International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

# $E^2$-SCRP: An Energy Efficient Secure Cluster-based Routing Protocol for 3D Underwater Acoustic MANET (UWMANET)

**Arun Kumar Yadav, Ashwani Kush**

***Abstract:*** ***In the current years, Underwater Mobile Ad hoc Network (UWMANET) has emerged as an enthusiastic field for supporting disaster prevention applications (Climate and Weather Observation, Earthquakes in Ocean (Tsunamis), underwater level navigation and tracking). In UWMANET, conventional data transmission methods have certain drawbacks such as high energy consumption, packet loss rate and end-to-end delay. Nowadays, mobile node i.e. Autonomous Underwater Vehicle (AUV) is widely used for data collection from underwater sensors, which act as a relay between sensor node and surface sink. Security is a significant issue in UWMANET, which is required for secure communications. In this paper, Energy Efficient Secure Cluster based Routing Protocol called $E^2$-SCRP is presented in 3D UWMANET environment. The qu-Vanstone based Elliptic Curve Cryptography (qV-ECC) based short-term public key generation scheme is proposed for sensor node authentication. To reduce energy consumption, layer based clustering algorithm is proposed using Type-2 Fuzzy Logic System (T2fls) where Trust value, Distance between neighbors, Relative mobility and Node buffer size for cluster head (CH) election are considered. Next step is to execute two different security schemes based on Event Management. For event occurred clusters, Ciphertext Stealing Technique (CST) is used to resolve the ciphertext expansion problem. For normal data transmission, Lightweight Digital Watermarking (LDW) with Firefly algorithm is proposed. Optimal route for data transmission is executed by Pigeons Swarm Optimization (PiSO) and the forward to sink node via Adjacent AUV. Experiments conducted using NS3 (3.26) and the performance is evaluated for several metrics include packet delivery ratio, energy consumption, end-to-end delay, security strength, and throughput.***

***Keywords: Three-Dimensional Underwater Mobile Ad Hoc Networks, Energy Efficient Secure Routing, Autonomous Underwater Vehicle, Pigeons Swarm Optimization, Event based Security Schemes, Qu-Vanstone based Elliptic Curve Cryptography.***

## I. INTRODUCTION

Today underwater acoustic mobile ad hoc networks (UW-MANET) focus increases among research communication, particularly for disaster prevention applications. Current UW-MANEThas some short comings such as high energy consumption, high delay and poor scalability. Furthermore.

**Manuscript published on 30 September 2019.**
***Correspondence Author(s)**
**Arun Kumar Yadav,** research scholar in Department Of Computer Science and Applications, Kurukshetra University, Kurukshetra, Haryana, India
**Ashwani Kush,** Associate Professor and Head in Department in Computer Science, IIHS, Kurukshetra University, Kurukshetra



network security is insufficient due to the presence of more attackers in network [1], [2], [3]. Attackers may inject fake messages or occupies acoustic channel for a long time Due to this reason, mobile nodes such as AUVs (autonomous underwater vehicle) are used. AUV is an underwater component that is used to collect the sensor information and forward it to the sink node [4]. Therefore, this network is called as underwater acoustic mobile ad-hoc network (UWMANET) [5], [6]. The components involved in this type of network are follows:

- Sensor nodes (sensing ocean information)
- Gateway nodes (buoy with acoustic link)
- Mobile nodes (AUVs)
- Mobile sink node (node without acoustic link like ship)

The ocean is a cosmic that consists the length around 140 million square miles and 70% of the Earth is covered by water. Today, underwater networks are discovered and used for wide range of applications includes environment monitoring (marine ecosystem), disaster applications (ocean currents and winds monitoring), undersea explorations (detect underwater oilfields), assisted navigation (locate dangerous rocks in shallow waters), distributed tactical surveillance (intrusion detection in Navy), and Underwater sea space, and ocean water level monitoring, etc. Underwater network is covered by number of different components such as batteries, sensors, modems, and robots. In this type of network, the research community still focuses on three major problems that are energy consumption, communication traffic, long data transmission delay and routing security. Furthermore, analyzation of the QoSperformance (throughput, packet delivery ratio, end-to-end delay and security length) is challenging in both dense and sparse mode of underwater applications [7]. Conventional methods in UW-MANET are based on three processes such as node discovery, clustering and data gathering. Data gathered in underground region is used for cluster formation, where cluster heads (CHs) and members are formed [8]. Similarly, some of the important issues of MANET that must be considered during routing such as quality of service (QoS) provisioning, and security. These network features improve the performance of networks [9].

In UW-MANET, malicious attackers damage the network in communication. When number of malicious activities increase, the entire network is smashed and destroyed within certain amount of time [10].

The detailed descriptions of UW-MANET open issues are following [11], [12], [13]:

(i). **Network Topology:** It is an optimum issue in underwater sensor network since recent network topology is either two dimensional or three dimensional.

(ii). **Node Distribution:** Distribution of nodes in underwater MANET is a significant issue, which is due to energy consumption and packet transmission loss. Hence, network topology must be optimized and managed in a proper way. However, different nodes are present there for underwater acoustic communications.

(iii). **Acoustic Links:** Diversity of performance metrics such as noise, path loss, multipath, Doppler spread and varied propagation delay, available bandwidth of the acoustic channel are present in acoustic networks.

(iv). **Energy Efficiency:** Underwater sensor nodes are energy constrained and it leads to important issue in UWMANET. The designed protocol must consume very limited amount of energy for secure and reliable data transmission. Secure and energy efficient routing protocol must be robust and flexible for secure communications. Though several existing secure and energy efficient routing protocols have been proposed to improve the data transmission, no recent woks have been executed for reliable communication

(v). **Robustness:** Attacker nodes are effectively identified in the network, which must be eliminated to avoid the cause of any node/link failures. The network must run for longer time without any participation of malicious nodes.

(vi). **Lightweight Cryptography:** In order to make the secure communication between the source and destination node, security protocol must be simple and easy to implement under resource constrained underwater environment.

To mitigate all the previous mentioned shortcomings, an energy efficient secure cluster-based routing ($E^2$-SCRP) protocol for 3D underwater acoustic MANET (UWMANET) is proposed. 3D space of UWMANET considers three coordinates $(x, y, z)$ of sensor node. With the use of multiple AUVs, proposed secure network increases PDR and reduces energy consumption and delay

**Major Contributions:** Proposed $E^2$-SCRP scheme presented with the following novel contributions:

- CH selects optimum (nearest neighbor) AUV for data transmission to surface sink node using weight value (distance to surface sink node, node projection and residual energy of node)
- This paper presents Energy efficient secure routing for packet transmission among CHs, which runs using Pigeons Swarm Optimization (PiSO) which uses three metrics for routing: node residual energy, distance to depth of ocean, and relative mobility of node
- This paper presents a new idea of events based security schemes for packet transmission. If any event (disasters) occurres in any region, fast and secure data transmission scheme is needed. For this purpose, CiphertextStealing Technique (CST) is used which solves ciphertext expansion problem and it alters the processing of last two blocks of plain text
- Lightweight digital watermarking is considered which is an information hiding technique that reduces computation cost than cryptography techniques (optimum watermark bits are generated using original data packet size and MAC address of the node)

**Paper Organization Map:** Section 2 describes the state-of-the-art for secure data transmission in underwater acoustic networks. This section covers all recent works related to clustering, routing and security with present limitations/drawbacks of each work. Section 3 plays significant role to address the main problems in this study. Section 4 describes the proposed $E^2$-SCRP in 3D underwater MANET, where we describe each sub-sections in detail. Section 5 deliberates the experimental results and analysis for the proposed $E^2$-SCRP and the comparison with previous works has also been presented. Conclusion and future work for this study is presented in Section 6.

