Efficient Routing Protocol for Wireless Sensor Networks based on Centralized and Distributed Heuristic methods

Swetha K[1], Hussana Johar R B[2], Dr.B.R.Sujatha[3]

[1] M.Tech Student, Department of ECE, GSSSIETW Mysuru, Karnataka, India
[2]Assistant Professor, Department of TE, GSSSIETW Mysuru, Karnataka, India
[3]Associate Professor, Department of ECE, MCE Hassan, Karnataka, India

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Abstract - ***The use of technology for environment and management has given way to increasing interest in the design and implementation of Wireless sensor networks (WSNs) in recent era. They are conquered with many challenging problems and inferences such as energy utilization, network lifetime and delivery of data within time frame need to be addressed while performing routing techniques, the tiny sensor nodes are battery operated and randomly deployed in harsh environment. To achieves the entire core challenges of the network operations. A new Energy-Efficient Delay–Aware Lifetime-Balancing (EDAL) protocol facilitates the reliable routing scheme for WSNs using centralized and distributed heuristic based on the tabu search and ant colony status gossiping routing techniques. An extensive simulation studies to rigorously evaluate the performance of proposed algorithms C-EDAL and D-EDAL using MATLAB. The simulation results shows that the heuristic approach reduces its computational overhead, scalability and efficient for large scale networks.***

Key Words: *Wireless Sensor Network, Centralized Heuristic, Distributed Heuristic, Scalability*

1. INTRODUCTION

In recent years, wireless sensor networks are considered among the most interesting technologies in the communication and networking field. It has received tremendous attention from academia and industry all over the world. A WSN typically consists of a more number of multifunctional, low-power and low-cost sensor nodes, with different sensing range, computation and wireless communication capabilities. And communicates over a short distance through wireless medium and collaborate to accomplish a common task, for example, military surveillance, industrial process control, environment monitoring, structural monitoring, and scientific observation. The basic philosophy behind WSNs is the capability of each individual sensor node is limited resource, the aggregate power of the entire network is sufficient for the required mission [1].

WSN may contain one or more base stations (BS) and hundreds of sensor nodes that are deployed either randomly or manually over a particular region of interest. Once the nodes are deployed, they have the ability to organize themselves into a wireless network and collaborate with each other to sense and get the information from the environment, perform data processing, aggregate the data, and send them to the BS [2]. The BS is a node with high capabilities and unlimited power that acts as a gateway to other networks. Many sensing applications share in common that their source nodes deliver packets to sink nodes via multiple hops, this leads to the problem on how to find routes that enable all packets to be delivered within required time frames, and simultaneously taking into account factors such as energy efficiency and load balancing

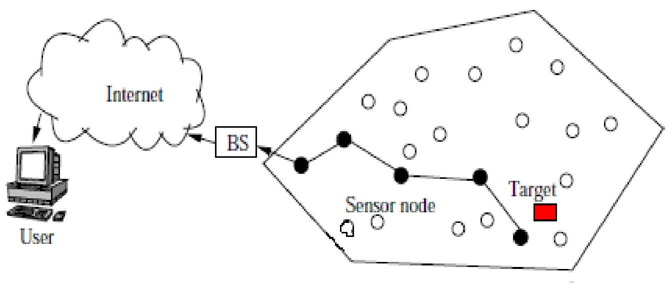

Fig-1: wireless sensor network

Depending on various applications, the sensor network is studied in homogeneous mode or may be in heterogeneous mode. Usually in homogeneous network, all the sensor nodes are considered to have similar physical and networking properties where in heterogeneous network, all the sensor nodes are considered to have multiple perceptive properties. Also, sensor networks are usually distributed in nature where sensor nodes are placed in short range communication range along with different computational capabilities. Hence, sensor nodes can be distributed either uniformly or in randomly. A base station is decided based on the application, where sometimes the base station is either deployed on the center of the distributed region or in some other specific location depending on the needs of applications [3].

