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An Efficient Multipath Packet Forwarding (MPF) Protocol with Modified Dijkstra Path Searching Algorithm in Underwater Wireless Sensor Network

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***Abstract*:** Underwater Wireless Sensor network is an emerging to be a promising technology in unveiling the mysteries of the marine life and other underwater applications. Routing in underwater wireless sensor networks differs from routing in global wireless sensor networks. However, distinctive features of UWSNs like multipath propagation delay, limited bandwidth, and energy constraints. This paper presents a Multipath Packet Forwarding (MPF) protocol with modified Dijkstra path searching algorithm is used for dynamic data transmission in this work. The proposed Multipath Packet Forwarding protocol is used for multiple paths which loops free and disjoint in message communication. In addition, during the path selection of the best shortest path forwarder node, the robust weight function parameters make it more efficient to consume minimum energy. The experimental result analysis indicates that Multipath Packet Forwarding (MPF) protocol with modified Dijkstra path searching algorithm has very good adaption ability to the UWSN in terms of Throughput, Packet Delivery Ratio (PDR), Packet Loss Ratio and Energy consumption.

Keywords: Underwater Sensor Network, Routing, WSN, Dijkstra, Multi-path.

I. INTRODUCTION

A Wireless Sensor Network (WSN) can be distinct as a network of devices that can corresponds the information message together from an observed field during wireless links. A WSN is a circulated network and it includes a huge amount of circulated tiny and self-directed short powered devices called sensor nodes also known as WSN [7]. WSN obviously includes a huge amount of spatially discrete, battery-controlled, small, embedded devices that are networked to sensitively gather, development, and express data to the users, and it has limited calculating and dispensation abilities.

Underwater Wireless Sensor Networks (UWSNs) contain numerous components such as vehicles and sensors that are positioned in a particular acoustic region to execute mutual examining and data gathering tasks. UWSNs are prepared with a restricted battery that cannot be re-energized or replaced. The problem of energy conservation for under water WSNs entails the progress of underwater communication and networking methods [3].

The underwater sensor networks can be done in two kinds of architectures. (i) A two dimensional architecture the nodes correspond with the sink during a multi-hop path. The sinks have a parallel transceiver for corresponding with the sensor nodes and a perpendicular transceiver for corresponding with the outside station. (ii) A three dimensional architecture the nodes are balanced at dissimilar depths. Autonomous Underwater Vehicles (AUV) is organized to collect data through sound modems. The underwater communication faces the disputes of absorption, propagation delay, multipath interferences, noise interference, etc. The collection is also limited. Underwater sensor networks architecture [1] is shown in Figure 1.

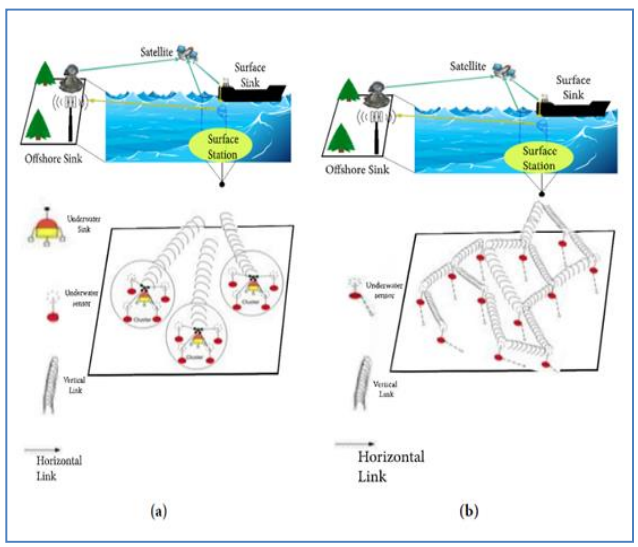

Fig. 1: Two- and 3-dimensional networks architecture for UWSN regarding communication given in (a) and (b), respectively

In Underwater wireless sensor networks, there are several sensor nodes accessible in the network area. The sensor nodes have the ability to sense the information and promote towards the superior surface target node. The information packets of the sensor nodes are developmental and distributed to the target using shortest path submission method [5]. The acknowledged data packet truthfulness is frequently dependent on the errorless communication. The ocean has time-varying link features and cruel noise, which construct the underwater networks additional challenging to have a finest data transmission.