## II. RELATED WORK

Several data collection methods have been proposed in underwater MANET. This section discusses the state-of-the-art presented on clustering, routing, and security schemes.

### A. *Prior Works on Clustering Schemes*

This section addresses the clustering issues and challenges in underwater MANET. Reference [14] presented uneven cluster deployment algorithm based network layered architecture for event coverage. The energy consumption of the communication load at different depths of the underwater network is analyzed. The network is divided into multiple layers and the network is formed with unequal clusters. Uneven cluster deployment strategy increases end-to-end delay and increases energy consumption. A hop-constrained clustering approach is presented [15] in underwater sensor networks, in which mobile nodes are used for data collection from underwater.

Retrieval Number: K13910981119/19©BEIESP
DOI: 10.35940/ijitee.K1391.0981119
Journal Website: www.ijitee.org



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

This approach is implemented for dense underwater sensor environment. The primary interests are focus on reducing data collection delay and energy consumption. Data collection is implemented using clustering process. CH gathering data and forward to AUV. When the clusters are formed, AUV plan for a Near-Optimal Tour to traverse around CHs and collect data and then forward to surface sink. Optimum CH election is significant, which lacks in this paper and it is not suitable for large scale networks. Mobile edge elements (AUV) are presented in [16] for real mobility modeling. Here, AUV velocity and mobility are taken as important parameters while collecting data from underwater (3D environment). In this paper, acoustic and magnetic communications are integrated for real communications. It minimizes data collection time. Energy consumption is balanced in the entire network and other performance metrics such as network lifetime, packet delivery ratio and throughput are improved. The main limitations of this paper are: it does not support for long range communications which leads to high data collection time at AUV, and it does not scale well for monitoring disaster events. For normal data transmission, it requires high data transmission time. In [17] authors have proposed underwater layers based unequal clusters for underwater sensor networks using energy efficient routing protocol. There are three processes are incorporated in this paper as follows: Layered and Unequal Cluster Formation, Transmission Routing, Update and Maintenance of Clusters. This paper addresses the hotspot problem and improves the data transmission and collection performance.A Multi-Objective Optimization Technique is presented to compute the cost value for candidate head. In transmission routing, this proposed protocol considered two metrics such as Forwarding Ratio and Residual Energy of underwater sensor nodes. Inter and intra clusters update is presented in this paper. Unequal clusters formation is a good solution for hotspot problem, but it does not suitable to mitigate all issues in clustering.

*B. Prior Works on Routing Schemes*

In [18] a hybrid approach called Spherical Divisions and Vector-based forwarding routing protocol was proposed for data forwarding and it addresses three critical issues of UWSN such as routing security, communication traffic. The objective of this paper is to improve the performance of routing in dense UWSN applications by spherical divisions and finally it obtained lower energy consumption, high network reliability and saturated level of PDR. Vector based forwarding is the basic routing protocol which improved by spherical divisions. However, spherical layout is difficult to interpret for large scale networks, which consists of many long and overlapping edges. In [19] autonomous deployment and adjustment of nodes with blanket coverage (ADAN-BC) is proposed. However nodes are not scattered based on appropriate distance since it create large holes or gap in the deployment area. Hence considered node mobility is one of the solutions for sensors deployment. The deployment of mobile sensor nodes is performed randomly for better network coverage. Clusters are generated based on distance between mobile sensor nodes and its residual energy, but does not considered relative mobility of a node, which increases energy consumption. A new multilayered routing protocol (MRP) is proposed [20] to determine the efficient path and also it proposed to improve the overall functioning of the end-to-end delay, network lifetime and effective utilization of energy. Furthermore, a new splice method is presented that can be used for efficient data transmission through shortest path nodes. The splice function determines the sum of energy pertaining to a connected node and also the route having the greatest energy is considered to send data from sensor nodes to sink node. It is suitable for specific number of nodes in a network i.e. sparse network. End-to-end delay is high because of finding path with maximum possible energy with minimum distance must be considered for data transmission. Reference [21] addressed to the energy-constraint problem in acoustic communication. However, UAN is challenging to collect data and it is used AUV for data fusion and transmission to Surface Sink. AUV consists of higher energy and it can be easily recharged, which is used to fetch data from sensor nodes. To consume more energy, min-weighted rigid graph based topology optimization scheme is proposed. Single AUV aided data collection does not improve energy efficiency, which increase end-to-end delay and particularly, it is not suitable for event based applications.Reference [22] discusses the concept of node sinking algorithm in underwater sensor networks. It addresses the problem of network deployment (connectivity and coverage). The network is composed of anchored nodes. The sensor nodes are deployed randomly on the ocean surface. The contributions of this paper is threefold: efficient three dimensional sphere packing pattern to choose the first batch of sink nodes, then sank node connectivity are verified and finally fix coverage holes by already sank nodes. Node sinking algorithm is not effective for large scale 3D underwater sensor networks environment.

Reference [23] discusses the new idea of 3D Zone of Reference (ZOR) with Time Differential on Arrival (TDOA) is proposed in underwater acoustic sensor networks. In ZOR area, underwater information is collected and forwarded to AUV. When static node would lose their energy, then the node with highest residual energy and degree is elected for data transmission. Gauss markov model is proposed to compute node energy and mobility to transmit the underwater information. In this work frequent election of static node is essential, which consume more power.



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

### C. Prior Works on Security Schemes

Reference [24] presented the key agreement scheme based on Elliptic Curve Point Multiplication, which reduces the computational overhead and it support for session key agreement and identity authentication. The proposed key agreement scheme works against various attacks such as replay attacks, spoofed node attacks, node replication attacks, Sybil attacks, and so on. It increases computational overhead due to high depth (Distance) of sensor nodes. In [25] hybrid architecture is proposed that incorporates various functionalities such as node cooperation, context-awareness, physical layer security, context awareness and cognition. Different network levels are adapted in environmental changes and the status of the network is updated and it resists against array of attacks. Attacker can occupy the acoustic link for a long time. In [26] ultra-lightweight scheme is proposed in underwater acoustic networks, which solves the fundamental security problem. A lightweight security scheme called 8-round block cipher algorithm is used instead of using S-box block encryption algorithm. It is based on Chaotic Theory and it increases the key space by modified iteration rounds. The proposed lightweight encryption resists adversarial and brute force searches attack. Authentication without encryption scheme does not efficient in UAN since adversary can inject fake message and sent to sink node.

Reference [27] proposes an agent based secure enhanced performance approach (AB-SEP) for MANET. Agent nodes are chosen through optimal node reliability factor, which is computed on the basis of node characteristics such as energy level, normalized distance value, mobility, degree difference and optimal hello interval of node. A set of agent nodes are selected for the malicious behavior detection, which is computed by fuzzy-based secure architecture (FBSA). Fuzzy based secure network architecture increases complexity because more number of fuzzy rules increase communication overhead and solves it which leads to uncertainty issue.

A secure and anonymous routing scheme [28] with short digital signature algorithm is proposed without any online trusted third party recommendation, which is used for authentication between source and destination. Then trapdoor scheme is proposed for routing messages. Ciphertext expansion problem occurred which increases communication overhead between source and the destination node. However, digital signature algorithm generates signature and append to the original data packet. For example, SHA-256 generates signature with 256 bits size, which increases the message size.

## III. PROBLEM STATEMENT

Fig 1 represents the pictorial representation for UW-MANET. In this figure numerous underwater sensor nodes are positioned at the bottom of the water and it is distributed randomly over the 3D network. Underwater sensor nodes gather sea information in specified region and forward sensed information to surface sink via multi-hops and mobile nodes [29], [30], [31].

