A Novel Approach for Energy Efficient Route Optimization and Data Forwarding by Employing Nature Inspired QoS enabled WCAP Technique to Enhance Lifetime in WSNs

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ABSTRACT

In Wireless Sensor Networks sensor nodes plays a major role in determining the network lifetime considering energy as a limited resource. Since WSNs are deployed in large numbers in many remote locations and unattended areas, adhoc transmissions act as a key component which in need to consider various parameters in wireless sensor applications and protocols. Increase in lifespan, robustness, fault tolerance, and self-configuration are the major parameters. Enhanced Energy Efficient Routing Protocol (EEE-RP) is the preceding protocol introduced for energy efficiency and data forwarding. On the other hand, adequate methodology for route selection is necessary for efficient packet delivery. Here, the protocol only considers data forwarding, and it does not optimize the ideal path for maximum packet delivery ratio.

Hence there exists a necessity of energy efficient route optimization and data forwarding technique to forward the data from source to destination. To overcome the route optimization issues, Nature inspired QoS enabled Water Cycle Algorithm based Protocol (QoS-WCAP) is proposed in order to optimize the route by sharing the communication among the water drops which enhances the quality of service. Multi-hop routing technique is utilized to exchange the data between the clusters and transfers to Base Station (BS).

Roulette Wheel Selection and Pareto based Investigation methods are employed to find the finest path for efficient data forwarding in optimized manner to minimize the energy. All the tests are carried out by NS2.35 simulator. Simulation results indicated that QoS-WCAP performs better in terms of energy consumption, delay, packet delivery ratio, and failure tolerance level and network lifetime.

Keywords: Wireless Sensor Networks, Water Cycle Algorithm, Route Optimization, Multi-hop routing, Energy Efficiency

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1. INTRODUCTION

WSN is made up of hundreds or thousands of sensor nodes that communicate with one another using network technology. For effective communication from both the ends, it requires a large number of nodes to be deployed. In this modern and emerging technology era usage of WSN is very huge especially for tracking and monitoring. Mainly it is used in military applications for surveillance and also other observance. The main characteristics of a WSN includes power consumption constraints for nodes, handling node failures, node mobility, nodes heterogeneity, nodes homogeneity, property of scalability, capability of handling insensitive conditions of environment. WSN employs the concept of multi-hop communication rather than single-hop communication in order to save energy. When there is a possibility of a connection or node failure, WSN quality fails. The sensor node's location is determined either by itself or with the assistance of a neighbour node. The network management process will detect a connection or node failure and take appropriate action to correct it. In this scenario, healthy nodes wait for the network management process to finish, which takes a long time to identify alternate routes to send the collected data to its destination. In this case route reconstruction may give overheads in WSN leads to network failure or a reduced lifetime. In a contemptuous monitoring application, a link or node failure may lead to time consumption in identifying the alternate routes thereby leading to the massive loss or sometimes network shutdown. Hence there is a need of effective optimization in detecting the node failure, to find the ideal route between source and destination node for efficient data forwarding by minimizing the delay, maximizing the packet delivery and lifetime of network. Nature inspired genetic algorithms are employed for route optimization. Cross layer bee routing is introduced for route optimization to maximize the energy and to overcome the congestion problem [1]. Whereas QoS enabled IWDARP is utilized to identify the node link failure and to discover the finest path for data delivery [2]. Minimal utilization of resource by optimizing the route and the highest residual energy nodes are chosen for data forwarding and it helps for better packet delivery rate.

The primary goal of routing protocols is to increase the lifespan and efficiency of WSNs by taking into account a sensor node's ability to overcome source constraints such as power limitations, low processing speed, and limited band width for better and stable communication [3]. Numerous researchers modeled the routing protocols for data forwarding and utilized multihop for less energy consumption instead of single hop mode since the multihop transmits the captured data eventually to the BS in an optimized manner. Water based algorithms [4] are employed to enhance the overall performance of WSN and generates the solutions stage by stage to get the optimal solution. Signal optimization [5] is done using various chaotic signal functions and closing the best signal to improve the stability and to moderate the convergence problem. Nevertheless, dynamic optimization is expected to maintain data forwarding and packet distribution ratio energy efficiency. To overcome the issue, nature bio-inspired algorithms are used to find the best route between source and destination. The use of technology in this fifth generation is highly prevalent everywhere to solve problems for critical solutions in all sectors. This paper deals with how advanced machine learning technology along with a bio-inspired algorithm helps in spotting the apple leaf disease and identifying it at an early stage to maximize the production of apples and minimize plant degradation. As everyone is aware, apples are rich in nutrition and have medicinal value. They are one of the most productive fruits in the world. A variety of diseases occur frequently that stop the yield and production on a large scale, leading to economic loss. In that case, timely detection of disease in an effective manner is essential to ensure that the diseases are diagnosed at an early stage.

