hybrid routing method was designed in [5] for WSNs with mobile sink joining proactive and reactive schemes. But, the packet delivery ratio was not improved using energy-efficient hybrid routing method. A rendezvous-based routing protocol in [6] created the rendezvous region in middle of network and constructed a tree within the region. But, rendezvous-based routing protocol increased delay during the data transmission. A smooth path construction algorithm was designed in [7] depending on TSP. Then, the algorithm was extended with path adjustments depending on required contact time at every node. Though the delay was reduced, the network lifetime was not improved using smooth path construction algorithm.

A new algorithm was introduced in [8] for efficient trajectory in Mobile sink (MS) depending on rendezvous points (RPs). A new algorithm was introduced for addressing the same issue with delay bound path formation of MS. Though the data gathering was performed in efficient manner, the target tracking accuracy was not improved. A collection of fully distributed tracking algorithms in [9] responded to the queries like whether target remains in particular area. But, the target tracking time was not reduced using fully distributed tracking algorithms. A virtual grid based dynamic routes adjustment (VGDRA) scheme in [10] minimized routes reconstruction cost of sensor nodes while preserving the optimal routes to newest location of mobile sink. Though the cost was reduced, VGDRA scheme failed to improve the reliability.

An efficient routing recovery protocol with endocrine cooperative particle swarm optimization algorithm (ECPSOA) was designed in [11] to optimize the alternative path. In

ECPSOA, mutation direction of particle is identified by multi-swarm evolution equation. However, the routing delay remained unaddressed by using ECPSOA. A new routing metric called Contact-Aware ETX (CA-ETX) was designed in [12] to compute the packet transmission delay caused through packet retransmissions and intermittent connectivity. But, the routing overhead was not reduced using Contact-Aware ETX. New mobile access coordinated wireless sensor network (MC-WSN) architecture was described in [13]. However, the energy consumption was not reduced using MC-WSN architecture.

A new routing design algorithm depending on Variable Dimension Particle Swarm Optimization (VDPSO) was introduced in [14]. But, the network lifetime was not improved using VDPSO algorithm. A Distributed Data Gathering Approach (DDGA) in [15] was functioned by sensors to attain the optimal data gathering scheme. But, the classification was not performed during data gathering. Robust Ad-hoc Sensor Routing (RASeR) is a new protocol for data routing in mobile wireless sensor networks (MWSNs) in [16]. But, the latency was not reduced beyond certain level using Robust Ad-hoc Sensor Routing.

DATA GATHERING AND TARGET TRACKING TECHNIQUES FOR ENERGY EFFICIENT ROUTING IN WSN

Wireless Sensor Network is a self-organized network with small computing and communication nodes in different environments. In WSN, nodes are battery operated where they are monitored and report the collected information to sink node or base-station for future processing and analysis. Sink mobility helps to balance the nodes energy dissipation and link isolated network segments in difficult regions. Data gathering problem is a network utility maximization issue for improving the data packets collected by mobile sink while preserving the network.

Energy-Efficient Mobile-Sink Path Selection Strategy for Wireless Sensor Network

A hybrid unconstrained movement model for mobile sink is used for minimizing the energy consumption of sensor nodes. The direct data gathering issue from sensor nodes becomes unfeasible incase of many sensor nodes. Every sensor node visiting increases the mobile sink's traveling path length and leads to sensor nodes experiencing buffer overflow due to the data collection delays. A rendezvous-based model is introduced where the mobile sink visits subset of sensor nodes termed RPs. The sensor nodes outside the mobile sink path send data through multihop communications to RPs. The problem of finding the set of RPs visited by mobile sink is described. The main aim is to reduce the energy consumption through multihop transmissions from sensor nodes to RPs. It also reduces the number of RPs in order to limit the resulting tour below the deadline of data packets. The sensor nodes in dense parts of WSN transmit large number of packets. The priority assignment to sensor nodes in dense parts in tour computation minimizes the congestion points as well as energy consumption and increases the WSN lifetime. It also reduces the energy-hole problem.

A delay-aware energy-efficient path (DEETP) is an NP-hard problem addressed by heuristic method termed weighted rendezvous planning (WRP) for identifying the mobile-sink node. In WRP, the sensor nodes are connected with large number of connections to other nodes and positioned away from computed tour in terms of hop count with higher priority. WRP identifies the near-optimal traveling tour for reducing the energy consumption of sensor nodes. WRP assigns the weight to sensor nodes with forwarded number of data packets and hop distance. WRP helps to choose the sensor nodes with the highest weight. The selected sensor node transmits the large number of data packets with best hop distance from tour with minimal network energy consumption. The hop distance between sensor nodes and RPs minimizes the multihop transmissions. Rendezvous planning utility-based greedy (RP-UG) minimizes network energy consumption by reducing the physical distance between sensor nodes and RPs.