Agent based secure routing is proposed in [32] UWSN, which resists wormhole, selective forwarding, neighbor discovery, and sink hole. It contributes two algorithms such as secure neighbor discovery and determines the prioritized optimal paths. Secured neighbors are discovered by direction of arrival (DoA) estimation. Network management is very complex due to the presence of more agents (agents for security agency and agents for routing agency). Hence it is suitable for small scale UWSN. Energy and latency is high for large scale UWSN with poor scalability. In [33] High availability of data collection module is presented using multiple-AUVs (HAMA) [33]. This paper is based on 3D underwater sensor networks using multi-hop communications for data transmission via multiple AUVs. AUV is traverse in ellipse shape and moving with different directions. This work has failed to obtain minimum energy consumption and it leads to large end-to-end delay. Primary aim of this paper is to design a suitable energy-efficient and secure routing scheme for monitoring underwater areas. More specifically, this paper presents 3D underwater MANET, which interest based on following two research questions.

(1). How will multi-AUVs supported for data collection and multi-hop secure communications in underwater monitoring applications?

(2). How will the complex network topology (3D network) related to several features (energy consumption, node mobility, AUV trajectory, network density, security, packet delivery/loss ratio, etc.) be managed?

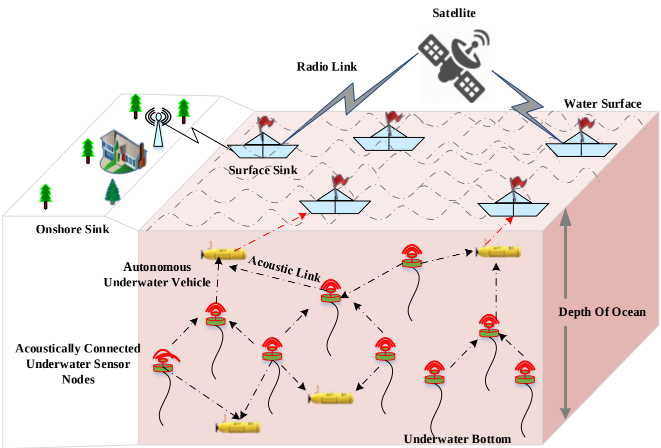


**Fig.1Overall Underwater-MANET Architecture**

*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

## IV. PROPOSED WORK

This section discusses the proposed work in detail. Objective of this work is to propose energy aware secure routing protocol that is suitable for disaster situation (i.e. underwater) especially for 3D UWMANET. Several components are incorporated in 3DUWMANET: (1) Sensor Nodes, (ii). Mobile Nodes (AUV) and Surface Sink. Herein, AUV is the only fastest way to find underwater information, which prevents disaster under ocean in earlier way.

### *A. Architecture Design for 3D Underwater Sensor Model*

3D underwater sensor model is designed in this paper. In order to deal with the issues in 2D, 3D cube model is presented, which is implemented to monitor and collect data from underwater area in 3D coordinates $(X, Y, Z)$. For node sensing capability monitoring, Boolean Perceptual Model is proposed, which monitors the surrounding underwater areas for deep sensing. The underwater sensor nodes gather sensed information from underwater and forward the collected data to neighbor nodes (relay CH) and then to AUV and finally reach to the surface sink node. Multiple AUVs are deployed in the network and traverse in elliptic trajectory to visit all CH nodes and collect normal data and events based data. Assumptions are taken in this paper is follows:

- Underwater sensor nodes are stable, which is deployed randomly over the network
- 3D underwater mobility model i.e. AUV is presented. Initial position of AUV is given and also initial and heavy velocity of the AUV is given i.e. $v_i$ and $v_h$, respectively.
- Location of "N" underwater sensor nodes are represented as follows $(S_1, \ldots, S_i, \ldots S_N)$ and each sensor node is represented in $S_i$
- End-to-end point communications between sensors nodes are not affected since nodes are stable and do not move for time period t.
- Energy level of AUV and surface sink node is infinite and rechargeable
- Energy level of sensor node $S_i$ is $e$, which consumes for several acts (data collection and transmission).

The proposed system architecture is shown in Fig. 2 and Fig. 3 and the work flow is described as follows: in a given underwater area, nodes are registered to the surface sink. Nodes are splits into number of clusters. In each cluster, CH is elected for data aggregation and transmission and then given cluster_join request to all sensor nodes within its vicinity, which are named as cluster members (CMs). AUV collect data from CH and send to the surface sink node. CM uses acoustic signal for making communication to the CH. CH consumes energy for data processing and transmission. If it dies, another node is selected to play the role of CH. For that the entire network energy is balanced.

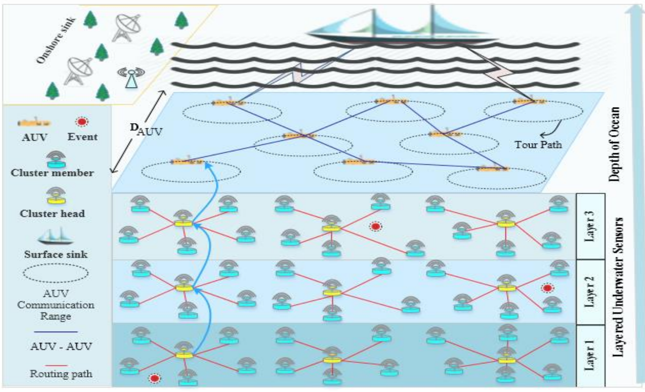


**Fig.2. Architecture Design**

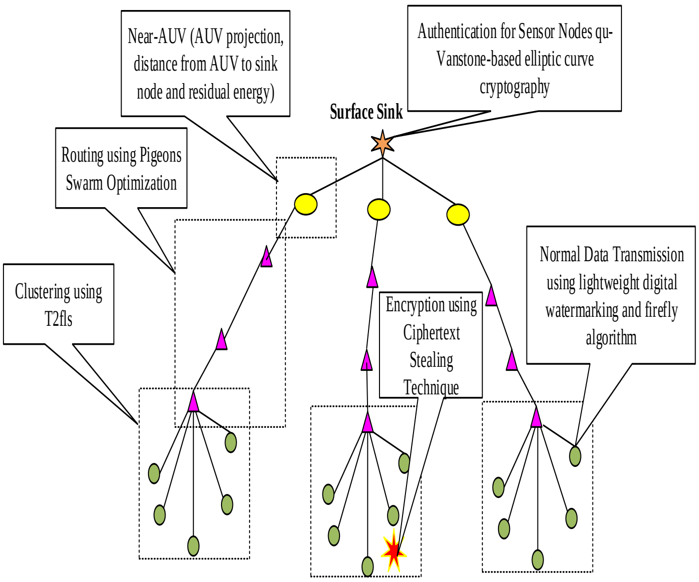


**Fig.3.Proposed Work Flow**

### *B. Nodes Registration and Authentication*

Firstly, register the sensor nodes to surface sink (certificate authority) using qV-ECC (qu-Vanstone-based elliptic curve cryptography). It is a certificate based long-term public key generation scheme since encryption packets without authentication are inefficient and are not scalable and secure for a long time. This long-term public key is updated based on certain time-interval since it is activated for certain amount of time and distributed over the network. There are three main reasons for choosing this algorithm:

(i). It particularly outperforms for resources constrained applications environment and the resources are computation power, energy, storage space and bandwidth.

(ii). It is the best alternative algorithm for tradition certificate based security algorithms

(iii). It consists of several set of security levels and its main aim is to execute certificates with small sizes

*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

The qV-ECC is composed of several ranges of security levels such as 80bits, 112bits, 128bits, 192bits, and 256bits. For each extra security bit, the amount of computation is double. The procedure of qV-ECC is following.

