A NOVEL METHOD OF ROUTING PROTOCOL THROUGH CROSS-LAYER BASED ON COLLECTION CENTRE POINT NODES

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Abstract
Wireless sensor networks (WSN) are becoming increasingly prevalent in a wide variety of contexts, elevating the Quality-of-Service (QoS) problem in WSN-based applications to the forefront. When developing a routing system, it's important to keep in mind the impact of queuing for the delay and hostile packet drop on network throughput. Network protocol performance can be evaluated in a supervised condition by manipulating the ecosystem's different properties. This paper introduces a novel protocol design based on the Collection Centre Point Nodes. It proposes a next-hop selection, which uses the shortest path distance in each grid. The design of this proposed simulator can yield more power to receive the incoming packets due to its high energy threshold. This approach leads the protocol implementation to lower traffic in the network. The work presents a QoS-aware routing algorithm to improve performance in terms of packet delivery ratio, network lifetime, and security. In addition, the suggested routing algorithm reduces time and energy usage in comparison to existing similar secure routing methods.

Keywords: Simulator, Computer Networks, Network performance, Delay improvement, High energy packet receiver.

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1. Introduction

The widespread importance of computer networks today extends far beyond the realm of traditional computing and business. Cloud facilities, Industrial 4.0, Wireless Sensor Networks (WSN), Cyber-physical architectures, crucial infrastructural security, automobiles, trains, and military applications are only a few of the key application domains that could benefit from this technology[1]. The modular design of networking infrastructure enables the evolutionary process of benchmarks that concentrate on specific issues, permit the reusability of strategies, and permit the simultaneous design of various layers within a single architectural style or for distinct systems to be made compatible or adaptable[2].

Hardware and software are both essential parts of today's sophisticated networking technology[3]. The accessibility of computational hardware that is both more dependable and quicker is causing a shift in the traditional relationship between hardware and software, in addition to the architecture of network devices. Currently, embedded nodes that are mostly dependent on hardware and nodes focused on software can coexist[4]. Within these two types of nodes, similar functions are carried out using a variety of tools[5].

A wireless sensor network (WSN) refers to a system of interconnected, hardware-limited wireless sensors responsible for keeping tabs on specific locations. There is a wide variety of uses for WSNs. Quality-of-Service provisioning is crucial in use cases that rely on wireless sensor networks. Many applications may have varying QoS requirements for their data[6].

Concepts linked to quality-of-service create additional difficulties in the case of routing algorithms[7]. Routing protocol algorithms' competitive advantage can be traced back to their emphasis on path diversity. Yet, this results in erratic performance from routing. This means that it can be challenging to provide desired QoS values while using various routing approaches due to the inherent uncertainty of the latter[8]. It's important to remember that QoS algorithms typically restrict the path that a packet can take while in transit, which goes against the principle of path variety underlying a routing mechanism[9]. In order to preserve its supremacy, a routing protocol must include QoS techniques that restrict the variety of paths that can be taken depending on the pathlength. If the network takes the same stance on flows requiring varying degrees of Quality of Service, it can direct all of them along the most optimal path[10]. Nonetheless, links of inferior quality can still be used to support streams that require a relatively low-level QoS[11]. Because of this, QoS requirements of the flows can be taken into account while allocating system resources[12]. Parameters that represent the physical aspect of the WSN, like Packet Delivery Ratio (PDR), number of hops, etc., are used extensively in minimal path routing methods.

It's possible, nevertheless, that there exist paths with physically inferior connectivity that offer superior packet transmission possibilities. While most network traffic may be directed to the channels with the highest physical trait, overcrowding may develop there if the shortest path routing is used. However, this can be less of an issue if the traffic state of the links is taken into account throughout the routing procedure.

This article presents an original idea for a QoS-conscious network protocol centred on collection centre point nodes[13]. It recommends using the shortest path distance in each grid to determine the next hop in the chain. Because of its high energy threshold, the architecture of this suggested simulator will have more power to receive incoming packets than previous simulator designs.

The paper is arranged systematically. Section 2 presents an overall literature review on state-of-the-art network protocol approaches. In section 3, we discussed the Quality-of-service conscious network protocol design and its mathematical background. Section 4 presents the results and discussion of this whole experimental study. The conclusion of the article is discussed in the fifth section.

2. Related Works

The protocols used in WSN are developed to function well across a variety of network tiers. The networking model serves as the foundation for the operational functions that are performed by each of these layers[14]. Protocols implemented in NS2 are a collection of regulations defining how two or more computers, people, or other entities should interact with one another and how they should exchange data. We intend to implement our network protocol in NS2 simulator. NS is a discrete event simulator designed for use in studies of computer networks [15]. TCP, routing, and multicast protocol simulations over wired and wireless (local and satellite) networking systems are all made possible with NS's extensive support. Ns has come a long way since its inception as a fork of the REAL network simulator in 1989. NS2 stands for Network Simulator Version 2 [2]. There is a heavy emphasis on Unix in its structure. It is scripted using TCL. C++ and the Object-oriented Tool Command Language are the two primary languages of NS2 (OTcl). The OTcl prepares simulation by building and setting objects and scheduling discrete events, whereas the C++ describes the simulation objects' internal process (i.e., a backend).