Optimization Framework for Mobile Data Collection in Energy-Harvesting Wireless Sensor Networks

An environmental energy harvesting is a promising technique to present the sustainable energy sources for battery-powered wireless sensor networks (WSNs). A two-step method is introduced for mobile data collection in energy harvesting sensor networks. The initial step is to identify the anchors and find out the shortest tour between them within bounded threshold that represents the data collection delay upper bound. The anchors are representative sensor nodes for gathering the data packets. SenCar ends near anchor simultaneously to collect all data. A difference between anchor and sink node is choice of anchors that are adaptive to energy status/harvesting rates and not same in particular time period. The sink nodes are static and selected by network administrators in network initializations.

Delay represents the time period from packet generation to the time taken by the packet for uploading to the base station. SenCar is adapted from off-the-shelve battery-powered vehicle. It provides with components, radio transceivers and location device from the base station to perform dissimilar tasks in sensing field. The distance is taken as euclidean distance between any locations in field. In presence of any obstacles or barriers, SenCar recalculates the route. In second step depending on selected anchors, the data rate of each sensor node, flow routing and optimal sojourn time are identified for SenCar at every anchor through addressing the communication optimization problem. In two-step method, the data communication algorithm considers anchors as an input to execute single optimization run where the overhead are acceptable. An optimal solution at a particular time instant is not optimal after certain time period. Then, finding of sub-optimal solution is cost-effective one.

A new two-step method is designed by introducing mobile data collection for energy harvesting sensor networks. An adaptive anchor selection algorithm is designed for SenCar while balancing between data collection and latency. For selected anchors, distributed algorithms are introduced to recognize the optimal data rates, link flows for sensors and time allocation for SenCar. The method converges to optimum, respond to dynamics of energy income, preserve perpetual network operation and increase the network utility.

Ring Routing: An Energy-Efficient Routing Protocol for Wireless Sensor Networks with Mobile Sink

A new hierarchical routing protocol termed Ring Routing is introduced with mobile sink for WSNs. The designed protocol includes three parts on sensor nodes, namely ring node, regular node and anchor node. Ring nodes create the ring structure in a closed loop of single-node-width. Ring Routing is advertisement of sink position to ring, regular nodes for collecting the sink position information from ring when required and nodes distributing the data through anchor nodes. Anchor nodes acts as intermediary agents linking the sink to the network. The three sensor roles are not stationary where the sensor nodes change positions in WSN operation.

Sensor nodes are susceptible to own positions. The position information is depending on global or local geographic coordinate system consistent with the deployment area. The nodes position is identified by satellite based positioning system like global positioning system (GPS) or energy-efficient localization techniques in WSNs. Every sensor node knows the position of its neighbors. The information allows the greedy geographic routing and attained using neighbor discovery protocol. The coordinates of network center point are identified by all sensor nodes.

Ring Routing is routing protocol aimed for large-scale WSNs positioned outdoors with sensor nodes and mobile sink. Ring Routing forms virtual ring structure that allocates the sink position to get easily delivered to the ring and regular nodes to obtain the sink position from ring with minimum overhead when required. The ring nodes control the roles with the regular nodes by efficient mechanism and reduce the hotspot problem. The mobile sink chooses the anchor nodes along their path and anchor nodes relay sensor data to the sink. When the sink position information attained through dropping freshness of sensor node, the sensor data is relayed through old anchor nodes to current anchor node without any packet loss. The designed mechanism uses the progressive footprint sequencing.

Ring Routing depends on lesser broadcasts. Ring Routing is used for sensors with help of asynchronous low-power MAC protocols in WSNs. Ring Routing failed to have MAC layer needs apart from the support for broadcasts. Ring Routing function with any energy-aware, duty cycling MAC protocol. Ring Routing is used for event-driven and periodic data applications. Ring Routing presents fast data delivery because of the immediate accessibility of ring structure and used for time-sensitive applications.