Assume that $E$ is an Elliptic Curve at finite field $Z_p$, generator is $G$ for subgroup order "n". $Z_p$is the cyclic subgroup composed of set of points of the curve. Each sensor node $S_i$ of the network creates a point, which is chosen by random variable $p \leftarrow Z_p$ and computation point is $P = G^p$. $S_i$forwards $p$ to surface sink. If the surface sink obtained $p$, it will do the following processes:

(i). Choose a random variable $q \leftarrow Z_p$

(ii). Calculate points $E_Q = G^q$

(iii). Calculate certificate $C$ by $P$ and $E_Q$

(iv). Creates the implicit certificate $C_{S_i}$ and append the time period T

(v). Compute Sign by $\overline{H}(C_{S_i})$ to $S_i$

When $S_i$obtained $C_{S_i}$and sign. Then it calculates long-term private key$Pr_{Key}$: $sign + \overline{H}(C_{S_i}).p\%n$. Finally, it defines the certificate lifetime $\Delta T$ and time to update the actual certificate $T$. In this way public and private key pair is generated.

### *C. Clustering Scheme*

This section discusses the concept of clustering in which clusters are formed for number of sensor nodes. To form clusters more effective, nodes are arranged in a form of layers from the bottom to water surface area in a 3D environment. Underwater sensor network is divided into three layers *(layer-1, layer-2, and layer-3)* based on depth of sensor nodes. It is not predefined and based on the number of nodes it is divided into several layers. Number of layers depends on water depth and the vicinity of nodes among different layers. When the average depth of the Ocean is 2.5 to 3kilometers and the vicinity is 500m, then 5-6 layers are required. To mitigate the problems in conventional fuzzy logic system and to cluster the networks, Type-2 Fuzzy logic system (T2fls) is proposed which solves uncertainty problem. There are four blocks are used in T2fls that are fuzzifier, knowledge base, inference engine, output processing and defuzzifier.

**a. Fuzzifier:** It normalizes the input values from crisp inputs

**b. Knowledge base:** It defines the relationship between input and output variables using IF-THEN rule

**c. Inference Engine:** It combines the input and knowledge base to get the final solution

**d. Output processing:** It provides a single value as an output

**e. Defuzzifier:** It produces the denormalized values from crisp outputs. The T2fls can be seen in fig.4

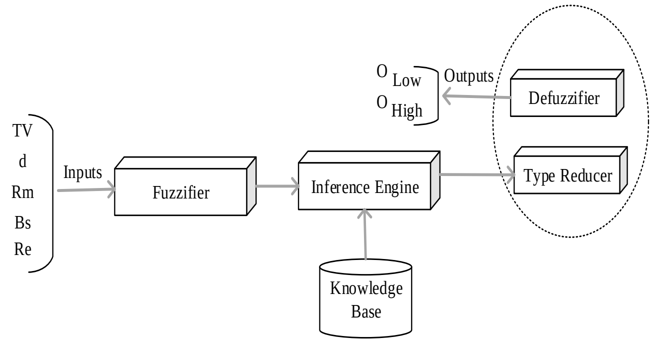


**Fig.4.T2fls Representation**

Benefits of using T2fls are follows: (i). It is very easy to implement with the use of fuzzy rules (Natural Language and Expert Knowledge) and (ii). It is more adaptive than conventional fuzzy logic algorithm since it finds the very complex relationship between the input and output and solves the high level of uncertainty issues. Various input parameters for clustering are as follows:

- **Trust value Tv:** It is computed on the basis of the number of successful communications and number of failed communications
- **Distance between neighbors d:** Distance between the neighbors is computed using Received Signal Strength Indicator (RSSI)
- **Relative mobility Rm:** It is estimated by the speed of sensor nodes when moving from one direction to another.
- **Node buffer size Bs**: It is measured by the number of packets are waited in a queue for processing
- **Residual Energy Re**: It is estimated as the current energy level, which is computed on the basis of initial energy level.

For computing the distance between two nodes, Euclidean Distance is used. In 2D underwater environment, the following distance function is used $d\ (x, y)$. It is computed by:

$$d = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2} \quad (1)$$

In 3D, the distance function $d\ (x, y, z)$is follows

$$d = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2} \quad (2)$$

In T2fls, output variables are $O_{Low}$ and $O_{High}$denotes the minimum (Low) and maximum chance (High) for a node to act as a CH or not. Proposed clustering is processed with three processes: CH election, CH advertisement and transmission of data.

### *D. Security Schemes*

This is the third contribution of this paper. Apply two different security schemes to add security for a network. Proposed E2SCRP for disaster prevention application is used to find any event in underwater sensor network. When an event occurs in the network that node immediately sends sensed information to cluster head and cluster head finds optimal route and sends through AUV to surface sink node.

Retrieval Number: K13910981119/19©BEIESP
DOI: 10.35940/ijitee.K1391.0981119
Journal Website: www.ijitee.org



Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

For event occurred cluster, Ciphertext Stealing Technique (CST) is used to alter last two blocks of plain text and encrypted using qV-ECC. Our proposed CST solves the ciphertext expansion problem. For common data transmission, we use lightweight digital watermarking (LDW) by *firefly algorithm*. The optimum numbers of watermark bits are generated by original packet size and MAC address of the node. Then the watermark bits are embedded into original packet and are sent to the immediate relay node.

➢ *Ciphertext Stealing Technique*

It is a general and simple method that utilizes a Block Cipher Mode of Operation that permits for processing data that are not evenly divisible into blocks without expansion of the ciphertext i.e. original data and encrypted data are equal in size. It reduces the cost of complexity. In CST, encryption and decryption of data is done by using the Standard Block Cipher Mode of Operation for all data, but separate data is processed for last two blocks. Assume that the last two blocks of the data are $P_{N-1}$and $P_N$. These two blocks are equal in size of bits B and M for $P_{N-1}$and $P_N$, respectively. For encryption and decryption of data, Key k is used. The following functional operators are used.

- Head: It outcomes the first “a” bits of data
- Tail: It outcomes the last “a” bits of the string
- Encrypt: It outcomes the block cipher in encrypted format by key k
- Decrypt: It outcomes the block cipher in decrypted format by key k
- XOR: It is a bitwise exclusive OR, which is equivalent to bitwise addition
- ||: It is a concatenation operator, which combine the strings
- $0^a$: “a” string of zero bits

➢ *Lightweight Digital Watermarking*

This watermarking scheme is supported for data integrity, which is very useful for improving security in data communications from one-hop to another. From this result, malicious nodes cannot inject any false report at any point. Three operations are involved in LDW that are watermark generation, watermark extraction and watermark embedding. For optimum set of watermark generation, firefly algorithm is proposed. This algorithm computes the optimum bits of watermark based on the packet size since insufficient watermark leads to poor security or increases the computational burden. For this reason, LDW is proposed.

### E. Optimum Routing

This section illustrates the routing algorithm to find optimal route for data transmission by Pigeons Swarm Optimization (PiSO). In PiSO, different metrics for routing include distance to depth of ocean, relative mobility of node, link quality and residual energy of node. After the cluster formation, AUV gathers data from CH nodes via Optimum Path. Conventional data collection approaches are treating the routing path is kind of NP hard problem and Traveling Salesman Problem (TSP). Based on the AUV mobility, PiSO algorithm is proposed to gather data within a short span of time. In PiSO, operators are used such as Map and Compass and Landmark Operator. The purpose of each operator is following:

- **Map and Compass Operator:**It is used only if all pigeons do not know the landmark or destination node at the stage of initialization. They find the flying position and direction based on the magnetic field and the position of the sun. The position of each pigeon is updated based on the global optimum solution to the current round.
- **Landmark Operator:**It is used only if certain pigeons find the landmark or destination node. therefore, these kind of pigeons can easily move to the destination node and other pigeons are traverse behind it.