There are three key varieties of protocols in ns2 simulator implementations. They are described as:

- Network protocols.
- Routing protocols.
- MAC protocols.

We are working on the QoS- conscious Routing protocol here. The routing protocols in WSN can be divided into three distinct categories on the basis of their design, which are linear, hierarchical, and location-based routing protocols. The topic of providing QoS WSNs is significant for the field of study, and there are still many questions to be answered.

By constructing a QoS framework according to a particular usage context, which features trade-offs, a practicable QoS supervising system can be formed by identifying essential QoS needs and measurements. In routing protocols, traffic on high-quality connections persists because nodes' relaying priorities are set according to the physical features of the links. An opportunistic routing policy that takes traffic diversity into account was presented by Naghshvar *et al.*[16]. It utilized a measurement of draining time to unscrupulously pick and guide packets via the pathways anticipated to have a low overall traffic level. Parsa*et al.* developed a mechanism that picks and prioritizes the set of forwarders depending on the QoS levels of the flow. The implementation of this format is a more even allocation of traffic across the network [17].

When it comes to latency and power usage, Yahiaoui *et al*. proposed an innovative protocol relying on an on-demand routing method. Clusters are the foundation of the network's structure. These clusters are chosen based on a number of criteria, including power capacity, connection richness and actuators availability [18]. Zhang *et al.* proposed and created a novel routing protocol's candidate forwarding node set to find a middle ground between energy consumption and performance [18]. The authors prioritized the information recorded by industrial sensors and divided it into three categories. This routing algorithm provides a variety of options for the prompt and dependable transmission of data from a wide range of industrial sensors. Shi *et al.* worked on many aspects of a routing protocol to increase its effectiveness in terms of throughput, latency, and packet drop [19]. Their goal was to improve the protocol QoS.

When considering how to enhance the energy consumption of sensor networks for intra-cluster connectivity, Agarkhed *et al*. presented a method based on stochastic management for efficient monitoring [20]. The method presented in this work achieves better results due to its ability to discharge the energy-intensive operations, hence decreasing energy use, minimizing delay, and maximizing the throughput. Inspired by the natural behaviour of the optimized bird mating algorithm, Faheem *et al.* have suggested a unique energy-effective and dynamic clustering-based QoS-aware routing protocol. By enhancing the packet delivery ratio and decreasing end-to-end latency, the suggested protocol outperforms the original design in several critical areas [21].

3. Protocol Design

3.1. RPTC

Routing protocol to Cross-layer communication is abbreviated as RPTC here. It is a general protocol, not an application area yet. This section discusses the proposed RPTC protocol design and the mathematical model behind it.

3.1.1. Malicious packet dropping

State-of-the-art works has introduced watchdog nodes which monitor the network and check for any malicious node by monitoring packets in transmission. This has the drawback of limiting the usage of watchdog nodes. Instead of watchdog nodes, a new type of node called Collection Centre Points (CCP) nodes are introduced in this work, which acts as a destination for each grid and collect data from all the nodes which are present in that grid. If there are any packets dropped from any source, then it can intimate the source to resend those packets.

3.1.2. QOS AWARE Routing Metrics and Algorithm

Existing: Current paper refers to selecting the parent node and then switching the new node to find the better next hop node for packet transfer.

Proposed: Next hop selection will be based on the shortest path distance in each grid. Since the packet travel length is limited within the grid, hence the routing of packets can not add much cost, and there is no requirement for extra packets transmission to find the next hop node

3.1.3. Congestion degree measurement

Existing: Previous papers solved this problem of congestion degree meas by introducing asynchronous LPL(Low power listening) and queue model.

Proposed: CCP nodes are designed in such a way that it high energy such that they will have more power to receive the incoming packets. And collected packets will be sent to Mobile Sink Charger (MSC). Thus, congestion will be minimal.

3.2. Protocol Design

The network is divided into 6 grids. Nodes are unevenly deployed in each grid. Each grid is numbered from 1 to 6, starting from the bottom left corner of the grids, as shown in the table below.

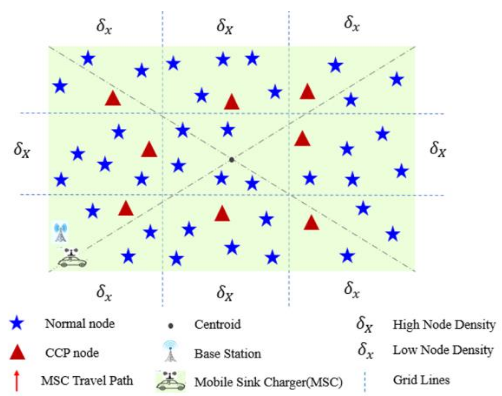
Table 1. The Grid Distribution

Grid 7 (low density)	Grid 8 (high density)	Grid 9 (low density)
Grid 4 (high density)	Grid 5 (low density)	Grid 6 (high density)
Grid 1 (low density)	Grid 2 (high density)	Grid 3 (low density)