The existing Radius-based Courier Node Routing Protocol (RCRP) [8] is essentially a multi-path routing method, which believes only restricted depth information for the collection of data advancer sensor node. This information is not adequate to recognize the location of the sensor nodes. In calculation, the circumstances become worse when two sensor nodes at the equivalent depth forward the unnecessary information towards the sink node.

Courier node routing protocol is multipath packets forwarding mechanism has been adapted at seabed level from source to static courier nodes to target nodes. Source nodes are deployed at the seabed level whereas courier nodes are deployed on multiple layers in fixed way from sea surface to seabed. Courier nodes are the powerful nodes and having high battery power, courier nodes collects the information from source nodes through ordinary nodes and forwards that information towards sink nodes which are deployed on sea surface.

This paper present a Multipath Packet Forwarding (MPF) Protocol method is used for multipath data transmission without courier node. To overcome the previous courier routing protocol [8] limitation, modified Dijkstra algorithm is used in MPF protocol by calculating more than one path for message transmission. It has been proved that MPF improvised than previous courier routing protocol.

The objective of this work is to design and develop the Multipath Routing Packet Forwarding (MRPF) protocol for Underwater Wireless Sensor Network is proposed to handle end-to-end delay and packet delivery ratio measures. Due to problem of single path data transmission issue, the proposed method calculate the k multiple Shortest path routing is to find the highest Connection Probability (CP) path between any given source-to-destination pair in a distributed way.

The rest of the paper organized is as follows: Related work detailed is in Sect. 2. In Sect. 3, Design and implementation. In Sect. 4 Performance Evaluation and conclusion is in Sect. 5.

II. RELATED WORK

***Llor, J., Malumbres, M.P.* (2012) [6]** analyzed the evolution of underwater acoustic prediction models from a simple approach to more detailed and accurate models. Then, different high layer network protocols are tested with different acoustic propagation models in order to determine the influence of environmental parameters on the obtained results. After several experiments, they can conclude that higher-level protocols are sensitive to both: (a) physical layer parameters related to the network scenario and (b) the acoustic propagation model. Conditions like ocean surface activity, scenario location, bathymetry or floor sediment composition, may change the signal propagation behavior. So, when designing network architectures for UWSNs, the role of the physical layer should be seriously taken into account in order to assert that the obtained simulation results will be close to the ones obtained in real network scenarios.

***Aziz et.al.*, (2013) [2]** discussed the survey focused on the energy efficiency issue and present a comprehensive study of topology control techniques for extending the lifetime of battery powered WSNs. First, they reviewed the significant topology control algorithms to provide insights into how energy efficiency is achieved by design. Further, these algorithms are classified according to the energy conservation approach they adopt, and evaluated by the trade-offs they offer to aid designers in selecting a technique that best suits their applications. Since the concept of “network lifetime” is widely used for assessing the algorithms’ performance, they highlight various definitions of the term and discuss their merits and drawbacks. Recently, there has been growing interest in algorithms for non-planar topologies such as deployments in underwater environments or multi-level buildings. For this reason, they also include a detailed discussion of topology control algorithms that work efficiently in three dimensions. Based on the outcomes of their review, they identified a number of open research issues for achieving energy efficiency through topology control.

***Xu, G., Shen, W., Wang, X* (2014) [10]** provided a comprehensive review of the state-of-the-art technologies in the field of marine environment monitoring using wireless sensor networks. It first describes application areas, a common architecture of WSN-based oceanographic monitoring systems, a general architecture of an oceanographic sensor node, sensing parameters and sensors, and wireless communication technologies. Then, it presents a detailed review of some related projects, systems, techniques, approaches and algorithms. It also discusses challenges and opportunities in the research, development, and deployment of wireless sensor networks for marine environment monitoring.

Jiang, P., Wang, X., Jiang, L **(2015) [4]** designed an efficient deployment method to guarantee optimal monitoring quality is one of the key topics in underwater sensor networks. At present, a realistic approach of deployment involves adjusting the depths of nodes in water. One of the typical algorithms used in such process is the Self-Deployment Depth Adjustment Algorithm (SDDA). This algorithm mainly focuses on maximizing network coverage by constantly adjusting node depths to reduce coverage overlaps between two neighboring nodes, and thus, achieves good performance. However, the connectivity performance of SDDA is irresolute. They proposed a depth adjustment algorithm based on Connected Tree (CT). In CTDA, the sink node is used as the first root node to start building a connected tree. Finally, the network can be organized as a forest to maintain network connectivity. Coverage overlaps between the parent node and the child node are then reduced within each sub-tree to optimize coverage. The hierarchical strategy is used to adjust the distance between the parent node and the child node to reduce node movement. Furthermore, the silent mode is adopted to reduce communication cost. Simulations show that compared with SDDA, CTDA can achieve high connectivity with various communication ranges and different numbers of nodes. Moreover, it can realize coverage as high as that of SDDA with various sensing ranges and numbers of nodes but with less energy consumption.