### F. Data Transmission

Finally, choose optimum (near) AUV for data transmission to the sink node by AUV projection, distance from AUV to sink node and residual energy. Then fused data is forwarded to sink node in secure way. In this paper AUV is used as the mobile edge element. In 3D realistic mobility underwater applications environment, an optimum position of AUV must be defined. In order to find the AUV direction, two angles are used. However AUV suffers due to its Gravity and Buoyancy. For this purpose, Speed Synthesis Algorithm has been proposed. Mobile AUVs are deployed in underwater environment at predefined depth.

## V. SIMULATION SETUP & PERFORMANCE ANALYSIS

To validate the performance of the proposed $E^2$SCRP protocol, several experiments are conducted and the simulation results for the proposed protocol are tested and compared with previous works. This section is divided into three sub-sections i.e. simulation environment, comparison study and results and analysis.

### A. Simulation Environment

In simulation, NS-3.26 is used, which is a network simulator and this version is released in October 2016. It supported for several features such as Spectrum WifiPhy, New TCP congestion control (TCP Vegas, Scalable, Illinois, H-TCP, YeAH, Bic, and so on), traffic control module (FQ-CoDel, PIE, Byte Queue Limits). It is better supported for IEEE 802.11e (Wi-Fi module). This simulator is configured in Ubuntu-14.04 LTS (32 bit OS).

*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

For simulation of the environment, a underwater sensor network is created which consists of 200 underwater sensor nodes, 6 mobile nodes (AUV) and 1 mobile sink node (surface sink). The simulation area is 5000m × 5000m × 5000m, and transmission range for each node is 300m. For node mobility, Random Way Point Model is used and the node speed is 10m per second. The packet size is 512, and 1024 bytes. Simulation parameters and it values are illustrated in table.I.

**Table.I: Simulation Parameters**

| **Parameters** | | **Values** |
|---|---|---|
| Simulation Area | | 5000×5000×5000 $m^3$ |
| Environment/Network Parameters | No of nodes | 200 |
| | Sink position | 1500, 1500, 1500 |
| | Simulation rounds | 300 |
| | Number of AUVs | 6 |
| | Traffic Type | CBR |
| | Simulation Time | 1000s |
| | AUV moving trajectory | Elliptic Points |
| Underwater Sensor Node Parameters | Initial Energy | 100 Joule |
| | Node Speed | 10m/s |
| | Sensing Range | 300m |
| | Mobility Model | Random Way Point Model |
| | Data Generation Rate | 2 packets per second |
| Energy Consumption Parameters | $e_{tx}$ | 2W |
| | $e_{px}$ | 0.75W |
| | $e_{pHR}$ | 0.25W |
| | $e_{IL}$ | 10mW |
| Packet Parameters | Packet Size | 1024 bytes |
| | Packet Transmission Speed | 50Kbps |

Simulation is conducted at each second and AUV are randomly distributed over the network that is moving towards elliptic way. The ordinary underwater sensor nodes move horizontally in underwater regions with a speed of 0.5m/s. Then, implementation of the proposed protocol takes place to obtain the performance. Figure represents the simulation environment in three dimensional system (before nodes deployment). Fig. 5, Fig. 6, Fig. 7 shows the simulation diagram for the proposed protocol of the Underwater Surveilance Region.

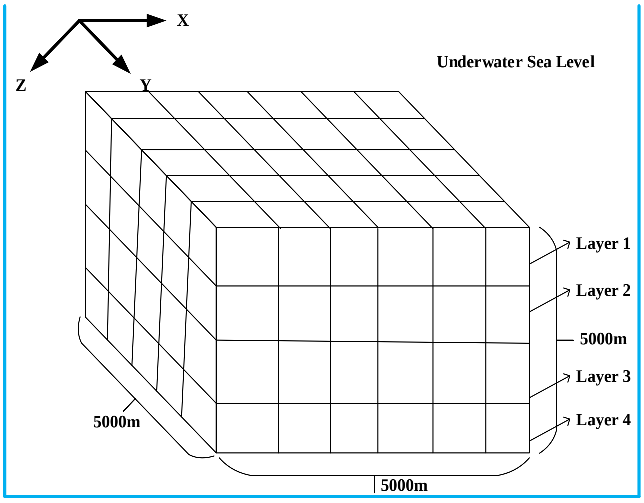


**Fig.5.Underwater Environment (Before Nodes Deployment)**

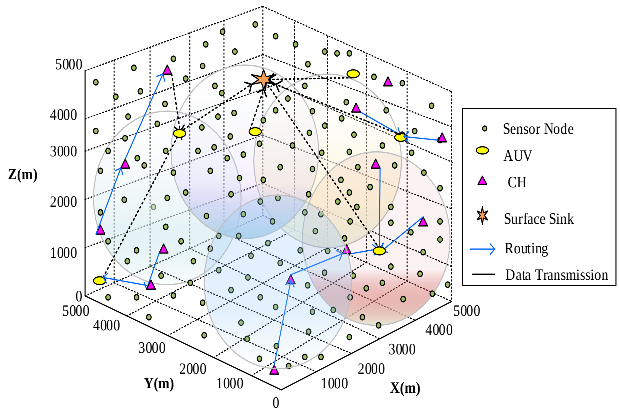


**Fig.6.Simulation Diagram (After Nodes Deployment)**

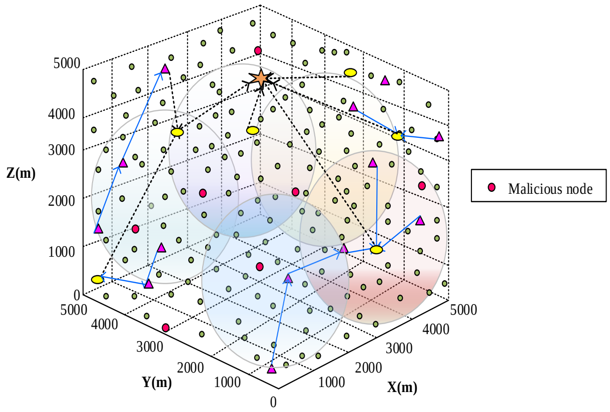


**Fig.7.Simulation Environment (Malicious Nodes)**

*B. Comparison Study*

In this section, the performance evaluation of the proposed protocol with the previous works including HAMA [33], and ABSR [32] has been studied. Five performance metrics are considered for performance evaluation such as packet delivery ratio, energy consumption, end-to-end delay, security strength and throughput.

*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

Table II illustrates the theoretical comparison between the proposed and previous works with their limitations.

**Table.II: Comparison between the Proposed and Previous Works**

| Method | Contributions | Limitations |
|---|---|---|
| HAMA | Data collection and communication has made via Multiple AUVs and flexible time scheme is proposed | • Average end to-end delay is very larger<br>• Energy consumption is high<br>• It does not suitable for disaster applications |
| ABSR | There are four contributions incorporated in ABSR: (1). Authentication agents for a node to find the secure neighbor, (2). Routing agents for a node to establish communication, (3). Node communicate using AUV, and (4). Modify AUV trajectory | • Very complex in nature<br>• Energy consumption is high<br>• It does not suitable for disaster applications |

➢ *Packet Delivery Ratio*

It is the ratio of packets delivered successfully in the destination node by the number of packets forwarded by the source node. Packet delivery ratio is a positive metric, which must be higher than the precious works. Fig depicts the performance of packet delivery ratio of the proposed protocol compared to HAMA and ABSR.