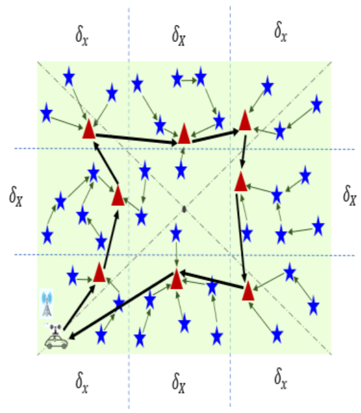
- Reason for uneven deployment: As the cornered grids are far away from the centroid of the network, the node will be away, and MSC will have a more significant distance to travel. Therefore, the protocol will be enhanced by omitting the cornered grids; MSC will visit the even grids.
- CCP selection: Initially, CCP will be selected for each grid. The Centroid point can be identified, which is the centre point of the entire network. Nodes in each grid which are close to the centroid will be selected as CCP nodes for each grid. The list obtained is called as temp CCP list. Nodes which are in even grids will be put under Final CCP List. The reason for this is that the MSC node will visit only Final CCPs and not the ones in the odd grids to reduce the travel path of the MSC node.
- MSC node: MSC node can act as a data collector (sink node), which will visit each CCP in the final list and collect the data packets sent by source nodes present in respective grids. Since MSC is not visiting the cornered CCPs, these CCPs send the data collected to the nearest CCP in the final CCP list. Therefore, the final CCP collects data from sources in their grid and the nearest cornered grid. Then, it forwards these packets when MSC comes close to final CCPs.

MSC will keep broadcasting small packets while travelling. When any final CCP node receives this packet, it responds back. As soon it receives any such packet from final CCP, it waits to collect the data from final CCP, then moves to the next final CCP. Finally, MSC collects and sends all the data to the base station.

Fig 1(a), 1(b), 2(a), 2(b) and 3 depicts some of the important stages of this network simulator design.

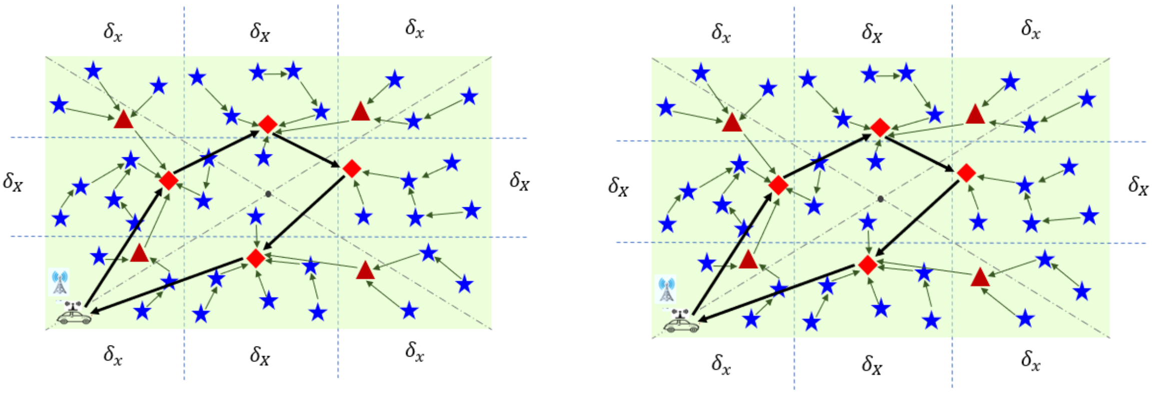


1(a)



1(b)

Fig.1(a). Selection of CCP from Centroid; **1(b)**. Packet flow to CCP nodes



2(a) **2(b)**

Fig. 2(a) MSC Path Construction considering all CCP nodes; **Fig.2(b)**MSC Path Construction considering FinalCCP Nodes

$$\frac{ac}{(ab+bc)} = \frac{5}{(3+4)} = 0.714 \rightarrow ac\ 28.6\%\ less\ than\ (ab+bc)$$

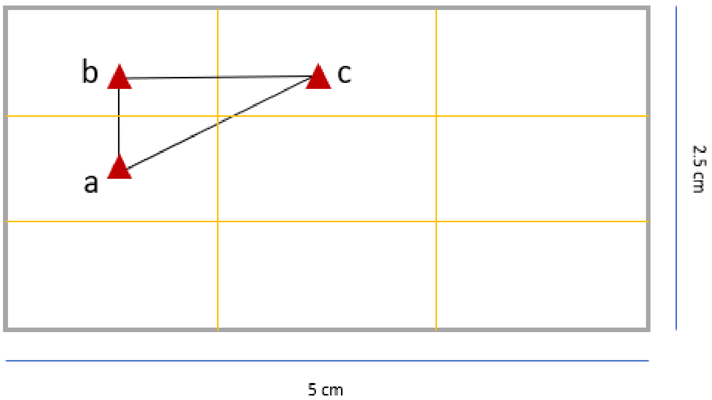


Fig.3. Reduction in MSC path length if TempCCP nodes are omitted

a) Mathematical Equations for the problem formulation considering density metric for the Energy Optimization of the CCP nodes, along with equations for distance and energy constraints.