Zenia et.al., **(2016) [11]** reviewed, the core design aspects for an ideal UWSN are identified which are energy-efficiency and reliability. These design aspects are evaluated in terms of energy consumption and communication efficiency – in order to provide an insight to the network designers on ideal design metrics. It is found that the protocols are highly selective, and the fitness of any protocol depends solely on the application and design requirements, which is addressed by this review. They also provided a comprehensive overview through comparison and simulation to analyze and summarize the MAC and routing protocols under concern.

Tuna, G., Gungor, V.C **(2017) [9]** discussed a Wireless Sensor Networks (WSNs) have attracted the attention of both the research community and the industry, and this has eventually lead to the widespread use of WSNs in various applications. The significant advancements in WSNs and the advantages brought by WSNs have also enabled the rapid development of underwater wireless sensor networks. In UWSN's, in addition to deployment, determining the locations of underwater sensor nodes after they have been deployed is important since it plays a critical role in many applications. Various localization techniques have been proposed for UWSN's, and each one is suitable for specific scenarios and has unique challenges. They presented an overview of potential UWSN applications; a survey of the deployment techniques and localization algorithms for UWSN's has been presented based on their major advantages and disadvantages.

Muhammad Khalid, et.al., **(2018) [8]** discussed an Underwater wireless sensor networks (UWSNs) use acoustic waves to communicate in an underwater environment. Acoustic channels have various limitations such as low bandwidth, a higher end-to-end delay, and path loss at certain nodes. Considering the limitations of UWSNs, energy efficient communication and reliability of UWSNs have become an inevitable research area. The present research interests are to operate sensors for a longer time. The currently investigated research area towards efficient communication has various challenges, like flooding, multiple copies creation path loss and low network life time. Hence, it is different from previous work which solved certain challenges by measuring the depth, residual energy, and assigning hop-IDs to nodes. This study has proposed a novel scheme called radius-based courier node (RMCN) routing. RMCN uses radius-based architecture in combination with a cost function, track-ID, residual energy, and depth to forward data packets. The RMCN is specifically designed for long-term monitoring with higher energy efficiency and packet delivery ratio. The purpose of RMCN is to facilitate a network for longer periods in risky areas. The proposed routing scheme has been compared with depth-based routing and energy-efficient multipath grid-based geographic routing with respect to alive nodes left, end to end delay, delivery ratio and energy consumption.

III. METHODOLOGY

The proposed method accepts the network simulation parameters as input, where the Multipath Packet Forwarding (MPF) Protocol with Dijkstra Algorithm is applied. The overall proposed flow diagram in figure 2 follows a high dimensional data clustering procedure form start to end state.