Various techniques have been identified to detect plant leaf diseases, but the accuracy has not improved. Traditional deep learning methods are utilized by the researchers to improve the accuracy level in a real-time environment, but object detection accuracy is not achieved remarkably. At an early stage, only visual observance is done to identify the plant's leaf diseases and the same is diagnosed subject to risk and disease spotting time. To overcome the challenges, genetic algorithms with deep learning techniques have been studied to discover a novel method called Reconnaissance Cognitive Stochastic Diffusion Search Method with Enhanced Invasive Weed Optimization to spot the disease at its early occurrence, which helps farmers to diagnose the disease at the right time in order to increase production.

2. BACKGROUND STUDY

Sadollah et al. [6] proposed evaporation rate based water cycle algorithm for finding overall optimal solution for multimodal functions based on the level of water evaporation in rivers and streams during the flow. The balance between the evaporation and exploitation phase is compared with WCA. As a result, the solution quality is high and the algorithm outperforms the baseline versions. The authors [7] employed genetic algorithms to evaluate the fitness function and to optimize the protocols to enhance the lifetime of network and minimize the energy consumption. Dionisis et al. [8] discussed about the multi objective optimization techniques for WSN for effective data transmission. Various data aggregation methods are employed to reduce data redundancy and noise removal and also discussed about the optimal search techniques for QoS maintenance. To address network connectivity problems, Davide et al. [9] suggested hybrid evolutionary approaches based on genetic swarm optimization to refine communication signals in multihop routing schemes. The authors [10] introduced a novel approach called combinatorial optimization to solve the clustering issue by utilizing the binary particle swarm optimization to stop the excessive energy consumption during the exchange of information between nodes. This technique also helps to prolong the lifespan of network for efficient capturing and data transmission process. Liu et al. [11] presented an improvised energy-efficient WSN routing protocol. To boost energy efficiency, LEACH protocol techniques are used. For further development, a new threshold is used for CH selection among nodes and is used in hybrid communications. For network optimization, residual node energy and average energy are taken into account. The authors [12] suggested the RVSRP optimization approach, which uses the virus dissemination system and the infecting host cell method to detect dynamic connection failure and find an alternative route for effective data transmission which helps to reduce delay and energy consumption and maximize the network lifespan, data distribution, and fault tolerance. In RVSRP, swarm optimization is an advantage for detecting node failure in the network search space. The authors [13] suggested EEE-RP to effectively forward data packets and boost QoS in WSN by forwarding data packets to their destinations in the most effective and optimal way possible using the best route, reducing end-to-end delays. Machine learning techniques such as reinforcement learning, random walk computation, and Markov decision process framework methods are used to forward data packets in a flexible and noise-free manner. MRET is employed to identify the next hop node in the network search space. The protocol helps is minimizing the energy depletion rate and enhance the lifetime. The protocol has the possibility to rebuild the path, but it has flaws in dynamically detecting connection failure during the data transmission process. As a result, a new protocol is needed for the most effective data forwarding in an optimal way. The authors [14] suggested an opportunistic routing approach for multihop WSNs that forward packets in a sequential manner before the previous node transmits its data to the destination. In a distributed environment, the best possible route is found and data is transmitted efficiently. Data forwarding is done in a competent way in a three hop route directly. QC grey wolf optimization was developed by Yang Liu et al. [15] to reduce excessive overhead without modifying physical infrastructure and ensuring that sensor coverage is high in the deployed environment. To extend the network's lifetime, a sensor duty cycle model is created using the Genetic and Simulated annealing algorithm. Jun Huang et al. [16] proposed a bio inspired optimization algorithm to design WSN in IOT and utilizes ant swarm concept to find the optimal solution. Sorting and crowding distance methods are adopted to allow the protocol to find the optimum solution. The protocol works in wide range of distributed environment and helps in easy deployment in unattended area. The fault tolerance level is high compared to the existing versions. To achieve higher throughput and power efficacy, Chengtie et al. [17] developed a comprehensive cross layer algorithm for data transmission by combining compressed sensing and optimal theory. Signals are optimized and the congestion rate is optimized for energy consumption. The transmitting channel with the best energy efficiency is chosen by the nodes, resulting in a higher packet distribution ratio. Ayman et al. [18] introduces water flow like algorithm for TSP by comparing the datasets of baseline versions. Candidate solutions with assumptions about the problems are solved by employing WFA through object grouping. Hybrid metaheuristic is also used to produce optimal solution. Searching behaviors, scalability and performance has been tremendously high in WFA compares to the existing protocols. The authors [19] proposed RABCRP to detect link failure by employing artificial bee colony algorithm to find the optimal path for effective data delivery process. Greedy selection method is utilized to generate a new solution and the survivability ratio of nodes is high when comparing to the previous protocols. Ali Ghaffari, Eldho KJ proposed software defect detection model and [20-21] proposed an energy-efficient routing concept that uses the A-star algorithm to send data packets in the shortest path with the minimum amount of residual energy while maintaining high connection efficiency. Through dynamically partitioning data, the protocol improves network lifespan, packet distribution ratio, data arrival, and minimizes end-to-end latency and energy consumption..