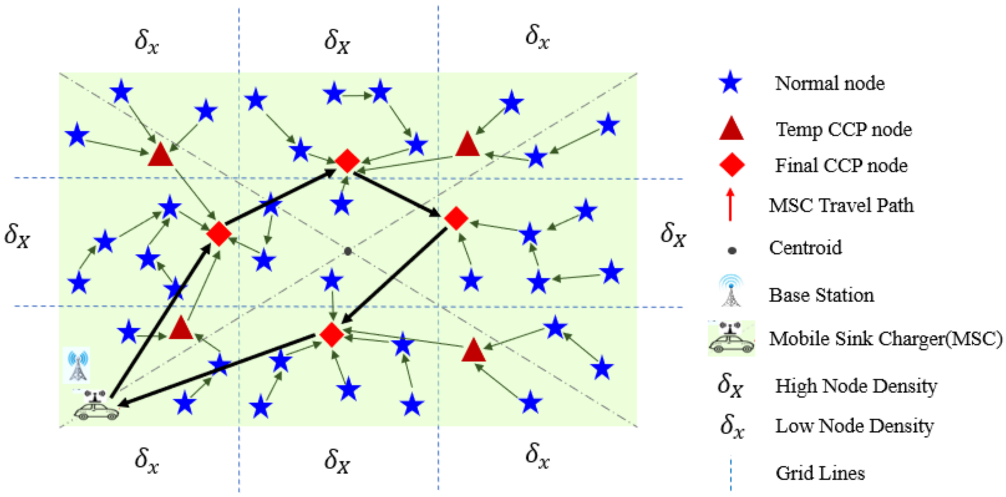


Fig. 4. System Architecture

For cluster set: $C = \{g_1, g_2, ...g_k\}$,where k number of grids. Here, k = 9.

- **The density of the Entire network:**

$$\delta = \frac{N}{k} \quad \text{---------------(1)}$$

If the nodes are uniformly distributed with density δ in each grid, then each grid will have an equal possibility of having a CCP node. This leads to allowing MSC nodes to travel in each grid. Thus, the travel length of MSC will increase.

Non-uniform distribution is applied to eliminate specific grids. Two density factors X and x are defined in such a way that the density obtained using these factors will follow the below criteria:

$$\delta_X > \delta > \delta_x \quad \text{--------------(2)}$$

Therefore, CCP nodes are selected from grids having density δ_X and $\delta_x$density grid CCP nodes are eliminated.

Normalizing node densities with respect to normal distribution node density (δ), then we get below equations:

$$\gamma_X = \frac{\delta_X}{\delta} \text{ and } \gamma_x = \frac{\delta_x}{\delta} \quad \text{--------------(3)}$$

Then, equation (2) becomes,

$$\gamma_X > 1 > \gamma_x \quad \text{--------------(4)}$$

As the MSC node traverses through high-density grids, data collection on these grids will be high. Thus, the density values should be selected to minimize the data travel length among normal nodes within the high-density grid.Nodes within low-density grids should be reachable from one to another as fewer nodes can be deployed.

To mitigate the above two conditions, γ_X and $\gamma_x$values should be such that the difference between the two will not be too far. Hence, $\gamma_X = 0.65$ and $\gamma_x = 0.35$ will be optimal to attain network connectivity (point 2 defined above) and better performance in terms of energy (point 1 defined above)

High Node Density:

$$\delta_X = \gamma_X * \frac{N}{k_X} \quad \text{.. (5)}$$

Low Node Density:

$$\delta_x = \gamma_x * \frac{N}{k_x} \quad \text{.................................. (6)}$$

Uniform distribution is applied to deploy δ_X and δ_x number of nodes in each grid accordingly.