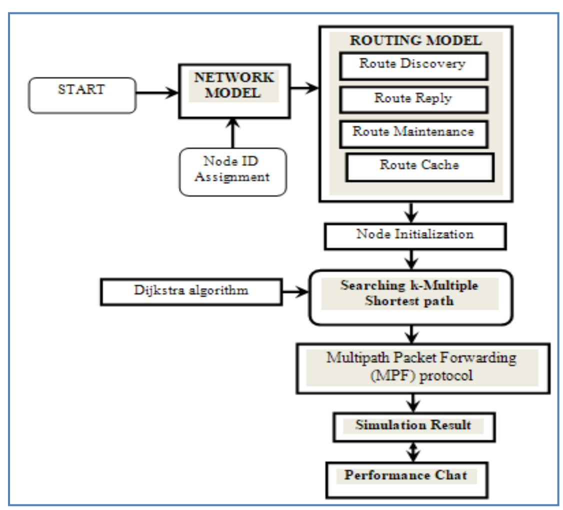

Fig.2: Proposed system flow diagram

A. *Network Model*

In network model simulation are estimated in networks of 83 nodes. As the amount of sensor nodes in the UWSN network is improved, the dimension of the simulation region is also enlarged so that a stable node density is preserved. The simulation model regions are assigned as 300m x 300m, 500m x 500m and 1300m x1300m correspondingly. Each sensor nodes are moving according to the random waypoint mobility model. Senor node momentums are arbitrarily circulated among zero and a few maximum, where the highest speed or momentum differs between 0 and 10 milliseconds. The break time is constantly every 5 seconds. Every data point signifies a standard of 10 runs with the similar traffic representations, but different randomly produced mobility setting. Whole traffic is Constant Bit Rate (CBR) traffic with 512 byte data packets at the distribution rate of 8 packets per second.

B. *Mobility Model*

The Random Waypoint Model (RWP) is one of the mainly extensively used mobility models in routine analysis of Wireless sensor networks. This research work examines the fixed spatial distribution of a sensor node moving according to the RWP form in a specified convex region. For this it provides an implicit appearance, which is in the shape of a single-dimensional essential giving the compactness up to normalization regular. This consequence is also comprehensive to the case where the waypoints have a non-uniform allocation. Moreover, the customized RWP model, illustrates where the waypoints are on the path limit. The systematic consequences are demonstrated through mathematical instances. Furthermore, the systematic consequences are related to learn confident performance procedures in ad hoc networks, explicitly connectivity and traffic load distribution.

In the model distribution, the execution of this mobility model is as follows: as the model begins, every sensor node arbitrarily chooses distinct position in the model field as the destination. It then schedules towards the target or destination with stable swiftness selected consistently and randomly from [0, *S*], where the parameter *S* is the highest acceptable speed for each sensor node. The speed and path of a sensor node are selected separately of additional sensor nodes. Leading realization the target, the sensor node ends for a period distinct by the 'break time' parameter. If *BT*=0, this guides to permanent mobility. After this period, it again selects a different random target sensor node in the model field and travels towards it. The entire procedure is recurring again and again until the model ends.

In the Random Waypoint model, S_{max} and BT_{break} are the two essential parameters that decide the mobility performance of sensor nodes. If the S_{max} is little and the break time BT_{break} is extended, the topology of underwater wireless sensor network suits reasonably constant. On the other hand, if the sensor node shifts quick (i.e., S_{max} is fat) and the break time BT_{break} is tiny the topology is predictable to be extremely active. Changeable these two constraints, particularly the S_{max} constraint, the Random Waypoint model can produce different mobility states with dissimilar stages of nodal speed.

The development of mobility metric is to capture and compute this nodal momentum notation. To evaluate of qualified momentum or relative speed among node *x* and *y* at time *t* is,

$$QM(x,y,t) = \left|S_x(t) - \frac{S_y(t)}{M}\right| \quad eqn.(1)$$

Then, the mobility metric is considered as the compute of qualified momentum averaged over all nodes pairs and above all time. The recognized classification is as follows,

$$M = \frac{1}{|x,y|}\sum_{x=1}^{L}\sum_{y=x+1}^{L}\frac{1}{T}\int_0^{MT} QM(x,y,t)dt \qquad eqn.(2)$$

where |*x*, *y*| is the amount of distinct node pair (*x*, *y*), *L* is the entire number of sensor nodes in the model field (i.e., UWSN), and *MT* is the model time.

Using this mobility models proficient to approximately calculate the stage of nodal speed and distinguish the dissimilar mobility states based on the stage of mobility. The qualified momentum (*QM*) linearly and monotonically amplifies with the highest permissible speed.

C. *MODIFIED DIJKSTRA SHORTEST PATH ROUTING DETECTION ALGORITHM*

The modified multi-path Dijkstra's search algorithm works by iteratively choosing the sensor node with the lowest present distance from the precedence queue (primarily, this is the origin or source sensor node). Each iteration algorithm "increases" that node by navigating the adjacency record of the chosen sensor node to observe if some of those nodes can be achieved with a path of a shorter distance. The algorithm finishes when the precedence queue Q is blank, or consistently, when all sensor nodes have been measured. Note that the algorithm as obtainable in pseudo code simply calculates the shortest distances. The definite paths can be improved by accumulating "back pointers" for each sensor node demonstrating a portion of the shortest path.