2. EDAL ALGORITHM DESIGN

The EDAL protocol is proposing to achieve the entire core challenges of the sensor network, the OVR problem is analyzed and centralized and distributed heuristic algorithms are developed

2.1 Mathematical Model

There are N sensor nodes deployed randomly, which are modeled by a connectivity graph of G = (V, E), where E represents wireless links between nodes. Each link is assumed to be directional, and associated with a metric q indicating its link quality. In the sensing tasks performance, there are M nodes selected as sources. All packets must be sent to the sink within a required time deadline of d. function of the delivery tasks is aiming that all packets need to be delivered with the minimum total cost. A list notations used is as shown in Table1. Based on these notations, each link l_{ij} Є E and each route k, then x_{ijk} as

$$x_{ijk} \begin{cases} 1, & \text{if route k contains link } l_{ij} \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Next initialize cij for links with appropriate values. If the link quality is poor then the link cost should be proportionally higher. And also to meet our objective of lifetime balancing, higher weight to be assigned to those links connecting nodes with less remaining energy, therefore such links will be less frequently selected by the algorithm. Based on these criteria, developing the following formula to assign cij with values

$$c_{ij} = \frac{L - \min l_i, l_j}{q_{ij} \times q_{ji}} \times T_{tpi} \times t_{ij} \quad (2)$$

Where,

$$l_i = L \times \frac{e_i}{E_{max,tp_i}} \quad (3)$$

The Equation 3 defines for computing the remaining energy level of node i. and the ceiling value is computed to differentiate fully energy depletion and almost energy depletion. Combination of Equation 3 and 4 ensure that those nodes with less remaining energy or poor communication links will have a lower chance of being selected as forwarders. Then formulation of optimization objective, which is delivering all packets to the destination under the constraint that no packet has violated the time deadline such as follows.

$$\min \sum_{k\in K} \sum_{i\in N} \sum_{j\in N} c_{ij} x_{ijk}$$

(4)

$$\sum_{j\in N} x_{0jk} = 1 \qquad \forall k \in K \quad (5)$$

$$\sum_{i\in N} x_{ihk} - \sum_{j\in N} x_{hjk} = 0 \quad \forall h \in (N - \{p_{k1}\}), \forall k \in K \quad (6)$$

$$\sum_{i\in p_k, j\in p_k} t + \frac{t_{ij}}{q_{ij}} < \forall p \in R_k \; d_{pt_{kp}} \qquad \forall k \in K \quad (7)$$

Table-1: Notations of EDAL

N	Total number of nodes
M	Total number of source nodes
E	Total number of links
K	Total number of routes
L	Maximum level of node energy
E_{max}	Total energy of each node
T_s	The transmission power of node in type s
P_{kp}	The p^{th} packet transmitting on path k
l_{ij}	The link connecting node i and j
q_{ij}	The link quality of the link l_{ij}
c_{ij}	The weight of the link l_{ij}
t_{ij}	The time for transmitting a packet over l_{ij}
e_i	The current remaining energy of node i
l_i	The current energy level of node i
d	The delay requirement of packet
t_i	The processing time on node i

Where the objective of the equation (4) is to minimize the total communication cost, and if two approaches lead to the same cost, then one with lesser number of participation nodes should be selected. The equations (5), (6) and (7) ensures the functions such as

- All routes must end at the sink.
- The number of routes incoming a node should be the same as the number of routes outgoing, if the node is not located at the beginning of a route.
- The time for the packets being transmitted on the routes should not violate packet delay requirements.

2.2 Analysis of Open Vehicle Routing Problem

In this section we prove that the mentioned formulation is NP-hard.

Theorem 1: The problem of finding the minimum cost routes to deliver packets within their deadlines.

