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RESEARCH ARTICLE

Quality of service enabled intelligent water drop algorithm based routing protocol for dynamic link failure detection in wireless sensor network

S Nithyanandh[1]*, **V Jaiganesh**[2]

1 Ph.D. Scholar, Department of Computer Science, Dr.NGP Arts and Science College, Coimbatore, 641035, Tamil Nadu, India. Tel.: +91-9750318331
2 Associate Professor, Department of Computer Science, Dr.NGP Arts and Science College, Coimbatore, 641035, Tamil Nadu, India

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*__Corresponding author__.
S Nithyanandh
Ph.D. Scholar, Department of Computer Science, Dr.NGP Arts and Science College, Coimbatore, 641035, Tamil Nadu, India.
Tel.: +91-9750318331
nknithu1@gmail.com

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Abstract

Objectives: To propose a better routing protocol method to increase the lifespan of the network and to make the sensed data to reach from source to destination without any data loss. **Methods:** This study proposes a routing protocol inspired by nature namely, Quality of Service enabled Intelligent Water Drop Algorithm based Routing Protocol to detect link failures and provide efficient routing. **Findings:** Comparison has been made with baseline protocols to check its effectiveness and found that the proposed protocol has better performance than the baseline protocols. This research work enhances and adopts the intelligent water drop algorithm with the properties of velocity of water drops and water drops carrying level of soil for finding the better stable route for communication and detecting the link failures dynamically. The results determine that the proposed routing protocol is able to perform better than existing protocols and methods in terms of Energy Depletion rate, Survivability of nodes during transmission, delivering the packets from one end to another end, delay, failure tolerance and increase in Network Lifespan.

Keywords: WSN; Delay; Energy; Routing; Water-Drop

1 Introduction

Wireless sensor networks (WSN) need huge number of nodes towards successful communication. In order to minimize the energy utilization, WSN makes use of multi-hop communication rather than single-hop communication. The route between two different sensor nodes is classified as either weak or strong. The route is considered as strong only if sender node and receiver node have more than threshold level of the energy. If the nodes do not have the threshold level of energy, then link may get failed during the transmission of data. Link failures are the major reasons for the WSN to get failed. The present study is to optimize the routing by using the bioinspired protocol to avoid the link failures and to increase the network lifetime. Intelligent Water Drop algorithm is the proposed one to detect the link failure during the data transmission process.

IWD algorithm is a new optimization method inspired by the water drops flows in rivers which can make optimal paths to the destination.

Two tier optimization protocol [1] proposed to seek the cluster heads, which can enhance the quality of clusters to meet the objective. Routing was performed based on checking the fitness scheme and tree based structure. It attempts to find the best route from cluster head to base stations. Enhanced tree routing [2] proposed for WSN that have structured node based on address assignment methods. It follows the single-hop communication strategy to have better performance. It aimed to reduce the storage and computing cost at each node by using the address assignment method.

3D greedy routing [3] was proposed to provide assurance for delivery of data packet to base stations for further processing. To make the data packet to deliver to the destination, it finds the route in 3D instead of 2D. Since greedy method addresses disadvantage, but it has the advantage of providing the packet delivery in reduced time. Balanced routing protocol [4] proposed for WSN utilized in the military for the purpose of tracking and surviving. It works based on batch concept, while performing the routing it segregates the topology into equal sized cluster and designed to operate in a round robin fashion. It developed a rule for handling the data packet by nodes for avoiding the packet loss. Fading aware routing protocol [5] works based on multi-hop communication. It attempts to find the routing path that has no-risk or low-risk. The risk indicates the chance of losing data packet and getting more delay. Before sending the data packet, it analyzes the energy level at each node if the energy found is less than the threshold value then it avoids that route and finds the alternative route.