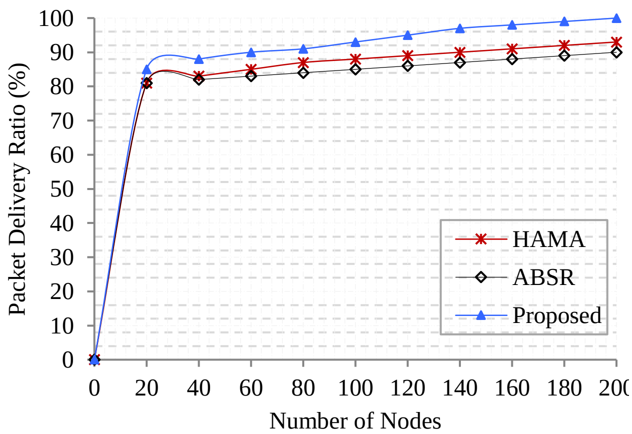


**Fig.8.Packet Delivery Ratio Vs. number of nodes**

For packet transmission, compute the optimum path from source to the destination node, which increases the speed of packet transmission and improve the efficiency of the proposed protocol. Proposed protocol has reached 100% of packet delivery ratio with the use of path selection and AUV selection for data transmission to the Surface Sink. In HAMA, 93% of packet delivery ratio is obtained, which is relatively less compared to proposed protocol. In HAMA, multiple AUVs are used, which delivers packet via AUV. For multi-hop communication, an energy-efficient and optimum path is required. In ABSR, 90% of packet delivery ratio is obtained. In this work, several agents are used for establishing the path for secure communications between the source node and surface sink. From the plotted results, it concludes that the proposed protocol has obtained high packet delivery ratio than HAMA and ABSR.

➢ *Energy Consumption*

Energy consumption estimation is the main part of this paper since the aim of this paper is to address the energy consumption issues in underwater communication. Low energy consumption of underwater sensor nodes must be obtained and collect data in underwater surveillances. Energy consumption model is deliberated as follows:

An energy consumption model in multi-path data transmission with free space is suited for UWMANET. Typically, energy consumption for underwater sensor nodes is mainly due to Data Collection, Processing and Communication. However, nodes energy consumption is based on the transmission distance, packet size, and communication environment. Sensor nodes energy consumption is computed in transmission of bit/byte packets to adjacent node, which is computed in following:

$$e_{tx} = \begin{cases} LE_{elec} + LE_{fs}D^2, D < D_0 \\ LE_{elec} + LE_{mp}D^4 \ D \geq D_0 \end{cases} \tag{3}$$

Where $L$ is the packets bit size, $D$ is the distance from Transmitter to the Receiver, $D_0$ is the threshold value of distance for packets transmission, $E_{elec}$ is the radio dissipation of executing transmitter and receiver circuitry. $E_{fs}$and$E_{mp}$ are the amplifier coefficient for multipath and free-space proto-type. When $D < D_0$, the amplifier coefficient for free-space model $E_{fs}D^2$ is used and when $D \geq D_0$ the free space multipath prototype $E_{mp}D^4$ is used. In UWMANET, radio signals and acoustic signals are used. Transmit amplifier coefficient is represented as $A(f)^D$, where $A(f)$ is the Absorption Coefficient, $f$ is the acoustic signal frequency, and $D$ is the distance from transmitter to the receiver. When$f = 1000Hz$, $A(f)$ is computed by thorps equations, which is follows:

$$\log A(f) = 0.011 \frac{f^2}{1+f^2} + 4.4 \frac{f^2}{4100+f^2} + 2.75 \times 10^{-5} f^2 + 0.0003 \tag{4}$$

Thus, energy required for transmitter and receiver in UWMANET is follows:

*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering*
*and Sciences Publication (BEIESP)*

**DEFINITION 1**(*Energy Consumption for Transmission*): Energy consumption required of underwater sensor node for L bits packets transmission to the adjacent node is calculated by distance between two nodes and frequency range. It is expressed mathematically follows:

$$e_{tx} = \begin{cases} L_{E_{elec}} + LA\,(f)^{D}\, D^{2}, D < D_0 \\ L_{E_{elec}} + LA\,(f)^{D} D^{4}\; D \geq D_0 \end{cases} \quad (5)$$

**DEFINITION 2**(*Energy Consumption for Receive*): The rate of energy consumption to receive L bits packets is written as follows:

$$e_{rx} = LE_{elec} \quad (6)$$

In this paper CH is collect data packets from CMs and forward to another CH. Data packets between CH and CM is aggregated and forwarded to the surface sink.

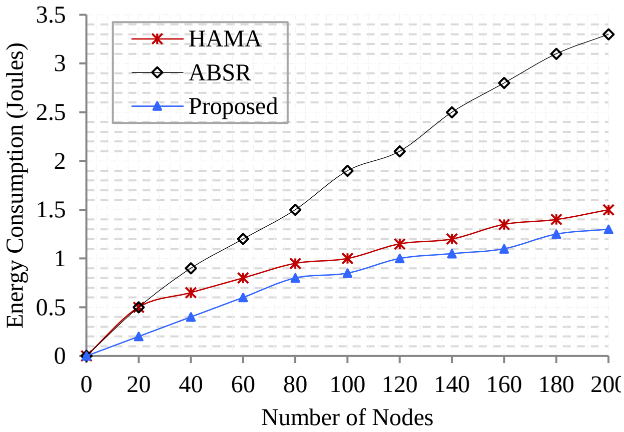


**Fig.9.Energy Consumption vs. number of nodes**

When compared the proposed protocol with the HAMA, and ABSR, proposed protocol has shown that it requires minimal energy consumption than previous works. ABSR consume more energy due to the presence of large number of agents for secure communication. However, agents based data transmission is complex for underwater applications. In HAMA, hop count is high for data packets transmission. Hence it does not suitable for disaster based applications. For events based data routing, optimum path which consume less energy is required. In proposed protocol, clusters are formed for nodes having similar characteristics. For effective cluster formation, Type-2 Fuzzy Logic algorithm is proposed, which consumes less energy and improves network lifetime. Fig illustrates the simulation results for the proposed protocol and two previous schemes related to simulation time. Total simulation time is taken for 1000s. Maintain the flexibility, stability and reliability of the network, even for large scale underwater sensor environment.

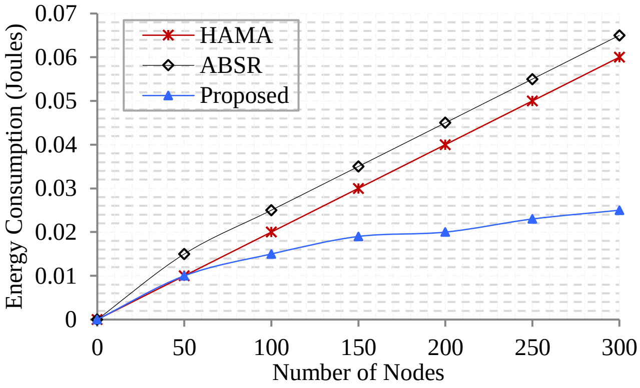


**Fig.10.Energy Consumption vs. Simulation Time**

- *End-to-End Delay*

The time of packet sent from the source node to the destination node is called end-to-end delay. It is expressed in the following equation:

$$End - to - End\ Delay = T, R_t + P_t + BA_t \quad (7)$$

Where $T, R_t$ is the packets transmission and reception time and it is based on the packet size and data transmission rate. $P_t$ is the propagation time between the transmitter and receiver node and also acoustic signal speed of water is considered in it, and $BA_t$ is the byte alignment time for waiting the packets in queue.