3. PROPOSED METHODOLOGY

The proposed energy efficient routing methodology for data forwarding utilizes water cycle algorithm technique to enhance QoS in WSN inspired by intelligent water drop algorithm. The stages of WCA involve precipitation, surface runoff, evaporation & condensation and cycle iteration process. Here, a stream is referred to as an individual of the population, a river is the second best option, and the sea is the best and most optimal option. The WCA process begins as the surface of water heats up and evaporates in the sunlight, and then the vapour cools and condenses into rain drops. Surface runoff is where water flows at a high rate from one spot to another. The water drops follow the shortest route across the lowest amount of soil in the surface.

3.1 The WSN Model

In this proposed model, assume that number of nodes are deployed in an environment is termed as $Node$ and every sensor node has a separate identification and $Node$(i) is a set of neighbouring nodes in the WSN surface. The assumptions are as follows,

1.Sensor nodes are deployed randomly

2.Identify the position of the nodes

3.Calculate the fitness value

4.Get the aggregate data gathered from N - N

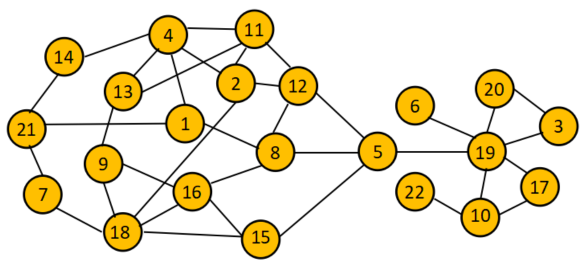
5.Check the node condition

6.Apply residual energy for data transmission

7.Update the optimal solution

8.Forward the data to destination

Here N-N represents Node to Node



Nodes of WSN Initialized (Source: RSG)