The searching technique is based on sustaining a comprehensive precedence queue of sensor nodes with precedence's equivalent to their distances from the origin node. In every iteration the algorithm increases the node with the shortest distance and revising distances to all available nodes.

The distance calculation using Euclidean distance as follows:

$$weight\ (wt) = \sqrt{X(i)_{xd} - X(i+1)_{xd}{}^2 + X(i)_{yd} - X(i+1)_{yd}{}^2} \quad eqn.(3)$$

Where, X is the Nodes assignment, x_d is x-coordinate, y_d is y- coordinate.

PSEUDO CODE FOR MODIFIED DIJKSTRA SEARCH ALGORITHM

Input: Graph *G*, weight *wt*, source *s*
Output: Updates the shortest distance.
// Initialize the whole nodes distance is set to zero
Initialize distance d[s] ← 0.
// Assign all nodes distance are infinity
for all vertex $v \in V$ do
d[v] ← ∞
Q ← {*V*}
// Extract Minimum path and assign the link for the shortest path
while Q ≠ Φ **do**
u ← Extract minimum(*Q*)
for all vertex $v \in u$*.Adjecencylist* **do**
// Calculate weight using equation 3.3
if wt[v] > wt [u]+w(u,v) then
d[*v*] ←*d*[*u*]+*wt*(*u*,*v*)
End process when all nodes have been *v* visited.

D. MULTIPATH PACKET FORWARD (MPF) PROTOCOL

A multi-path packet forward protocol in UWSN can be either unidirectional or bidirectional so the host must know this information about the neighbors. When the initial sensor node transmits a control message and comprises that, it has the connection to the subsequent sensor node as asymmetric, the next host set primary host position to symmetric in individual routing table. Lastly, when subsequent sensor node transmits over again control message, where the condition of the connection for the primary sensor node is specified as symmetric, then primary sensor node varies the condition from asymmetric to symmetric. In the finish both hosts knows that their neighbor is alive and the matching link is bidirectional.

ALGORITHM FOR MULTIPATH PACKET FORWARD (MPF) PROTOCOL

Step 1: A source node requests a path to target or destination sensor node the protocol begins path discovery. Throughout route or path discovery, origin node transmits Route Request (RREQ) packets through neighboring nodes.

Step2: While getting the RREQ packet every sensor node modernize their routing table

Step 3: Evaluate both Neighbor List (NL) and compute the amount of frequent neighbor nodes (frequent node) near between origins to target.
For *x*=0; x<amount_of_origin_neighbors; x++
For *y*=0; y<amount_of_destination_neighbors; y++
If (NL_Origin(x) =NL_Target(y))
Frequent _node++;

Step 4: Initialize single hop neighbors can achieve target node with most of three step and least of single hop. If highest target_hop_count beats three then target node and their earlier hop might be the malicious sensor node.

Step 5: If target_node_count > node_calculate_threshold then announce the target node and their earlier hop sensor nodes are malicious nodes.

Step 6: Broadcast malicious node declaration message to all sensor nodes.

Step 7: Several sensor nodes accepts malicious declaration message it eliminates malicious node identify from its Neighbor table and Routing Table.

IV. PERFORMANCE EVALUATION

The proposed system considers 83 nodes in Multipath Packet Forwarding (MPF) Protocol with Dijkstra Algorithm in Underwater Wireless Sensor network with nodes randomly deployed in a 1000 m × 1000 m simulation area. The simulation parameters is given below,

Table 1: Simulation Parameter

PARAMETER	VALUE
Simulator	NS2.34
Number of Sensor Nodes	83
Simulation Area	1000 × 1000 m
Channel Type	Wireless
Initial Energy	100 J
Routing Protocol	DSR
Antenna	Omni Antenna
Node Energy	100Joules
MAC	802.11
Transaction Power	1.5
Receiving Power	2.0

The performance of the protocol is evaluated with the following parameters:

- Throughput
- Packet Delivery Ratio (PDR)
- Packet Loss Ratio
- Energy Consumption

THROUGHPUT: The ratio of the entire amount of data that arrives at a receiver from a source to the time it takes for the destination to obtain the final message is referred to as throughput.

$$Throughput = \frac{Number\ of\ data\ delivered}{Total\ Time\ duraiton} \quad \text{eqn. (4)}$$