Energy efficiency based traffic control [6] makes use of deep learning ideas to decrease the consumption of energy. Neural Network was fully utilized to find the optimized path among the available multiple paths, where it checks traffic level each time while sending the packet. Reducing the energy consumption played a major role. Shortcut tree based routing [7] proposed to find the shortest route to destination node based on the distance level. It finds the shortest route based on the tree structure that it maintains at each node. Data packets are not simply sent in all available routes, instead it checks the shortest path. Multicast geographic routing [8] proposed to lessen the energy consumed by nodes for transmitting the data further towards destination. It forwards the data packet only after finding the location of destination node, if data packet is sent by following the routing table it enhances the congestion in WSN. Pareto optimization based routing [9] proposed to find the optimized configuration of the network for ensuring the best routing in WSN. Initially, it finds the available number of cluster heads, members, and quality of available link. It attempts to find the effective routing path that decreases the energy, even the networks are scaled. Geographic cross layer routing [10] attempts to find the better route in disaster relieving operations. It ensembles the medium access control mechanism and handshake mode communication to find the route status. Further, it checks the queue length before sending the data packet in a specific route. Intelligent water drop based coverage-connectivity and lifespan protocol [11] which minimizes energy consumption of the network based routing proposed to reduce the problem of energy holes and maintains the connectivity of networks and coverage ratio of the area. Novel localization [12] proposed the way nonlinear optimization method is used in addition to Received Signal Strength Indicator which is used to determine the interior distance between WSNs nodes. Intelligent water drop algorithm [13] proposed to solve node-selection problem by considering each water drop as an agent which is responsible to find the minimum number of sensor nodes with high data accuracy. Communication protocols for WSNs [14] that gives a useful insight of performance of various protocols in the homogeneous and heterogeneous networks. Enhanced IWDs [15] with exponential and approximate version of simulated annealing algorithm used to solve the multi-depot vehicle routing issues. Few other protocols are proposed [16,17] to deal with feature selection and analyze the performance of the routing to achieve better results. Various researches [18–24] were carried out in this thrust research area, but all focused only on finding the alternate route leading to more delay and packet loss.

Hence, link failures are necessarily to be found before it happens to avoid delay and packet loss. This research work proposes quality of service-enabled nature inspired routing protocol to overcome the link failures that arises dynamically in WSNs and the effect of intelligent water drop algorithm's use for finding the optimal route and detects the node failure. This method falls under the family of swarm intelligence.

2 Proposed Methodology

QoS-IWDARP proposed was inspired from nature and swarm optimization algorithms. Two major properties of the proposed protocol are:

1. Water-drops carrying level of soil
2. Water-drops velocity

When QoS-IWDARP flows in the riverbed, the soil is termed as *soil* (IWD), and the speed is termed as speed(IWD), where the speed gets dynamically changed. When QoS-IWDARP travels from higher-end to lower-end, i.e., from i to j, then *speed* (IWD)

is increased by $\triangle velocity\ (IWD)$ value. The level increase is commonly related to the inverse of i and j location soil, which is termed as $soil\ (i,\ j)$. The relationship of $speed\ (IWD)$ and $soil\ (i,\ j)$ is possible to mathematically state as:

$$\triangle speed\ (IWD) \propto \frac{1}{soil(i,j)} \tag{1}$$

It is possible to formulate a relationship between $\triangle speed\,(IWD)$ and $soil(i,\ j)$, the speed of IWD is possibly updated by $soil(i,\ j)$ as non-linearity based mathematical function and shown in Equation (2):

$$\triangle vel^{IWD}(t) = \frac{a_v}{b_v + c_v \times soil^{2\alpha}(i,j)} \tag{2}$$

The parameters a_v, b_v, c_v and α are chosen based on the needs of the user. The extra amount of soil is added to the water-drop is termed as $\triangle soil\,(IWD)$ or $\triangle soil\,(i,j)$ and an assumption is made that it takes a non-linear time period to travel from i to j. The possibility of $\triangle soil\,(IWD)$ is mathematically shown in Equation (3)

$$\triangle soil\,(i,j) = \frac{a_s}{b_s + c_s \times time^{2\theta}(i,j : vel^{IWD})} \tag{3}$$

where $time^{2\theta}(i,j : vel^{IWD})$ indicates the expected time period for QoS-IWDARP to travel from i to j, where it travels with the speed of $speed^{IWD}$, θ, a_s, b_s and c_s are positive numbers that are user-defined.

Update Velocity

$$uve^{IWDh}(y+1) = uve^{IWDh(y)+}\frac{bv}{cv + nv \times soil^{2(i,j)}} \tag{4}$$

When QoS-IWDARP pass through the edge of consistency graph, then $edge\ (i,k)$ utilize Equation (5) and Equation (6) for its update:

$$soil(i,k) = \left\{ \begin{array}{c} (1-\rho L) * soil(i,k) - \rho l \triangle soil_{min}\ if\ \triangle soil_{(i,k)} < \triangle soil_{min} \\ (1-\rho L) * soil(i,k) - \rho l \triangle soil_{max}\ if\ \triangle soil_{(i,k)} < \triangle soil_{max} \\ (1-\rho L) * soil(i,k) - \rho l \triangle soil_{(i,k)}\ otherwise \end{array} \right. \tag{5}$$

$$soil(IWD) = \left\{ \begin{array}{c} \{soil^{IWD} + \triangle soil_{min}\ if\ \triangle soil_{(i,k)} \leq soil_{min}\} \\ \{soil^{IWD} + \triangle soil_{max}\ if\ \triangle soil_{(i,k)} \leq soil_{max}\} \\ soil^{IWD} + \triangle soil_{(i,k)}\ otherwise \end{array} \right. \tag{6}$$

where $soil\ (IWD)$ represents the soil where $\triangle soil\,(i,k)$ holds the value between 0 and 9, which is used as a parameter to update the local soil. High and low-level values of soil updates are fully dependent on soil present in the edge.