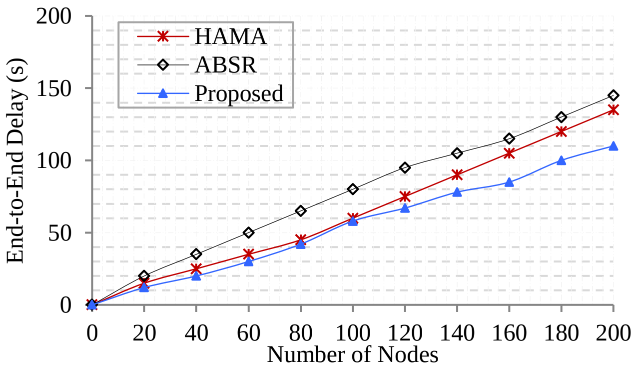


**Fig.11.End-to-end delay vs. number of nodes**

Fig shows the performance of end-to-end delay with respect to number of nodes. End-to-End delay changes with respect to the number of nodes increasing. Delay is a critical metric that can be used to analyze the network performance. HAMA and ABSR tends to increase end-to-end delay, due to multi-hop communications from the source to the destination node. The average end-to-end delay between the proposed protocol and previous schemes such as HAMA, and ABSR are 110%, 135%, and 145%, respectively.

- *Security Strength*

Security strength estimation is a security level metric, which is computed by cryptographic algorithms/functions for key generation, encryption and decryption. For e.g. AES-128 is primarily designed to give 128-bit level of security.

Retrieval Number: K13910981119/19©BEIESP
DOI: 10.35940/ijitee.K1391.0981119
Journal Website: www.ijitee.org



Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

It is equivalent to 3072 bits of RSA. Security strength for the proposed protocol and ABSR is shown in fig.

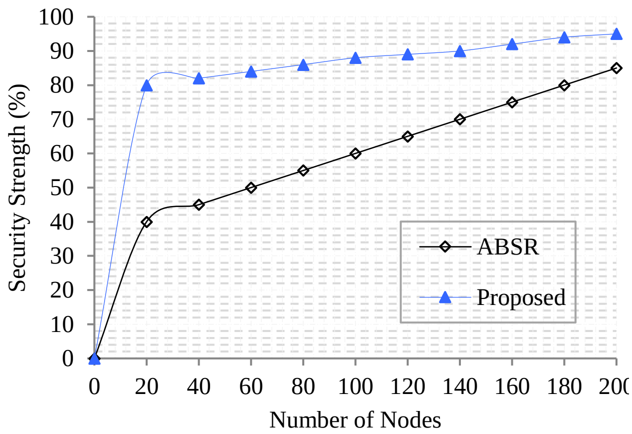


**Fig.12.Security strength Vs. Message size**

For various level of number of nodes, proposed protocol obtained better security level than ABSR. Underwater MANET has severe security issues and is also vulnerable to security attacks (Wormhole, Sinkhole, and Selective Forwarding). In order to transmit data from source to the sink node in a secure way, neighbor discovery process is initiated. If the neighbor is malicious, privacy and confidentiality are compromised. In ABSR, security is included and several agents are deployed in network to mitigate malicious activities. Deployment of multiple agents over the network increases the complexity in communication and computation. Three issues have been addressed in this paper such as authentication, data confidentiality and integrity with different and individual algorithms. With the results of algorithms proposed for authentication, data confidentiality and integrity.

*5.2.5Throughput*

It is a primary concern for any kind of network. Several ways have been proposed for throughput improvement that captures network traffic, average packet size sent from the source node, clustering (cluster head rotation), optimum route (effective neighbor discovery), avoids packet re-transmission and link failures, and so on. In addition throughput can be differed according packet loss and delay. Hence, other metrics are also required to improve the throughput. From Fig it can observe that the proposed protocol has obtained very good performance related to throughput. Throughput slightly increases when number of nodes increase. Multi-AUVs based data collection module in HAMA is well supported for data transmission, but it is required too much of packet retransmissions from the source node. Several agents such as routing agents, authentication agents are deployed in ABSR, which require special efforts for packets transmission. In addition throughput must be improved, particularly in disaster based applications.

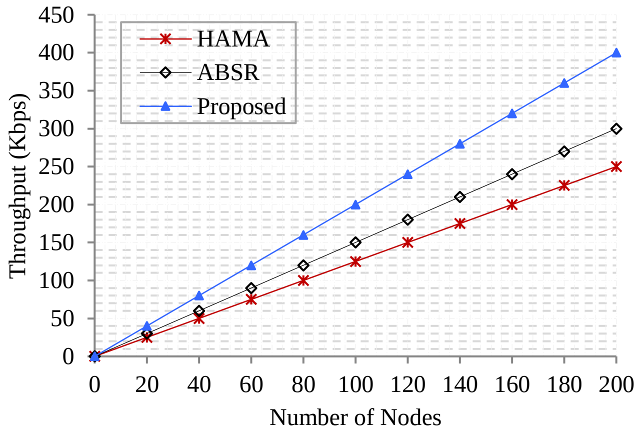


**Fig.13.Throughput Vs. number of nodes**

With the proper and stable CH election, optimum routing, and two different security schemes for data confidentiality are considered as the solid points for this level of throughput achievement.

*C. Results and Analysis*

Experiments conducted and the simulation results are obtained for several metrics. From the figures, it is concluded that proposed protocol has obtained good performance in Underwater Surveilance applications compared to the existing solutions (HAMA, and ABSR). The several drawbacks related to data collection, communication, routing and security are presents in previous works. An energy efficient secure routing protocol has been proposed to overcome these drawbacks, which is also good in all aspects related to authentication/registration to surface sink, cluster formation (CH, and CM), optimum routing (Inter-Cluster), near AUV selection, normal and event based data transmission, CH re-election. These approaches are combined to name as $E^2$-SCRP. Sufficient experiments have been provided to prove at the proposed protocol outperforms the previous works. Proposed protocol has several benefits such as high packet delivery ratio, minimum energy consumption, minimum end-to-end delay, maximum security strength, and maximum throughput. Table III shows the average comparison between the proposed protocol and HAMA, and ABSR.

**Table.III:Average Comparison Results Summary**

| Metrics | | Proposed vs. Previous Methods | | |
|---|---|---|---|---|
| | | HAMA | ABSR | Proposed Protocol |
| Packet Delivery Ratio (%) | | 79.90% | 77.72% | 85.09% |
| Energy Consumption (Joules) | Num. of nodes | 0.95J | 1.8J | 0.77J |
| | Simulation Time | 0.03J | 0.034J | 0.016J |
| End-to-End Delay (s) | | 64.09s | 76.36s | 54.72s |
| Security Strength (%) | | - | 56.81% | 80% |
| Throughput (Kbps) | | 125Kbps | 150Kbps | 200Kbps |

## VI. CONCLUSION AND FUTURE WORK

In this paper a novel $E^2$SCRP is presented for underwater MANET, where it is assumed that the sensor nodes are deployed in 3D underwater Surveilance environment. Nodes are registered at certificate authority for authentication then authentication for solving data integrity and confidentiality problems in UWMANET are performed. A new authentication algorithm named as qu-Vanstone-based ECC is proposed, which is better than conventional ECC. Clusters are formed using trust value of sensor node, distance between neighbors, relative mobility and node buffer size (CH storage threshold is monitored at time $t$) by Type-2 Fuzzy Logic. Less computational overhead is obtained due to layer based cluster formation by considering the depth of the ocean. Inter-cluster routing among CHs is implemented where the next best hop using Pigeon Swarm Optimization is selected. Furthermore, near AUV is selected for data transmission to the surface sink node. Proposed $E^2$SCRP protocol under large scale networks with less computational efforts than HAMA, and ABSR has simulated. Cluster based secure environment improves energy efficiency and reduces latency. Proposed E2SCRP is suitable for both small scale and large sale networks.