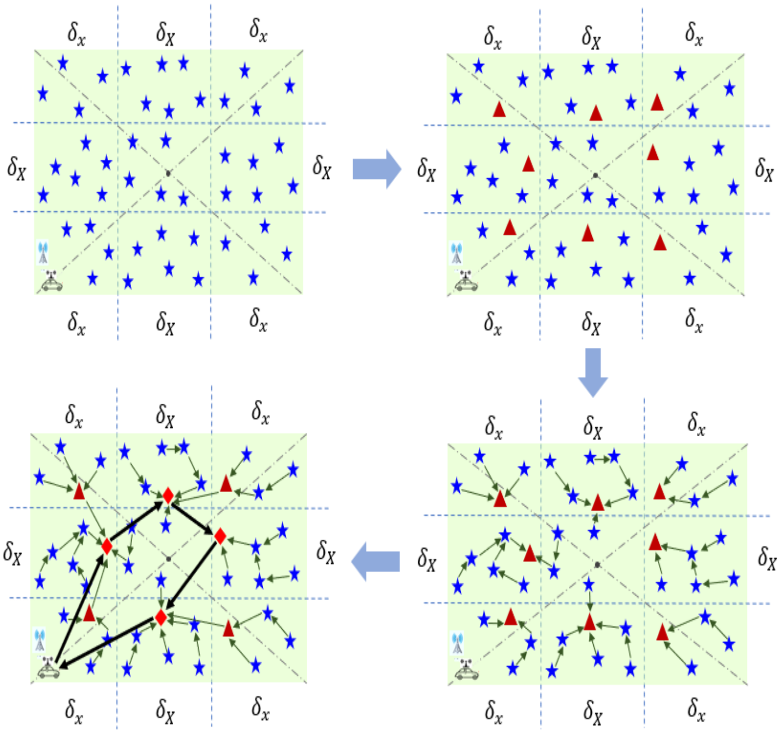


Fig. 5. Temp CCP List and Final CCP List Selection

- **Distance Constraint:**

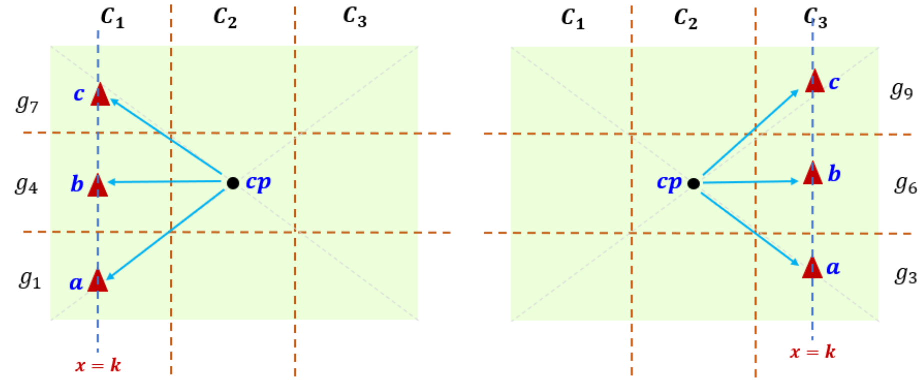


Fig. 6. The Distance Constraint

Group the grids in column wise such that shown in the above diagram $\{ C_1, C_2, C_3 \}$. Assuming $X - cordinate = c(constant)$, then a CCP is selected each grid of selected column(say, C_1). The distance is calculated from the centroid to each of these CCPs. It is observed that distance to CCP b is less compared to CCPs a and c. Corner grids are relatively far from centroid cp. Therefore, corner grids CCP nodes are omitted to reduce the travel length of the MSC node.

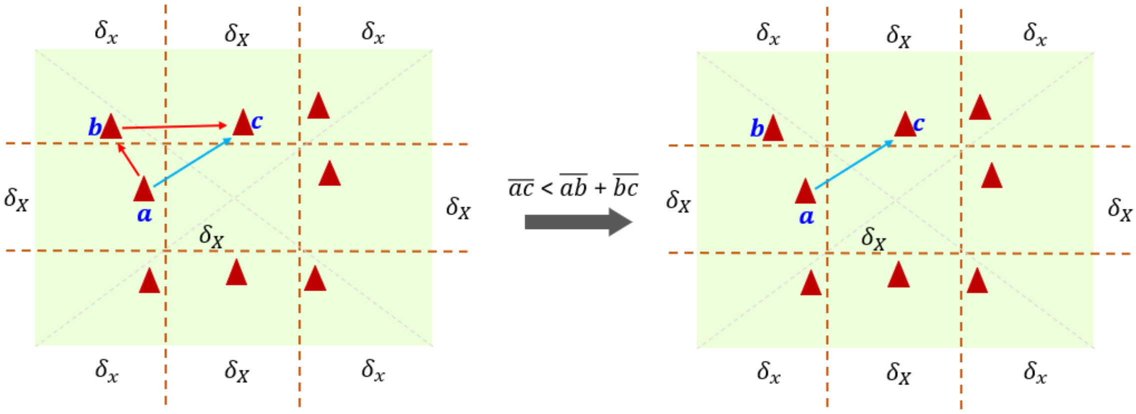


Fig. 7. The Energy Constraint in the Network Simulator

- **Energy Constraint:**

The average distance between any two nodes in the given line is given by:

$d = \frac{L}{3\delta}$ .... (7)

Extending the above equation to an area of (x, y), The equation can be rewritten as:

$d = \frac{avg(x,y)}{3\delta}$ .... (8)

Total energy consumption by a node is given by:

$E_{tot} = E_T + E_R$ .... (9)

In general, the energy (E) required to transmit data between any two nodes will be directly proportional to their distance d will each other. Therefore,

$E \propto d$ .... (10)

Also, the distance between any two nodes will be inversely proportional, as given below:

$d \propto \frac{1}{\delta}$ .... (11)

Combining the above equations (10) and (11) gives:

$E \propto d \propto \frac{1}{\delta}$ ======>$E \propto \frac{1}{\delta}$............ (12)

Conclusion 1:**Hence, energy consumed will be less if the density of the network is high.**

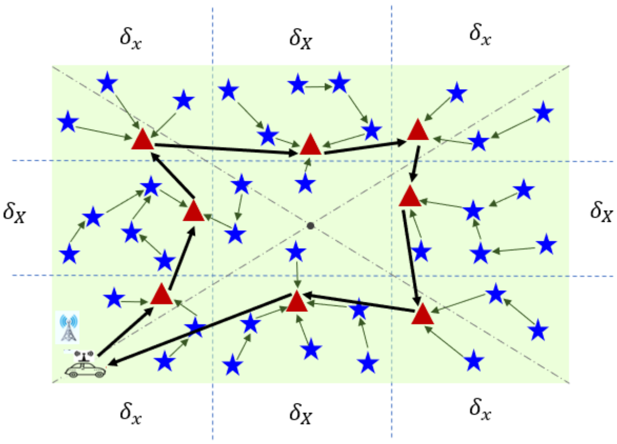
- **MSC Charger Module:**

From the above calculation, the energy required to receive packets from $\delta_x$for a period of $t_d$seconds if packets are generated at $pkt_{rate_}$per second is given if the packet size is 512 Bytes.