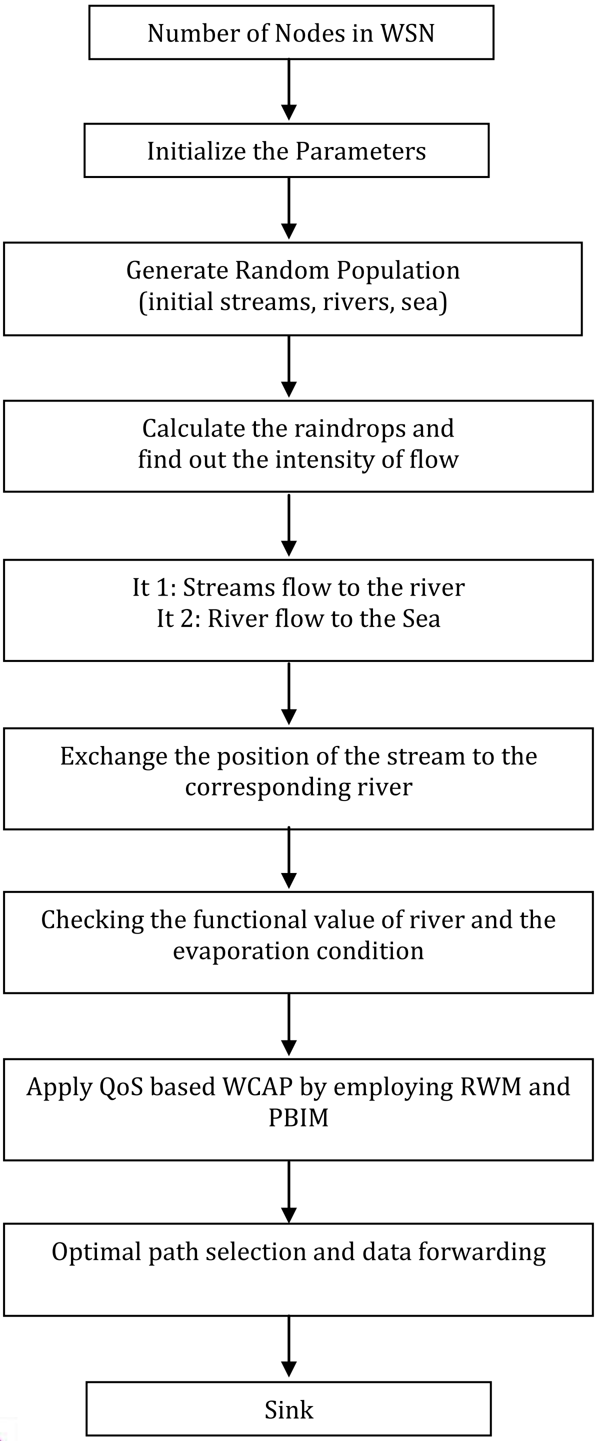


Figure1: Flow Diagram of QoS-WCAP

3.2 Implementation of QoS WCAP

Sensor nodes in wireless sensor networks must endure and balance the load in a QoS-enabled WCAP application scenario in order to deliver packets effectively and detect node connection failure. The new protocol proposes establishing a series of communications between cluster nodes and member nodes. After initialization, both network nodes continue to collect data and send it to their target CHs along with the path. Each cluster head caches the sensory information of other member nodes. The algorithm works unique when searching for the best location in the search space, and the nodes will look for the nearest nodes that don't have any load or have empty data transmission, and that node will be assigned as new, and the distance between the nodes will be calculated and updated.

$$\Delta speed(WD) \propto 1/(soil(a,b)) \qquad (1)$$

The closest node in the search space identifies the new sensor node, and the iteration process determines the best solution. The data was collected and sent to CHs during the route searching process, and the new route was identified using RWM and PBIM techniques. In order to apply the function, variable a,b is declared to establish the connection. The fitness value of node in layer a is higher than layer a+1. The number of layers can be found in multiplies. When the water cycle starts the surface of the soil and velocity is updated to find the optimal value by considering the depth of the soil

$$\Delta vel^{WD}(t) = \frac{a_v}{b_v + c_v \times soil^{2\alpha}(i,j)} \qquad (2)$$

3.3 Roulette Wheel Selection Method to find the best solution

In QoS-WCAP the location of the destination will be selected by IWD with the help of probability based function calculated by roulette wheel selection method. In RWM instead of fixing single point in the surface multiple points are fixed. So it is very easy to find out the position and update it very easily when the wheel is rotated. So, the probability of choosing the individual based on the fitness and quality and the RWM equation is utilized.

$$Px = \frac{fx}{\sum_{i=1} fi} \; where \; P = \{p1, p2, \ldots . pn\} \qquad (3)$$

3.4 Pareto Based Investigation Method to find the optimal solution in QoS-WCAP

Pareto based Investigation method is a decision-making mathematical method used to pick a small range of tasks that produce a substantial overall result. The major key of this method is picking up the right path that has less soil to increase the speed when the water flows in the sea. The water drop itself decides the route selection in the search space or river bed to reach out the destination. PIM is used to solve the decision making problems in optimization algorithms. It is used to analyze the performance of water drop in the river bed when it flows in the surface to find the optimal solution OS.