Proof: To prove this timidity, we have to select a known NP hard problem and certify that in polynomial measures, it can be reduced to our problem. The article NP-hard problem we select is the open vehicle routing problem with time deadlines (OVRP-TD), which is a contrary of vehicle routing problem with time windows (VRPTW). The problem aims to find the minimum cost routes from one point to a set of scattered points and has been proven as NP-hard. Formally, the problem is defined as follows, A graph G = (V, E) with n + 1 vertices V and a set of edges E. Let V contain 1 depot node and n customer nodes that need to be served within specified time frames. Each edge in E has a nonnegative weight, d_{ij} , and a travel time tr_{ij} . Partially, tr_{ij} includes the service 4 time on node i, which we denote as ts_i and the transportation time from node i to node j, which we denote as tl_{ij}, The objective is to minimize the total travel cost with the involvement of smallest number of vehicles.

Then now show that OVRP-TD can be reduced to our problem within polynomial steps. The graph G in OVRP-TD can be easily transformed to a corresponding sensor network topology by representing vertices with sensor nodes. The depot corresponds to the sink node or base station, and the customers correspond to the source nodes. The cost of the edges d_{ij} is a little tricky to handle, Specifically, To solve Equation (2) by adjusting the values of l_i, l_j , or the link quality q conveniently. On the other hand, although, the link quality q is actually determined since it is related to the transmission time from i to j. then given tl_{ij} as a known parameter in the OVRP-TD formulation, and obtain the appropriate value of q by enforcing that $t_{ij}=q_{ij}$ (in WSN formulation) = tl_{ij} (in OVRP-TD formulation). Memorize that t_{ij} is the minimum transmission time of a packet over link l_{ij}, when links are unreliable then multiple transmissions are needed to achieve reliable delivery of data. Because each transmission is absolute, the expected number of transmission rounds is $1=q_{ij}$. Therefore, the total transmission time is $t_{ij}=q_{ij}$. Since t_{ij} is a steady parameter depending on the radio hardware and bandwidth, we can decide appropriate q_{ij} for each link from tl_{ij} . After that, we can able to obtain the appropriate $l_{i(j)}$ values according to Equation (3). We have transformed OVRP-TD to a special case of EDAL problem formulation in polynomial steps. Given that OVRP-TD is NP hard, the problem defined by EDAL must also be NP-hard

2.3 Centralized Heuristics

Heuristic solutions are proposed to reduce computational overhead such as energy consumption, delay and increase in the network lifetime. In this section, a centralized meta-heuristic employs tabu search to find approximate solutions. And assume that M nodes have been selected as sources at the beginning of each data collection period. The heuristic algorithm consists of two phases: route construction, which finds an initial feasible route solution, and route optimization, which improves the initial results using the tabu-search optimization technique.

In the route construction phase algorithm, present a heuristic algorithm based on the revised push forward insertion (RPFIH) method. The original push forward insertion algorithm is modified to fit the needs of wireless sensor network. At the beginning of RPFIH, for each node, the minimum-cost path to the sink is found. RPFIH then finds the node that has the largest path cost to the sink and incrementally selects candidate nodes with the lowest additional insertion cost. For each candidate node, RPFIH also checks its feasibility by making sure that the overall delay requirement is met. If no candidate node can guarantee the delay, RPFIH initializes a new route with the node that has the largest path cost to the sink in the remaining sources and repeats this process until all sources are connected with the sink. Finally, RPFIH generates a set of found routes as the final output.

2.4 Distributed Heuristics

The problem with the centralized heuristic algorithm of EDAL is that it requires information to be collected from each node to a centralized one. In distributed sensor networks, this step will typically incur additional overhead. Therefore, it is usually desirable to distribute the algorithm computation into individual nodes. In this section, develop a distributed heuristics algorithm for EDAL, where at the beginning of each period, each source node independently chooses the most energy-efficient route to forward packets

The algorithm is based on the ant colony optimization and geographic forwarding. It consists of two phases: status gossiping and route construction. In the status gossiping phase, each source node sends forward ants spreading its current status, including its remaining energy level, toward its neighbor source nodes within H hops. Meanwhile, the status data of nearby nodes is collected by each source node with the received backward ants. During the gossip phase, the ants are forwarded with a modified geographic forwarding routing protocol, which chooses the node with the maximum remaining energy while making geographical progress toward the destination as the next hop. Once a node collects status information of all its nearby sources, it enters the route construction phase and runs minimum distance routing algorithm based on collected nearby neighbor status and the estimation of node status outside the immediate neighborhood.