Based on physics simple law of linear motion, $time(i,j : vel^{IWD})$ parameter is computed by using $speed(IWD)$ as follows:

$$time\left(i,j : vel^{IWD}\right) = \frac{1}{vel^{IWD}} \tag{7}$$

where $soil(i,\ j)$ is necessarily made to update because few quantity of soil is eradicated in the path it traveled and it is shown in Equation (8)

$$soil\,(i,\ j) = \rho_0 \times soil\,(i,\ j) - \rho_n \times \triangle\, soil\,(i,\ j) \tag{8}$$

where parameter (ρ_0 and ρ_n) used for local soil update is necessarily to be a number greater than zero. Amount of soil is computed as

$$soil^{IWD} = soil^{IWD} + \triangle\, soil\,(i,\ j) \tag{9}$$

Pareto based investigation is done for performing the calculation towards distance search space. The investigation involves scoring based schedules and for individual schedules, its average mean values are computed.

QoS-IWDARP gives preference only for the path that has a low level of soil, where it eliminates the path that has a higher level of the soil. It adapts the characteristic of probability-based function, which selects location j that is recommended by the roulette wheel selection method.

$$p(i,j:IWD) = \frac{f(soil(i,\ j))}{\sum_{k \notin vc(IWD)} f(soil(i,\ k))} \tag{10}$$

where $vc(IWD)$ indicates the nodes that are infeasible to the issues ranging from riverbed constraint

$$f(soil(i,\ j)) = \frac{1}{\varepsilon_s + \ g(soil(i,\ j))} \tag{11}$$

where ε_s is a positive number that has constant value and prevents division by zero in Eqn.(5.11), and $g(soil(i,\ j))$ is a method to put soil only toward positive numbers as shown below

$$g(soil(i,\ j)) = \begin{cases} soil(i,\ j) & if\ min_{l \notin vc(IWD)} soil(i,l) \geq 0 \\ soil(i,\ j) - min_{l \notin vc(IWD)} soil(i,l) & otherwise \end{cases} \tag{12}$$

The main intention of water-drops is to combine and work to reach the optimum path.

3 Evaluation of Performance

Evaluations are conducted to analyze the performance of protocols. Quality of Service of proposed protocol is analyzed against the baseline protocols namely NCCM-DC[12] and EADRA[11]. NS2 based simulation is conducted to evaluate the proposed protocol. Simulation settings used for simulation is shown in Table 1. Energy depletion, survivability, packet delivery ratio, delay, failure tolerance and network lifetime are the metrics used for evaluation. The parameter node-count is used for conducting simulation.

Table 1. Simulation Settings

Parameter	Values
Nodes Count	500 – 2500
Range of Network	600 *x* 600 m^2
Size of Data Packet	800 *bit*
Initial Transmission Range of Deployed Nodes	75*m*
Initial Energy of Each Node	20 *J*
Sensing Range	10 *m*
Threshold Distance	75 *m*

4 Results and Discussions

4.1 Energy depletion analysis

This metric shows the speed of energy that gets exhausted at the sending node while data gets transmitted. Figure 1 indicates the proportion of energy depletion at the node count by QoS-IWDARP and previous available protocols EADRA[11] and NCCM-DC[12]. It is noticed that QoS-IWDARP have used minimum level of energy and the previous available protocols have used maximum energy level.

4.2 Node survivability analysis

Node survivability shows the survival of nodes during the increase in the network load. Figure 2 indicates that nodes getting better survivability in QoS-IWDARP than EADRA[11] and NCCM-DC[12], it is because the energy is saved a lot in QoS-IWDARP.

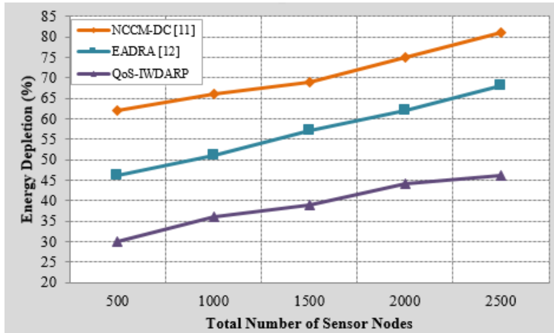

Fig 1. Energy depletion analysis

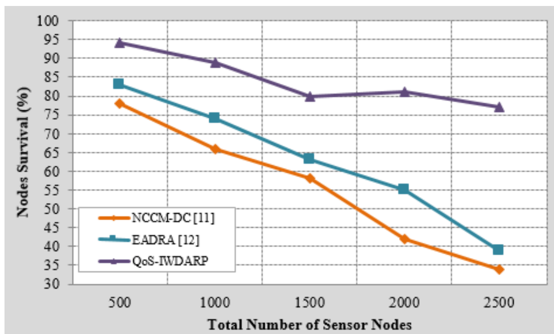

Fig 2. Survivability analysis

4.3 Packet Delivery Ratio Analysis

This metric reflects the proportion of receiving the data packets by receiver node in a successful manner. Figure 3 clearly indicates that packet delivery ratio is getting enhanced when node count gets increased, but the previous available protocols EADRA [11] and NCCM-DC [12] didn't deliver the packet in a better manner.