The sink motion information is not required for Ring Routing to operate. The ring routing failed to depend on predicting sink's trajectory and used for random sink mobility scenarios. Ring Routing employs the greedy geographic routing. Geographic routing is scalable and energy-efficient for WSNs. Geographic routing needs the local knowledge to function. Nodes at every hop transmit the data to neighbors near destination position. For minimizing the problems in identifying the routes in topology defects, many protocols are designed for increasing the geographic routing.

COMPARISON OF ENERGY EFFICIENT DATA GATHERING AND ROUTING TECHNIQUES IN WSN & SUGGESTIONS

In order to compare the energy efficient data gathering and routing techniques in wireless sensor network, number of nodes is taken to perform the experiment. Various parameters are used for improving the performance of energy consumption and data collection efficiency during data gathering and routing in WSN.

Energy Consumption (EC)

Energy Consumption is defined as the amount of energy consumed for routing the collected data packets to the mobile sink node. EC is given by the product of number of sensor nodes and energy consumed by one sensor node. It is measured in terms of Joules (J). The energy consumption is formulated as,

$$EC = Energy_{SN} * Total_{SN} \quad (1)$$

From (1), 'EC' denotes the energy consumption, '$Energy_{SN}$' represents energy consumed by single sensor node and '$Total_{SN}$' symbolizes the total number of sensor nodes. When the energy consumption is lesser, the method is said to be more efficient.

Table 1. Tabulation for Energy Consumption

Number of Sensor Nodes (Number)	Energy Consumption (Joules)		
	WRP Method	Adaptive anchor selection Algorithm	Ring Routing Protocol
10	23	45	54
20	26	48	58
30	30	51	63
40	32	55	67
50	35	58	71
60	39	62	75
70	42	67	79
80	46	70	83
90	49	73	85
100	54	77	89

Table 1 describes the energy consumption with respect to number of sensor nodes ranging from 10 to 100. Energy consumption comparison takes place on existing Weighted Rendezvous Planning (WRP) method, Adaptive anchor selection Algorithm and Ring Routing Protocol. From the table value, it is clear that the energy consumption using Weighted Rendezvous Planning (WRP) method is lesser when compared to Adaptive anchor selection Algorithm and Ring Routing Protocol. The graphical representation of energy consumption is shown in figure 1.

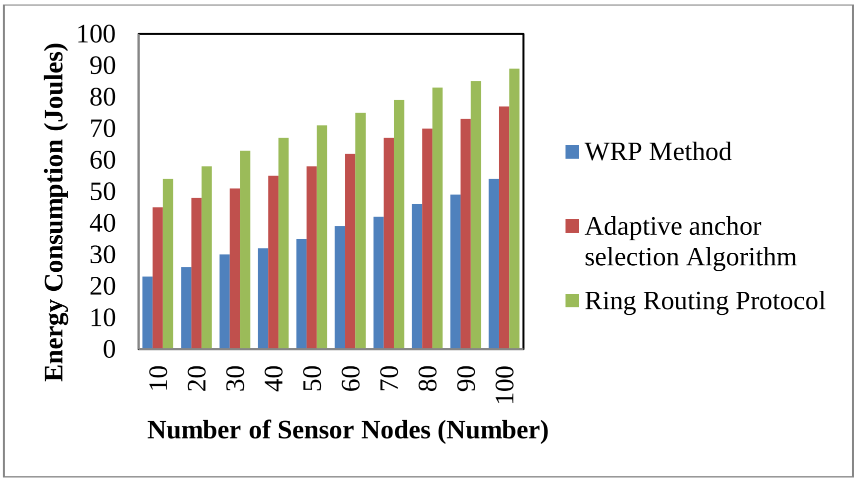

Figure 1. Measure of Energy Consumption

As shown in figure 1, energy consumption based on the different number of sensor nodes are illustrated. From the figure 1, Weighted Rendezvous Planning (WRP) method consumes lesser energy than Adaptive anchor selection

Algorithm and Ring Routing Protocol. While increasing the number of sensor nodes, the energy consumption is also increased correspondingly in all methods. Research in Weighted Rendezvous Planning (WRP) method consumes 65% lesser energy than Adaptive anchor selection Algorithm and 49% lesser energy than Ring Routing Protocol.

Data Gathering Efficiency

Data gathering efficiency is defined as the ratio of number of data packets that are gathered efficiently to the total number of data packets. It is measured terms of percentage (%). The data gathering efficiency is given by,

$$Data\ Gathering\ Efficiency = \frac{Number\ of\ data\ packets\ that\ are\ gathered\ efficiently}{Total\ number\ of\ data\ packets} * 100$$

When the data gathering efficiency is higher, the method is said to be more efficient.