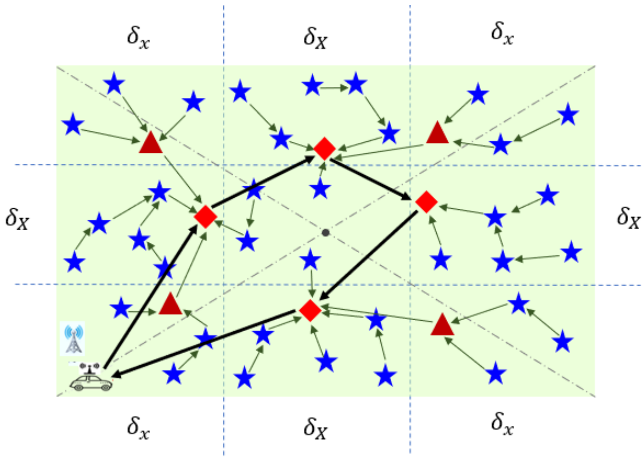
$E_{finalCCP\_Rx\_from\_TempCCP} = 0.00115 * pkt_{rate\_} * \delta_x * t_d$......................... (13)

Then, $E_{finalCCP\_Rx\_from\_TempCCP}$ amount of energy will be overhead for FinalCCP. MSC is designed to provide this much energy by charging when it visits Final CCP. Therefore, charging energy for Final CCP will be:

$$E_{charge\_per\_FinalCCP} = E_{finalCCP\_Rx\_from\_TempCCP} \dots\dots\dots\dots\dots\dots\dots (14)$$



9(a)



9(b)

Fig. 8(a). Travel Route with TempCCP List; **Fig. 8(b).** Travel Route with FinalCCP List

b) Pseudo code/Algorithmic steps for node deployment in each grid

1. Select grid size = k and grids are $\{g_1, g_2, \dots \dots g_k\}$
2. Loop through grids
For (gridIndex = 1; gridIndex<=k; gridIndex++) {
if (gridIndex % 2 == 0) {
add gridIndex to highDensityList
} else {
add gridIndex to lowDensityList
}
}
3. Find highNodeDenisty(δ_X*) and lowNodeDensity(*δ_x*) using the formula*

$$\delta_X = \gamma_X * \frac{N}{k_X}$$

$$\delta_x = \gamma_x * \frac{N}{k_x}$$

4. Loop through highDensityList
For (highGridIndex = 1; highGridIndex<=k; highGridIndex++) {
deploy δ_X *number of node grid highDensityList[highGridIndex] using the uniform distribution*
}
5. Loop through lowDensityList
For (lowGridIndex = 1; lowGridIndex<=k; lowGridIndex++) {
deploy δ_x *number of node grid lowDensityList[lowGridIndex] using the uniform distribution}*

c) Pseudo code/Algorithmic steps for the FinalCCP List selection

1. *Loop through highDensityList*
2. For each grid g_i selected from *highDensityList*
3. Loop through each node within grid g_i
For (nodeIndex = 1; nodeIndex<=sizeOf(g_i*); nodeIndex++) {*

Find the distance from nodeindex to centroid cp using the distance formula
Store distances indistanceList
nodeIndex which is close to centroid cp within the selected grid will be selected as CCP
add the selected node into FinalCCPList
}

d) Pseudo code/Algorithmic steps for the Short Distance calculation

1. For the given graph, $G = (X, Y)$ and node $N = \{n_0, n_1, \ldots \ldots n_m\}$
2. Divide the network horizontally at line $Y/2$ such that two regions will be formed
$$R_1 = \{0,0\}\ to\ \{0, Y/2\}$$
$$R_2 = \{0,0\}\ to\ \{Y/2, Y\}$$
3. For the given collection point set, $CP_{set} = \{ncp_i, ncp_2, \ldots \ldots ncp_m\}$
4. Divide CP_{set} into CP_{setR1} and CP_{setR2} where
$$CP_{setR1} = ncp_i, where\ ncp_i(Y) > Y/2$$
$$CP_{setR2} = ncp_i, where\ ncp_i(Y) < Y/2$$
5. Arrange CP_{setR1} in ascending order with respect to X position of each node in the set.
6. Arrange CP_{setR2} in descending order concerning X position of each node in the set.
7. Finally, MSC node can traverse to all nodes in CP_{setR1} and then, in CP_{setR2} in the same order.

4. Results and Discussion

We compared our proposed QoS-conscious protocol design with existing approaches like the optimized Collection-Tree Protocol (CTP-optimized), Hybrid Energy-Efficient Distributed (HEED) clustering system, and the Tree Cluster-Based Data-Gathering Algorithm (TCBDGA). The performance of the suggested protocol was mainly assessed using the key metrics listed below.

- **Energy Usage in Network:** WSNs need power when transmitting, receiving, and in resting mode. All parts, excluding the power unit, eat up power while performing their job. Each node's energy expenditure during packet transmission is added together to get the network's total energy usage.

- **Packet delivery ratio:** The packet delivery ratio is the proportion of successfully delivered packets compared to the entire amount of packets transmitted from the origin node to the recipient node within the network. So, this metric indicates a conclusion: in a WSN, data packets should arrive as many as possible at the intended target location. The mathematical representation of this metric is presented in equation 16.

$$Packet\ Delivery\ Ratio = \frac{\sum NP_{recieved}}{\sum NP_{sent}}$$

Here, NP indicates the number of packets.