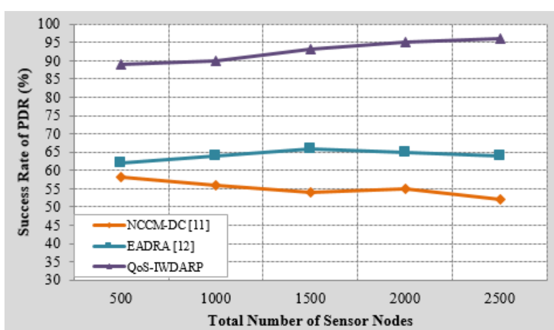

Fig 3. Packet delivery ratio analysis

4.4 Delay analysis

This metric shows the consumption of time by the protocols to make the data reach the destination. Figure 4 indicates that QoS-IWDARP consumes minimum time, where EADRA [11] and NCCM-DC [12] takes lengthier time to deliver the data.

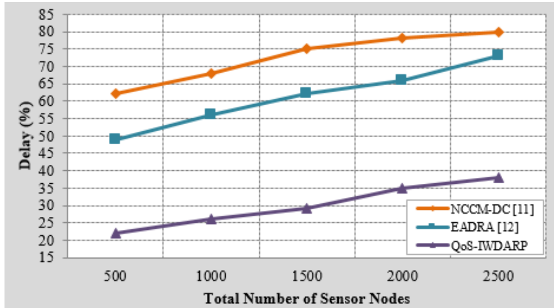

Fig 4. Delay analysis

4.5 Failure tolerance analysis

This metric indicates the nodes tolerant rate while the link gets failure. Figure 5 shows nodes tolerance level in QoS-IWDARP, EADRA [11] and NCCM-DC [12]. It is very clear that QoS-IWDARP is able to tolerate the link failure by finding the alternate route based on size of the data which is not followed by EADRA [11] and NCCM-DC [12].

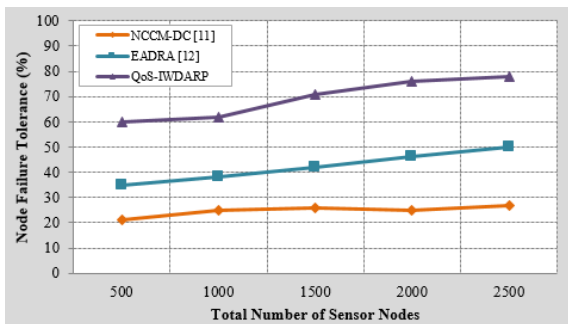

Fig 5. Failure tolerance analysis

4.6 Network lifetime analysis

This metric shows successful running of WSN even nodes scaled high. Figure 6 indicates that QoS-IWDARP have outperformed EADRA [11] and NCCM-DC [12] by providing better lifetime to the network.

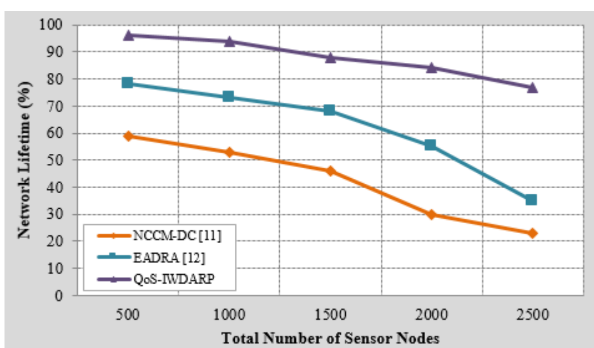

Fig 6. Network lifetime analysis

5 Conclusion

Nature inspired quality of service enabled routing protocol was proposed for WSN to find the better route to destination. Proposed protocol finds the route by analyzing the link failures. During the link failures it finds better alternative route by utilizing the concept of water-drop that flows in different route to reach destination. To analyze the proposed protocol's performance, comparison was performed with previous routing protocols namely Energy Aware Distributing Routing Algorithm (EADRA) and Network-Coding Cluster Level Multi-Path Duty Cycled Protocol (NCCM-DC). The proposed protocol QoS — IWDARP performs better than the previous protocols in seeking the link failures and minimizing the energy consumption to enhance network lifetime that is shown in results graph.

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