Table 2. Tabulation for Data Gathering Efficiency

Number of Data Packets (Number)	Data Gathering Efficiency (%)		
	WRP Method	Adaptive anchor selection Algorithm	Ring Routing Protocol
10	64	75	58
20	67	78	60
30	70	80	63
40	72	82	66
50	74	85	69
60	77	87	71
70	80	90	73
80	82	92	76
90	85	94	79
100	88	96	82

Table 2 describes the data gathering efficiency with respect to number of data packets ranging from 10 to 100. Data gathering efficiency comparison takes place on existing Weighted Rendezvous Planning (WRP) method, Adaptive anchor selection Algorithm and Ring Routing Protocol. From the table value, it is clear that the data gathering efficiency using Adaptive anchor selection Algorithm is higher when compared to Weighted Rendezvous Planning (WRP) method and Ring Routing Protocol. The graphical representation of data gathering efficiency is shown in figure 2.

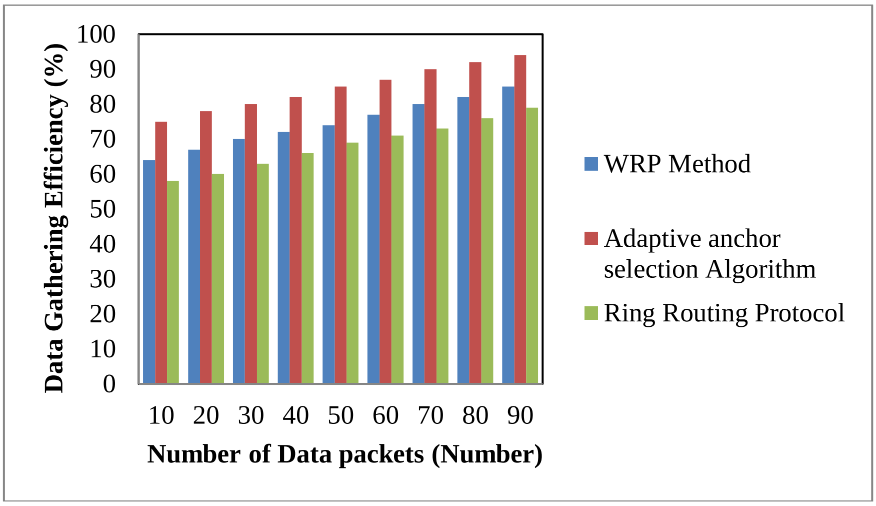

Figure 2. Measure of Data Gathering Efficiency

From figure 2, data gathering efficiency based on the different number of data packets are described. Adaptive anchor selection Algorithm has higher data gathering efficiency than Weighted Rendezvous Planning (WRP) method and Ring Routing Protocol. While increasing the number of data packets, the data gathering efficiency is also increased correspondingly in all methods. Research in Adaptive anchor selection Algorithm has 13% higher data gathering efficiency than Weighted Rendezvous Planning (WRP) method and 24% higher data gathering efficiency than Ring Routing Protocol.

Target Tracking Time (TTT)

Target tracking time is defined as the amount of time taken for target tracking in wireless sensor network. TTT is the difference of ending time and starting of target tracking in WSN. It is measured in terms of milliseconds (ms). The mathematical formula for target tracking time is given by,

$$TTT = ending\ time - starting\ time\ for\ targe\ tracking$$

When the target tracking time is lesser, the method said to be more efficient.

Table 3. Tabulation for Target Tracking Time

Number of Sensor Nodes (Number)	Target Tracking Time (ms)		
	WRP Method	Adaptive anchor selection Algorithm	Ring Routing Protocol
10	32	28	25
20	35	31	28
30	41	36	32

40	43	40	35
50	49	43	37
60	52	45	41
70	55	48	44
80	58	50	46
90	62	52	48
100	65	55	50

Table 3 describes the target tracking time with respect to number of sensor nodes ranging from 10 to 100. Target tracking time comparison takes place on existing Weighted Rendezvous Planning (WRP) method, Adaptive anchor selection Algorithm and Ring Routing Protocol. From the table value, it is clear that the target tracking time using Ring Routing Protocol is lesser when compared to Weighted Rendezvous Planning (WRP) method and Adaptive anchor selection Algorithm. The graphical representation of target tracking time is shown in figure 3.