$$time(a, b{:}\, vel^{WD}) = \frac{1}{vel^{IWD}} \quad (4)$$

The movement of the water drops is regulated by indirect communication between the depth of the paths and the volume of soil. The depth of the route has an impact on the flow of water drops which helps to prevent all water drops from taking the same path. Soil should be deposited and removed, preventing premature convergence and fostering the distribution of drops in several directions. The condensation stage is used to direct contact (information sharing) among the water drops.

$$soil^{IWD} = soil^{IWD} + \Delta\, soil(a, b) \quad (5)$$

PBIM technique aids in performing successful solutions. This stage can also be used to increase the consistency of the solutions obtained and cut down on the number of iterations.

$$p(a, b{:}\, WD) = \frac{f(soil(a,b))}{\sum_{k \notin vc(WD)} f(soil(i,k))} \quad (6)$$

The evaporation method is a sorting strategy that aids the algorithm in escaping from local optimal solutions. It occurs when the consistency of the obtained solutions does not change. Finally, To produce new solutions, the precipitation stage is used to reinitialize variables and redistribute WDs in the search space.

$$OS = \frac{Node\ occurance}{WD\ Sol}\ where\ WD = weight\ Node \quad (7)$$

Detailed Algorithm QoS-WCAP

i) Input
ii) Initialize the population
iii) *While* the condition not met

Cycle = Cycle + 1

iv) Calculate Surface Flow

Repeat

For each water drop

a) Chose the next node
b) Update Soil
c) Update Velocity

End For

d) Calculate the initial fitness value
e) Calculate the second best solution
f) Evaluate the solution quality
g) Update local optimal value

Evaporation of WDs
Condensation of WDs
Precipitation of WDs
End *While*

4. ABOUT IMPLEMENTATION PROCESS IN NS2 V.35 SIMULATOR TOOL

Performance evaluation was made to analyze the proposed bio inspired QoS-WCAP protocol to provide quality of service in routing and efficient forwarding the data than the previous routing protocols. For conducting the simulation NS2.35 is used. EEE-RP existing protocol is compared in order to find how far the new protocol shows the stability in enhancing the network lifetime and packet delivery ratio. The parameter node-count takes value ranging from 500 to 2750 with 2250 bit as size of data packet. Initial energy of every node is taken as 20J with a node threshold distance of 75m. Simulation settings used for simulation is shown in Table 1.

Table: Simulation & Experimental Settings

Parameters	Values
Number of Nodes	500 - 2750
Time period	125 ms
Rate of Data packets	0.5 packets
Initial Transmission Range of Deployed Nodes	80m
Type of Traffic	Wireless
Initial Energy of Each Node	25 J
Sensing Range	12 m
Threshold Distance	80 m
Mobility Model	Random Way Point
Simulation Time	5500 s
Data Payload	2250 bit

5. PERFORMANCE ANALYSIS METRICS OF QOS-WCAP

The following metrics are used in this analysis to compare the performance of the proposed protocol QoS-WACP against EEE-RP, which were chosen as the baseline protocol in the previous chapter. The metrics are,

- **Energy Consumption -** Conservation of energy by node during the data forwarding process.
- **Delay -** Latency time consumption by the protocol to deliver the packets from source to destination in the search space.
- **Packet Delivery Ratio -** Calculates the efficient transmission of packets from the source to destination in WSN.
- **Failure Tolerance -** Node tolerance level during the occurrence of error

- **Network lifetime-** Calculates the lifetime of the network performance for transmission

5. RESULTS AND DISCUSSIONS

The results portray the implementation and performance values of the newly proposed method QoS-WCAP.

5.1 Energy Consumption

Figure 2 depicts the energy consumption ratio of sensor nodes. It depicts the amount of energy expended in the WSN during data transfer from one end to the other. The energy consumption of QoS-WACP is intensively less than that of EEE-RP. Despite the fact that the number of nodes grows, energy consumption remains low due to the optimal route formation for delivery of packets from source to destination. QoS-WACP only used 7% of the energy which shows efficient data forwarding and transmission process.