Table 2: Throughput

NUMBER OF NODES	RCRP	MPF
5	0.05	**0.17**
8	7	**13.37**
11	15	**26.97**
14	23	**40.57**
17	31	**53.77**
20	39	**67.37**
23	47	**80.62**
26	55	**93.82**
29	63	**96.83**

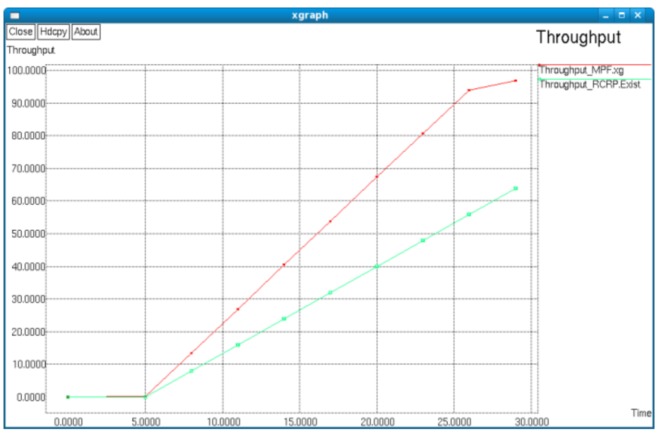

Fig. 3: Throughput

The comparison of throughput of the network is given using figure 3. In this diagram the proposed algorithm's performance is represented using the red line and the green line shows the performance of existing RCRP [8] method. For representing the performance of network the *Y* axis contains the throughput (kbps) and the *X* axis contains the simulation time in network experimentations. The proposed Multipath Packet Forwarding (MPF) protocol achieves 96.83% high throughput ratio due to no packet loss but the existing Radius-based Courier Node Routing Protocol (RCRP) method attains low throughput up to 65% due to more packet losses during the data transmission time through number of sensor nodes.

PACKET DELIVERY RATIO (PDR): It is the ratio of the number of packets received by the destination to the number of packets generated by the source node. So it have count amount of messages transmitted and amount of messages delivered and this is done by network simulator in which trace file is generated to show the message details. The graph results show the comparison between RCRP [8] and Proposed MPR.

$$PDR = \frac{Amount\ of\ Data\ Delvered}{Amount\ of\ Data\ Transmitted} \quad eqn. (5)$$

Table 3: Packet Delivery Ratio

NUMBER OF NODES	RCRP	MPF
5	0.92	**1.0**
8	0.91	**1.0**
11	0.94	**1.0**
14	0.97	**1.0**
17	0.21	**1.0**
20	0.96	**1.0**
23	0.98	**1.0**
26	0.92	**1.0**
29	0.97	**1.0**

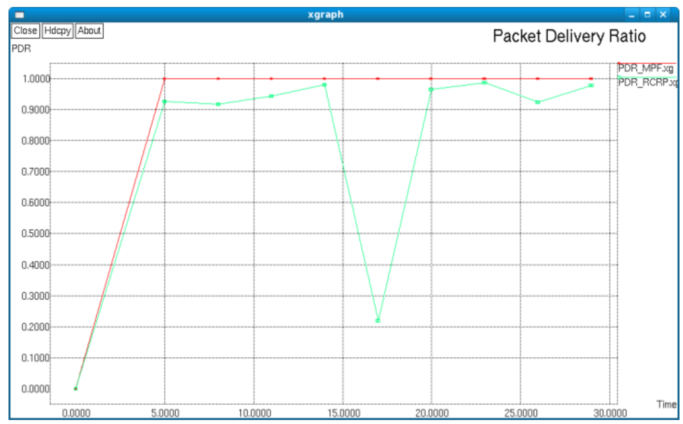

Fig. 4: Packet Delivery Ratio (PDR)

The proposed Multipath Packet Forwarding (MPF) protocol achieves 1.0 (i.e., 100 %) packet delivery ratio due because of data transmission along with three consecutive paths and no packet loss but the existing Radius-based Courier Node Routing Protocol (RCRP) method also attains high packet delivery ratio but particular time of data transmission there is some losses 0.21 (i.e., 21 %) due to collisions occurred among the sensor nodes. So the delivery ration is low based on losses of packets.