2.5 Performance Metrics

The following parameters are measured in the EDAL protocol

2.5.1. Route Discovery Time

Route Discovery Time is used to find out the time taken for the control packet to go from the source node to destination node and then back from the destination node to source node. The Route discovery time is given by the formula

$$RDT=t_{stop}-t_{start} \qquad (8)$$

t_{start} =Time at which RREQ is sent
t_{stop} =Time at which RRPLY is received

2.5.2. Number of Hops

Number of Hops is defined as the number of intermediate nodes between the source nodes to destination node.

2.5.3. Energy

The Energy of the route is used find out the total energy consumed over the entire route. The energy consumption is computed by using the following formula

$$TE = \sum_{i=1}^{l} E_{ci} \quad (9)$$

Where
l=number of links
E_{ci}=Energy consumption of ith node
The Energy Consumption between two nodes is given by

$$E_c = 2E_{Tx} + E_{gen} \quad d^{\gamma} \quad (10)$$

Where
E_{Tx}= Energy required for Transmission
E_{gen}= Energy required for packet generation
d= distance between two nodes
γ=Attenuation factor $(0.1 \le \gamma \ge 1)$

2.5.4. Number of Dead Nodes

Number of Dead Nodes is defined as the set of nodes whose battery energy is less than the threshold.

2.5.5. Number of Alive Nodes

Number of Alive Nodes is defined as the set of Nodes which is defined by

$$N_{alive}=T_{nodes}-N_{dead} \quad (11)$$

Where
T_{nodes}= Total number of nodes in the network
N_{dead}=Number of dead nodes
N_{alive}= Number of Alive nodes

2.5.6. Network Lifetime

Network Lifetime is a time duration at which the first dead node occurs in the network

3. RESULTS

The centralized and distributed EDAL is simulated using MATLAB tool We constructed a simulation scenario for centralized EDAL that uses four clusters and each cluster has 8,9,10 and 12 number of nodes respectively, created base station (BS) at the centre of all cluster and given the source node as the node ID 7, destination node as the node ID 34 as shown in the Fig.2

3.1. Centralized EDAL

Fig.2 shows the x axis and y axis as the x position and y positions of nodes in the network. The nodes belonging to different clusters are representing in a different colors and base station is located at the centre.

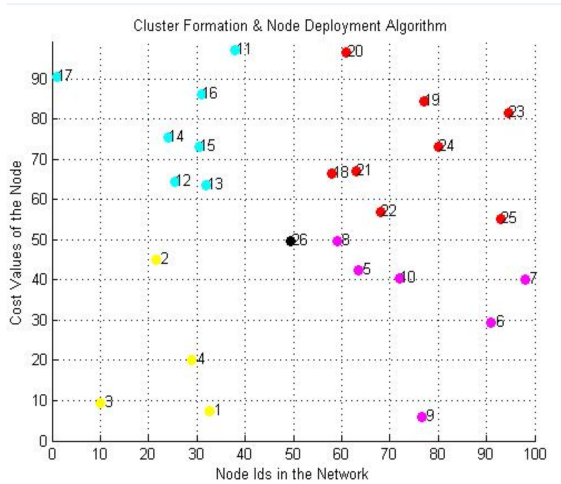

Fig-2: Cluster formation and node deployment

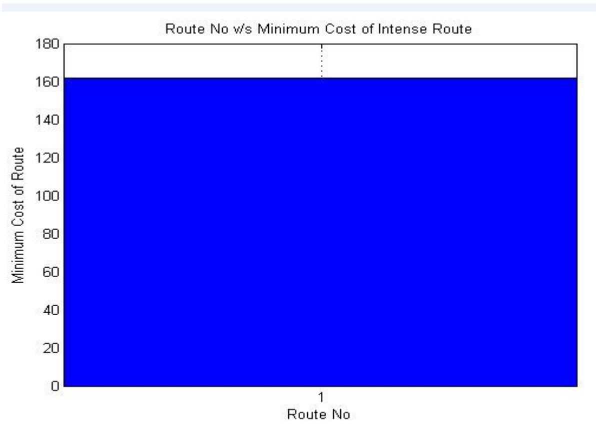

Fig-3: Cost of the best intensified route

Fig.3 shows the minimum cost of the best intensified route after route optimization technique is adopted in the centralized EDAL, it is the most effective minimum cost route