5.2 Delay Analysis

Figure 3 shows a delay study of the proposed QoS-WCAP protocol. Due to the increased node count and range, the latency time during data transmission is marginally increasing. During the trial, however, it was discovered that QoS-WCAP outperforms the current baseline protocols EEE-RP. The latency time varies solely due to a rise in node count and a wider coverage area. When compared to EEE-RP, QoS-WCAP took the least amount of time to forward data packets from source to destination, which was significantly less than current routing methods.

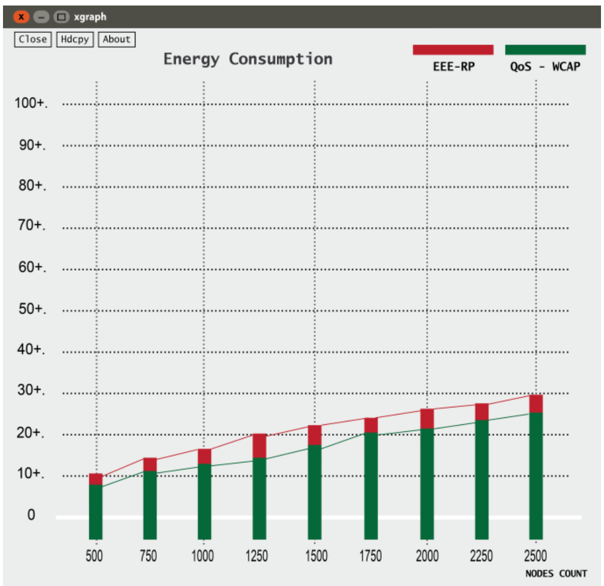


Figure 2: Energy Consumption Analysis

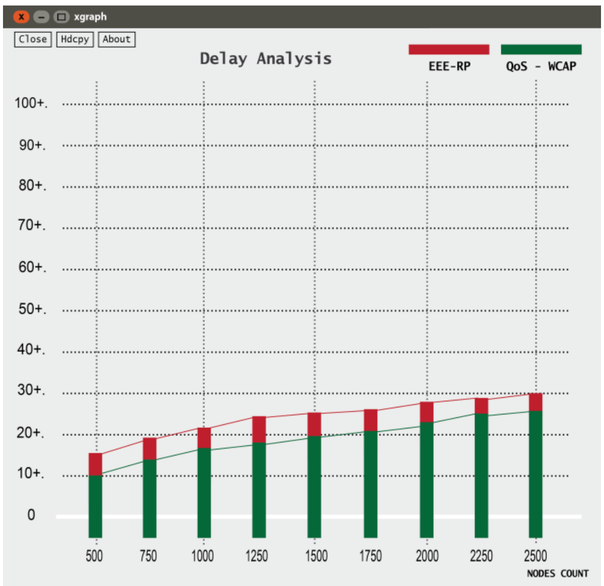


Figure 3: Delay Analysis

5.3 Detection Speed Time Analysis

Figure 4 shows the proposed QoS-WCAP protocol's packet delivery ratio. When compared to the current EEE-RP routing system, packet distribution is high. And as the node count increases, packet delivery remains nominally strong and reaching 98% as compared to baseline versions during the iteration. The packet delivery is high due to finest route selection by utilizing RWM and PBIM in QoS-WCAP to minimize the energy that leads to high packet delivery ratio.

5.4 Fault Tolerance

Figure 5 presents the fault tolerance level of sensor nodes. It shows the tolerance level during the data transmission and the occurrence of dynamic link failure. The node has own tolerance level to identify the faults. The tolerance level of QoS-WACP is high than that of EEE-RP. Despite the fact that the number of nodes increases, the tolerance level is high in the proposed protocol. QoS-WACP reached 97% tolerance level where the existing one is marginally low. The fault tolerance level also depends upon the deployment

5.5 Network Lifetime

Figure 8 illustrates the network lifetime. It shows how long the network is up and running during data transmission and how often data packets are efficiently transferred from one node to the next. The network life is increased by 98% when using QoS-WCAP, while the EEE-RP protocol has little effect on network life. The proposed QoS-WCAP protocol has significantly increased the network's lifespan. It demonstrates that the protocol has a high level of stability as compared to the existing protocol.