PACKET LOSS RATIO: The packet loss ratio represents the ratio of the number of lost packets to the total number of sent packets. Each packet has a deadline before which it must be executed, and if this is not possible, the scheduler tries to minimize the number of lost packets due to deadline expiry.

$$Loss = \frac{Number\ of\ lost\ packets}{Number\ of\ delivered\ packets} \quad \text{eqn. (6)}$$

Table 4: Packet Loss Ratio

NUMBER OF NODES	RCRP	MPF
5	1.466	**0**
8	1.652	**0**

11	1.138	**0**
14	0.401	**0**
17	53.90	**0**
20	0.692	**0**
23	0.266	**0**
26	1.504	**0**
29	0.453	**0**

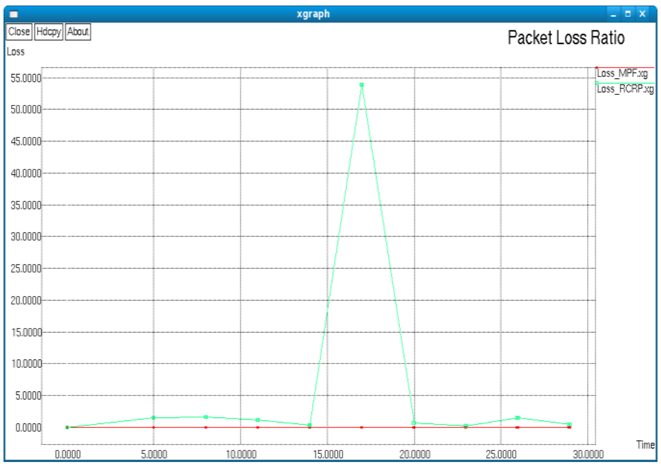

Fig. 5: Packet Loss Ratio

The proposed Multipath Packet Forwarding (MPF) protocol achieves 0 % packet loss ratio due to data transmission along with three consecutive paths. If there is any one of the path is failure then the proposed method split the packets in to remaining paths at that time but the existing Radius-based Courier Node Routing Protocol (RCRP) method also attains high packet loss ratio of 53.90 % of data transmission among multiple courier nodes when collisions occurred during that time period.

ENERGY CONSUMPTION: Energy consumption means the total energy consumed by the network to perform transmission, reception and data aggregation.

$$Energy = Total\ energy\ used\ in\ throughput * Time\ eqn. (7)$$

Table 5: Energy Consumption

NUMBER OF NODES	RCRP	MPF
5	4.78	**3.03**
10	4.92	**3.43**
15	5.08	**4.18**
20	5.32	**4.57**
25	6.42	**5.22**
30	6.65	**5.58**

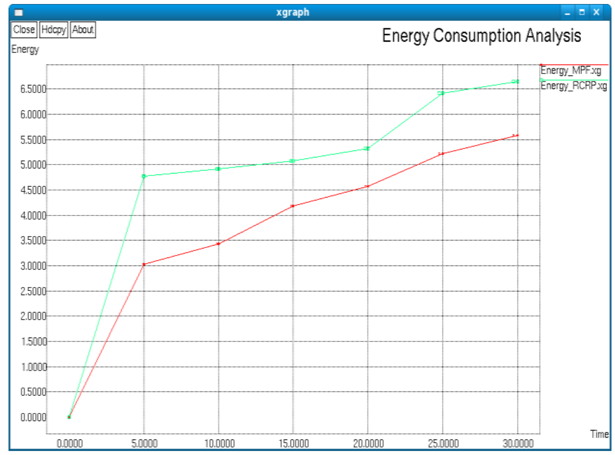

Fig. 6: Energy Consumption

The proposed Multipath Packet Forwarding (MPF) protocol low energy consumption 5.58 (joules) during the end of data transmission but the existing Radius-based Courier Node Routing Protocol (RCRP) method also attains 6.65 (joules) energy consumption of no defined consecutive paths in data transmission among the sensor nodes.

V. CONCLUSION

In this paper evaluated and analyzed the Multipath Packet Forwarding (MPF) Protocol with Dijkstra algorithm in underwater wireless sensor network on the strength of multipath selection for dynamic data transmission. In the proposed system performs a few modification to the original Dijkstra Routing Protocol to enhance the performance to improve 33% especial in terms of Throughput, Packet Delivery Ratio (PDR) improves 100 %, Packet Loss Ratio improves 100% and Energy consumption improves 1.07 joules in the proposed protocol in UWSN.

The future work will focus on develop a real time experimental test bed to test these protocols, also, finding diversities in simulation and in real time development is considered as a future work.

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