3.2 Distributed EDAL

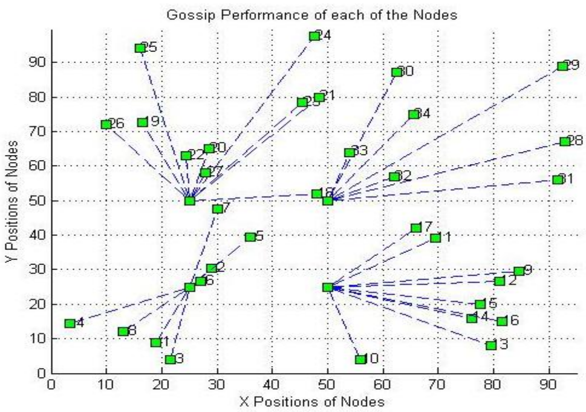

Fig- 4: Energy level status gossiping

Fig.4 shows the each cluster heads collects the information about the energy levels of all nodes in that particular cluster

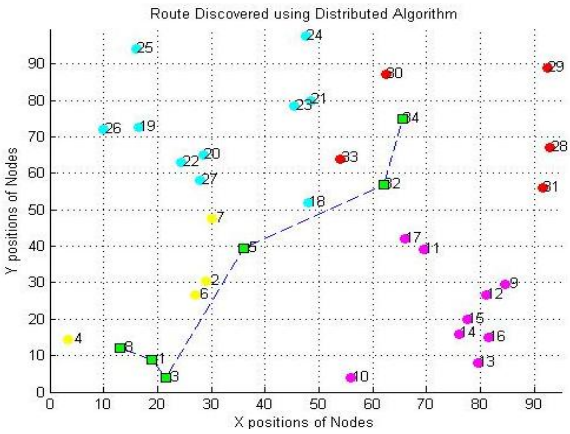

Fig-5: Best route from source to destination

Fig.6 shows the best route from source to destination by considering the energy efficiency, end to end delay.

4. CONCLUSIONS AND FUTURE WORK

In this work, we propose EDAL an Energy-efficient Delay-Aware Lifetime-balancing protocol for data collection in wireless sensor networks which is promoted by flourishing techniques developed for open vehicle routing problems with time deadlines (OVRP-TD). The aim of EDAL is to generate routes that connect all source nodes with minimal total path cost, under the constraints of energy efficiency, packet delay and lifetime balancing requirement and dispute that the problem formulated by EDAL is NP-hard. Therefore, we develop a centralized heuristic to reduce its computational complexity. Beyond that, a distributed heuristic is also developed to further decrease computation overhead for large scale network operations using MATLAB simulation and observed that simulation results of EDAL with baseline protocols achieves significant increase in energy efficiency and network lifetime without violating the packet delay constraints.

The future work could be extended by conducting a experiments on centralized and distributed EDAL protocol in a hardware testbed for WSNs this will allows to evaluating the protocol's performance in a more realistic environment and able to check the efficiency of real sensors. And also make the technique more efficient in terms of throughput and packet delivery ratio.