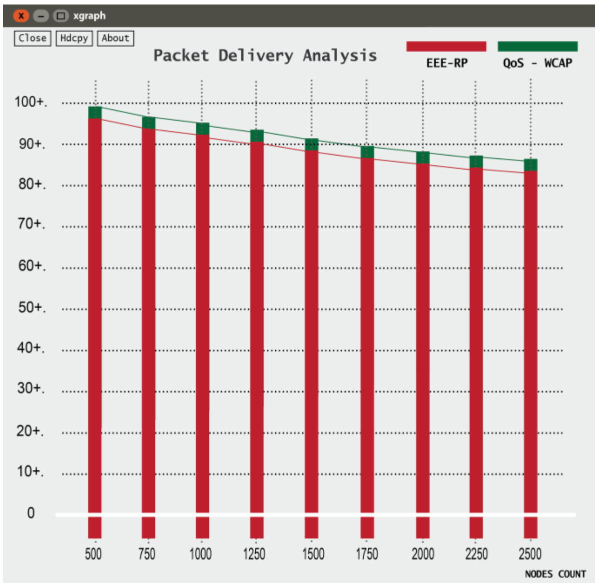


Figure 4: Energy Consumption Analysis

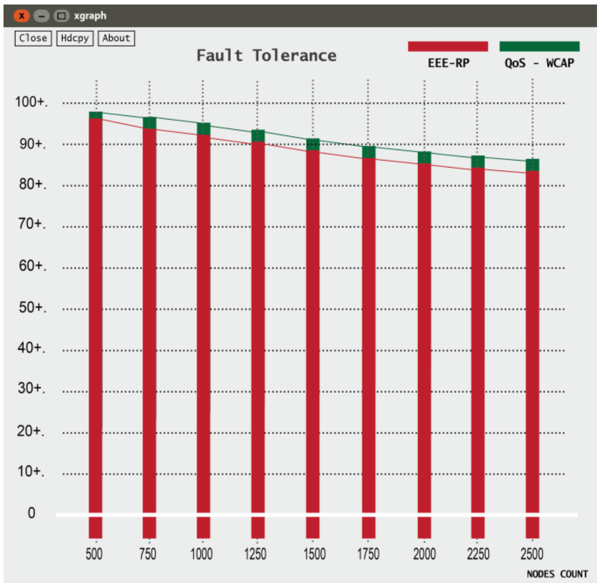


Figure 5: Delay Analysis

6. CONCLUSION

To increase the performance of wireless sensor networks, the research study suggested a new network data transmission energy-efficient protocol called the Quality of Service enabled Water Cycle algorithm based protocol (QoS-WCAP), to improve the efficiency of wireless sensor networks. Minimizing the delay would still increase the packet forwarding distribution ratio.

Constant approaches such as random walking data collection method and Pareto based investigation framework are used in this protocol to identify the dynamic link failure and discover the best ideal route for an effective data forwarding process to make data packets to reach the destination.

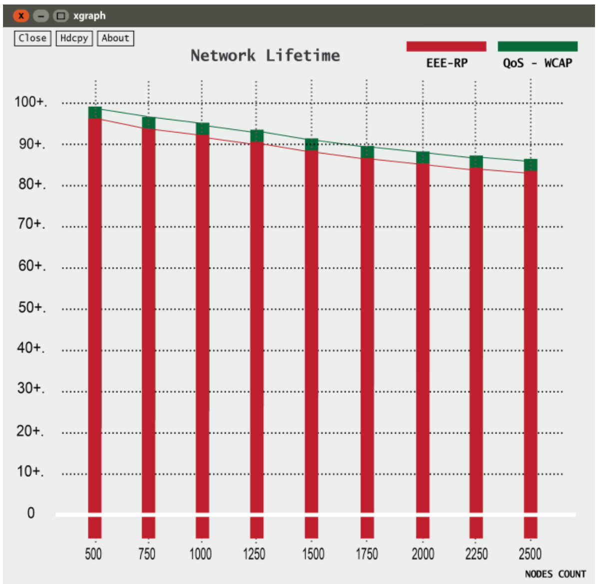


Figure 6: Network Life Time Analysis

The main idea is to collect data from cluster heads based on their demand or request, in order to reduce the sink's energy consumption and extend the network's existence. As compared to the baseline protocol, EEE-RP, simulations have shown to improve network efficiency in terms of packet delivery ratio, energy consumption, latency, packet delivery, and network lifetime.

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