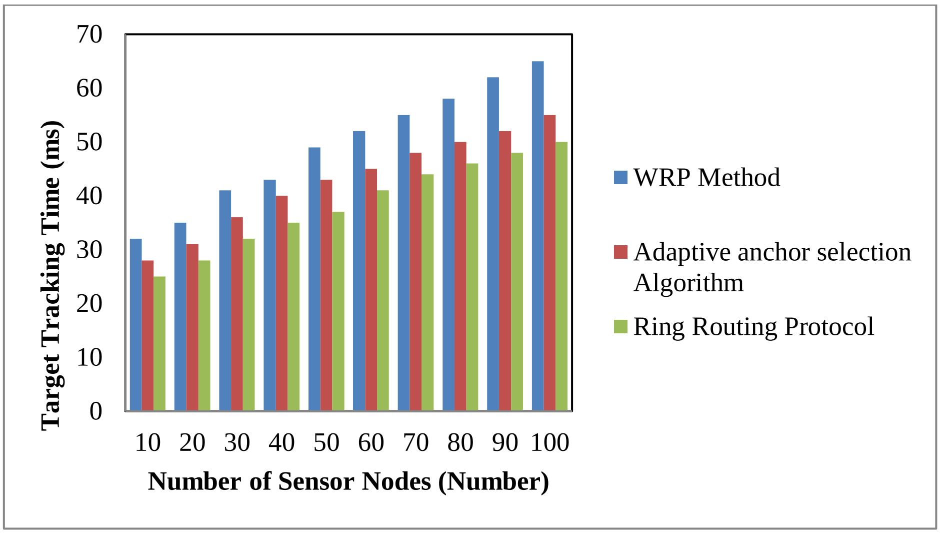

Figure 3. Measure of Target Tracking Time

As shown in figure 3, target tracking time based on the different number of sensor nodes is explained. Ring Routing Protocol consumes lesser time for target tracking than Weighted Rendezvous Planning (WRP) method and Adaptive anchor selection Algorithm. While increasing the number of sensor nodes, the target tracking time is also increased correspondingly in all methods. Research in Ring Routing Protocol consumes 27% lesser target tracking time than Weighted Rendezvous Planning (WRP) method and 10% lesser target tracking time than Adaptive anchor selection Algorithm.

DISCUSSION ON LIMITATION OF DATA GATHERING AND TARGET TRACKING TECHNIQUES

A heuristic called weighted rendezvous planning (WRP) was designed where each sensor node allocated weight corresponding to its hop distance from tour and the number of data packets that forwards to the closest RP. Heuristic method identifies the near-optimal traveling tour and reduced the energy consumption of sensor nodes. Weighted rendezvous planning minimized the data collection delays. But, the reliability was not improved using weighted rendezvous planning. An adaptive anchor selection algorithm was introduced for SenCar when balancing between the data collection quantity and latency. A distributed algorithm was designed to identify the optimal data rates, link flows for sensors and time allocation. An adaptive algorithm searched the nodes based on their energy and assured that the data collection tour length was bounded.

Ring Routing is an energy efficient, reliable routing protocol that provided the fast data delivery. Ring Routing was the routing protocol for large-scale WSNs with sensor nodes and mobile sink. Ring Routing depend on minimal amount of broadcasts and it is applicable for sensors utilizing asynchronous low-power MAC protocols. Ring Routing failed to need any MAC layer except the support for broadcasts. Ring Routing does not depend on predicting the sink's trajectory. Ring Routing is suitable for random sink mobility scenarios. But, the energy consumption was not reduced in efficient manner.

Future Direction

The future direction of target tracking and data gathering in wireless sensor network can be carried out using machine learning techniques and ensemble classifiers for energy efficient routing with minimal target tracking time and higher data gathering efficiency.

CONCLUSION

A comparison of different existing target tracking and data gathering techniques in wireless sensor networks are studied. From the study, the existing techniques resulted in higher target tracking time and consumed large amount of energy. A review shows that the reliability in terms of time was not enhanced using weighted rendezvous planning. In the existing techniques, the latency remained unaddressed. In addition, the routing overhead was not reduced using Contact-Aware ETX. The wide range of experiments on existing techniques computes the relative performance of the many data gathering and target tracking techniques with its limitations. Finally, from the result, the research work can be carried out in wireless sensor network for target tracking and data gathering using machine learning techniques and ensemble classifiers.

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