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REFERENCES

[1]. Y. Yao, Q. Cao, and A. V. Vasilakos "EDAL: An energy-efficient delay-aware and lifetime-balancing data collection protocol for wireless sensor networks" 2013.
[2]. T.H.Cormen, C. Stein,R. L.Rivest, and C. E. Leiserson "Introduction to Algorithms" 2nd ed. New York USA McGraw-Hill 2001
[3]. W. Heinzelman, A. Chandrakasan and H. Balakrishnan "Energy-Efficient Communication Protocol for Wireless Micro sensor Networks " 33rd Hawaii International Conference on System Sciences (HICSS 00) January 2000.
[4]. O. Braysy and M. Gendreau, "Vehicle routing problem with time windows" Transportation Science, volume 39, Feb. 2005
[5]. Z. Ozyurt, D. Aksen, and N. Aras "Open vehicle routing problem with time deadlines Solution methods and an application" Operations Research Proceedings 2005.
[6]. M. M. Solomon, "Algorithms for the vehicle routing and scheduling problems with time window constraints"1987.
[7]. L. Du and R. He "Combining nearest neighbor search with tabu search for large-scale vehicle routing problems" volume 25, May 2012.
[8]. C.-B. Cheng and K. P. Wang, "Solving a vehicle routing problem with time windows decomposition technique".
[9]. S. Murphy, J. J. Garcia-Luna Aceves "An Efficient Routing Protocol for Wireless Networks" ACM Mobile Networks and Application Journal, Nov.1996.
[10]. K. Akkaya and M. Younis "An Energy-Aware QOS Routing Protocol for Wireless Sensor Networks" Proceedings of the IEEE Workshop on Mobile and Wireless Networks, May 2003.
[11]. Jiang, C.; Yuan, D.; Zhao, Y. "Towards Clustering Algorithms in Wireless Sensor Networks— A Survey". In Proceedings of IEEE Wireless Communications and Networking Conference, Budapest, Hungary, 5–8 April 2009; pp. 1–6.
[12]. Arboleda, L.M. C.; Nasser, N. "Comparison of Clustering Algorithms and Protocols for Wireless Sensor

Networks", In Proceedings of IEEE CCECE/CCGEI, Ottawa, ON, Canada, 7–10 May 2006; pp. 1787–1792.
[13]. Haneef, M. Deng, Z. "Design challenges and comparative analysis of cluster based routing protocols used in wireless sensor networks for improving network life time". Adv. Inf. Sci. Serv. Sci. 2012.
[14]. Loscri, V. Morabito, G. Marano, S. "A Two-Level Hierarchy for Low-Energy Adaptive Clustering Hierarchy". In Proceedings of the 2nd IEEE Semiannual Vehicular Technology Conference, Dallas, September 2005
[15]. Chen, Y.-L.; Lin, J.-S. "Energy efficiency analysis of a chain-based scheme via intra-grid for wireless sensor networks". Comput. Commun. 2012, 35, 507–516.
[16]. Fasolo, E.; Rossi, M.; Widmer, J.; Zorzi, M. "In-network aggregation techniques for wireless sensor networks". IEEE Wirel. Commun. 2007, 14, 70–87.
[17]. Xu, D.; Gao, J. "Comparison study to hierarchical routing protocols in wireless sensor networks". Procedia Environ. Sci. 2011.
[18]. oshi, A.; Lakshmi Priya, M. "A Survey of Hierarchical Routing Protocols in Wireless Sensor Network".
[19]. Vidhyapriya, R.; Vanathi, P.T. "Conserving energy in wireless sensor networks". IEEE Potentials 2007, 26, 37–42.

BIOGRAPHIES

Swetha.K received the B.E degree Telecommunication Engineering and purs M.Tech in Digital Communication and Networking from GSSSIETW Mysuru 2015. Her main research interests are Wire Sensor Networks, communication networking.

Hussana Johar R B , M.Tech in information and communication systems MCE Hassan, BE from NIE Mysuru field of specialization includes wireless sensor networks, wireless body area networks, information coding, presently sh is working as a Assistant Professor in department of TE, GSSSIETW Mysuru

Dr. B. R. Sujatha, Ph.D degree in Ad-hoc networks, ME from IISC, field of specialization includes wireless sensor networks, wireless Ad-hoc networks, mobile networks, information coding and cryptography presently she is working as a Professor in the department of ECE, MCE Hassan.