- **3.End-to-End delay:** The delay experienced by a packet as it travels from its origination point to its final destination is known as its end-to-end delay. This term often comes up when talking about keeping tabs on an IP network. For determining end-to-end latency, it is important to have a general idea of the packet size, the link's data rate, and the propagating time between the source and the destination.

- **Network lifetime:** Since the loss of a node in a WSN could cause the loss of some of its functionality, its lifespan is referred to as the period until the energy supply of the first sensor or node exhausts. Simply said, it's the expected duration of full functionality for a WSN.

- **Throughput:** Total network throughput is the rate at which data is transferred from the source to receiving point. In this context, it is seen as an objective indicator of a protocol's success.

4.1. Network Lifetime

In comparison to conventional methods, a high network lifetime is achieved by the RPTC protocol. Fig. 9 compares the introduced RPTC to existing techniques in terms of network lifetime. The table compares existing techniques and shows the lifetime of the network of the proposed work. In WSN, the transmission of packets should be transmitted over distances, consuming more energy. The energy consumption of CCP nodes is low due to the best selection of CCP based on its distance from the centroid and the shortest route detection among the final CCPs of RPTC. Furthermore, the requirement for energy is lessened, and the network's lifespan is extended. When the lifetime of the network is increased, so is the data transmission efficiency. The lifetime of a network of the method proposed is 7000 (rounds) in 100 nodes, whereas the lifetimes of the current methodologies HEED, CTP-optimized, and TCBDGA are 4100, 5000 and 4300 rounds, respectively, in 200 nodes.

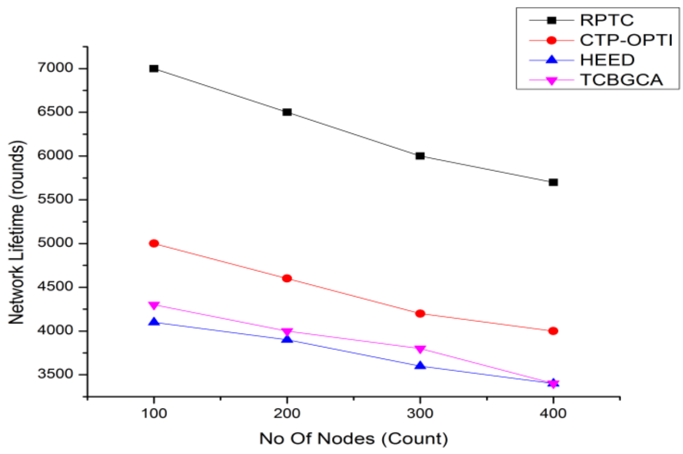


Fig.9. Graph Showing Network Lifetime

4.2. Packet Delivery Ratio

The packet delivery ratio (PDR) can be obtained from the total number of data packets arriving at estinations divided by the total data packets sent from sources. Fig. 10 shows the performance of the ratio of packets delivered and the packet drop. In 100 nodes, the proposed method outperforms other

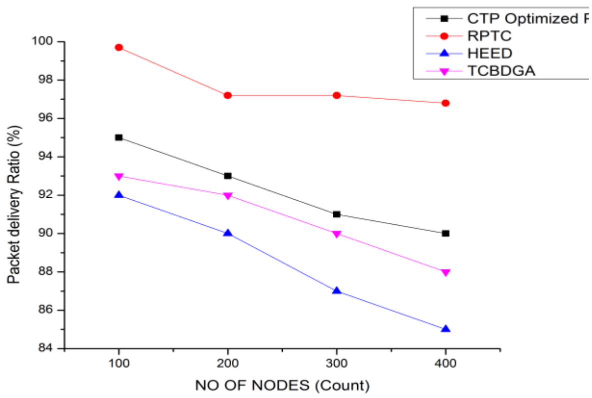


Fig. 10. Graph Showing Packet Delivery Ratio

energy-efficient existing approaches with a high PDR of 99.5%. The proposed method outperforms the previous approaches in terms of efficiency. In 100 nodes, the PDR of previous methods such as HEED, TCBDGA, CTP-Opti, and CORP are 93%, 95%, 98%, and 99.5%, correspondingly. For efficient data transmission, PDR should be high. For high PDR values, all data can be received at the destination node without any data loss. This metric grows as the number of nodes increases. As a result, when compared to existing approaches, the proposed model achieves high performance and efficiency.

4.3. Throughput

The proposed RPTC approach is compared to existing methods on the basis of throughput and end-to-end delay. The relevant graph is shown in Fig. 11. The proposed method achieved a high throughput of (0.982 Mbps) in 100 nodes. The existing HEED, TCBDGA, and CTP-OPTI methods depict through values 0.68, 0.76, and 0.89Mbps, respectively. The selection of CCP nodes is developed by considering their energy and distance from the centroid. This RPTC protocol has been working effectively. It is highly dependent on the lifespan of the WSN and the energy remaining. Throughput decreases as the Count of nodes increases. Fig. 11 shows that the implemented approach is significantly more efficient than other strategies.

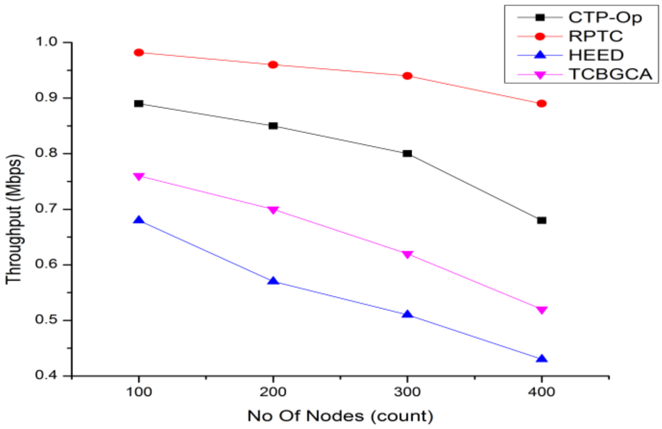


Fig. 11. Graph Showing Throughput Comparison

4.4. End-to-End Delay

The suggested RPTC latency is low due to the time necessary to calculate the likelihood of delivery and the shortest path. RPTC was created to reduce congestion in a network. The average time it takes to

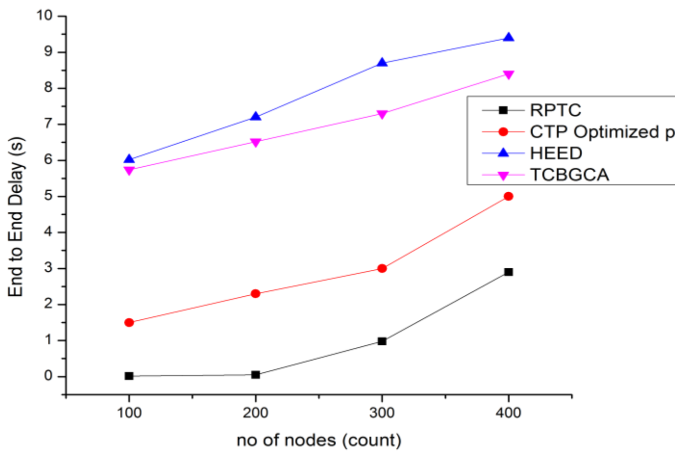


Fig. 12. Graph Showing Delay Comparison

route data from a source is measured in seconds to a destination. The average delay is the time saved for data transmission from the start node to the destination node between networks. In this context, Fig. 12 shows the end-to-end latency of the proposed RPTC and its comparison to current approaches. The proposed RPTC approach obtained a lower (0.01 s) end-to-end delay in 100 nodes than the other traditional methods shown in the graph (Fig. 12). The time delay increases with the number of nodes in a WSN. In 100 nodes, other approaches like HEED, TCBDGA, CTP-OPTI, and have time delays of 6.02, 5.74, and 1.5secs, respectively. The suggested RPTC identifies the shortest way to increase communication link reliability and reduce packet delay.

4.5. Energy Consumed

Figure 13 compares the energy consumption of the proposed task to that of existing procedures. The proposed RPTC uses lesser energy than state-of-the-art approaches; for 100 nodes, it uses 8.80 mJ, whereas CTP-optimized, CORP, HEED, and TCBDGA use 9.90,9.80,143 and 135mJ, respectively. The proposed approach uses 37 mJ for 400 nodes, whereas existing systems like CTPOP, CORP, HEED, and TCBDGA use 22.40, 37.71, 240, and 210mJ, respectively. As a result, the RPTC protocol is very efficient regarding data transfer.

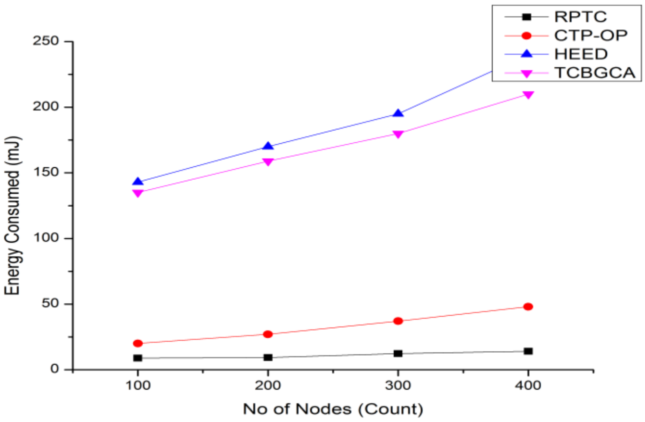


Fig. 13. Graph showing Energy Consumption

5. Conclusion

This article presents an original protocol design centred on the Collection Centre Point Nodes concept. It suggests a next-hop option that considers the shortest path distance in each grid to make its determination. Because of its high energy threshold, the architecture of this proposed simulator has the potential to generate more power, which can be used to accept incoming packets. We evaluated our proposed protocol model with various other protocol designs, such as the CTP-optimized protocol, HEED protocol, and the TCBDGA using the simulation results from ns2. This strategy results in less traffic being generated by the protocol implementation within the network. This study proposes a QoS-aware routing algorithm to improve performance in terms of the ratio of packets delivered, the lifetime of the network, and network security. In addition, when it was compared to other similar secure routing systems now in use, the time and energy required by the suggested routing algorithm were significantly less.

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