For further reduction of energy consumption, any scheduling algorithm can be proposed for putting sensor nodes into sleep state and active state. Then, proposed protocol can be applied in any real-world applications.

## REFERENCES


1. M.PhilLowney, Hong Liu, Eugene Chabot, "Trust Management in Underwater Acoustic MANET based on Cloud Theory using Multi-Parameter Metrics", InternetaionalCernahan Conference on Security Technology (ICCST), October 2018
2. Bhatia, Swapnil&Bartos, Radim& M, Kevin. (2019). Poster Abstract: Throughput-Delay Tradeoff in Small and Sparse Mobile Ad hoc Networks.
3. Michael Goetz, Ivor Nissen, "GUWMANET-Multicast Routing in Underwater Acoustic Networks", Military Communications and Information Systems Conference, Gdansk, Poland, October 2012
4. Khalid MahmoodAwan, Peer Azmat Shah, Khalid Iqbal, SairaGillai, "Underwater Wireless Sensor Networks: A Review of Recent Issues and Challenges", Wireless Communications and Mobile Computing, Vol. 2019, PP. 1-21, 2019
5. Ning Li, Jose Fernan Martinez Ortega, Vicente Hernandez Diaz, Lourdes Lopez Santidrian, Martinez Ortega, J. F., Diaz, V. H., & Lopez Santidrian, "Cross-Layer Balanced Relay Node Selection Algorithm for Opportunistic Routing in Underwater Ad-Hoc Networks", IEEE 32nd International Conference on Advanced Information Networking and Applications (AINA), 2018
6. Andrew Bolster, Aln Marshall, "Analytical Metric Weight Generation for Multi-Domain Trust in Autonomous Underwater MANETs", IEEE Third Underwater Communications and Networking Conference (UComms)
7. Mukhtiar Ahmed, MazleenaSalleh, M. Ibrahim Channa, "CBE2R: Clustered based Energy Efficient Routing Protocol for Underwater Wireless Sensor Network", International Journal of Electronics, Vol.105, Issue.11, 1916-1930, 2018
8. Seyed Mohammed Ghoretshi, AlirezaShahrabi, TuleenBoutaleb, "An Efficient AUV-Aided Data Collection in Underwater Sensor Networks", IEEE 32nd International Conference on Advanced Information Networking and Applications (AINA), Krakow, Poland.
9. Mukhtiar Ahmed, MazleenaSalleh, M. Ibrahim Channa, "Routing Protocols based on Protocol Operations for Underwater Wireless Sensor Network: A Survey", Egyptian Informatics Journal, Vol. 19, Issue.1, PP. 57-62, 2018
10. Guangjie Han, Jinfang Jiang, Ning Sun, and Lei Shu, "Secure Communication for Underwater Acoustic Sensor Networks", IEEE Communications Magazine, Vol. 53, Issue.8, PP. 54-60, 2015
11. Angelo Capossele, Chiara Petrioli, Gabriele Saturni, Daniele Spaccini, DaneileVenturi, D,Securing Underwater Communications. Proceedings of the International Conference on Underwater Networks & Systems - WUWNET'17, 2017
12. TooskaDargahi, Hamid H. S. Javadi&Shafiei, Hosein, "Securing Underwater Sensor Networks Against Routing Attacks. Wireless Personal Communications", Vol. 96, Issue. 2, PP. 2585–2602, 2017
13. Giuseppe Ateniese, Angelo Capossele, PetrikaGjanci, Chiara Petripolim Daniele Spaccini, "SecFUN: Security Framework for Underwater Acoustic Sensor Networks", OCEANS 2015- Genova
14. Shanen Yu, Shuai Liu, Peng Jiang, "A High-Efficiency Uneven Cluster Deployment based on Network Layered for Event Coverage in UWSNs", Sensors Basel, MDPI, Vol. 16, Issue.2, PP. 2016
15. Seyed Mohammed Ghoreyshi, AlirezaShahrabi, TuleenBoutaleb, Mohsen Khalily, "Mobile Data Gathering with Hop-Constrained Clustering in Underwater Sensor Networks", IEEE Access, vol.7, pp. 21118-21132
16. ShaobinCai, Yong Zhu, Tian Wang, GuangquanXu, Anfeng Liu, Xuxun Liu, "Data Collection in Underwater Sensor Networks based on Mobile Edge Computing", IEEE Access, vol. 7, 65357-65367
17. Fang Zhu, Junfang Wei, "An Energy Efficient Routing Protocol Based on Layers and Unequal Clusters in Underwater Wireless Sensor Networks". Journal of Sensors. 2018. 1-10.
18. Mohammed Reza Khosravi, HmaidHabibRostami, "Efficient Routing for Dense UWSNs with High-Speed Mobile Nodes using Spherical Divisions", The Journal of Supercomputing, Vol. 74, Issue 2, PP. 696-716, 2018
19. Guilista Khan, Rakesh Kumar Dwivedi, "Autonomous Deployment and Adjustment of Nodes in UWSN to Achieve Blanket Coverage (ADAN-BC)", International Journal of Information Technology, PP. 1-10, 2018
20. Gomathi R.M, J Martin Leo Manickam, "Energy Efficient Shortest Path Routing Protocol for Underwater Acoustic Wireless Sensor Network", Wireless Personal Communications, Vol.98, Issue.4, PP. 1-14, 2017
21. Jing Yan, Xian Yang, XiaoyuanLuo, Calian Chen, "Energy Efficient Data Collection over AUV-assisted Underwater Acoustic Sensor Network", IEEE Systems Journal, PP. 1-12, 2018
22. Zhongsi Wang, Bang Wang, "A Novel Node Sinking Algorithm for 3D Coverage and Connectivity in Underwater Sensor Networks", Ad Hoc Networks, Vol. 56, PP. 43-35, 2017
23. R.M. Gomathi, J. Martin Leo Manickam, "Energy Efficient Static Node Selection in Underwater Acoustic Wireless Sensor Network", Wireless Personal Communications, pp. 1-19
24. Yue Zhao, Bo Tian, Zhouguo Chen, Yiming Liu, Jianwei Ding, "An Energy-Efficient Key Agreement Mechanism for Underwater Sensor Networks", Lecture Notes in Electrical Engineering, Vol. 450, PP.1-13, 2017
25. ChhaganLal, Roberto Petroccia, KonstantinosPelekanakis, Mauro Conti, Joao Alves, "Toward the Development of Secure Underwater Acoustic networks", IEEE Journal of Oceanic Engineering, IEEE Journal of Oceanic Engineering, Vol.12, Issue.4, PP. 1075-1087, 2017
26. ChunyanPeng, Xiujuan Du, Keqin Li, Meiju Li, "An Ultra-Lightweight Scheme in Underwater Acoustic Networks", Journal of Sensors, PP. 1-10, 2016
27. DhananjayBisen, Sanjeev Sharma, "An Enhanced Performance through Agent-based Secure Approach for Mobile Ad Hoc Networks", International Journal of Electronics, Vol. 105, Issue.1, PP. 1-22, 2017


*Retrieval Number: K13910981119/19©BEIESP*
*DOI: 10.35940/ijitee.K1391.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

28. Xiujuan Du, Chunyan, Keqin Li, “A Secure Routing Scheme for Underwater Acoustic Networks”, International Journal of Distributed Networks, Vol.13, Issue.6, PP. 1-13, 2017
29. Chaofeng Wang, Li Wei, Zhaohui Wang, Min Song, & Nina Mahmoudian, “Reinforcement Learning-Based Multi-AUV Adaptive Trajectory Planning for Under-Ice Field Estimation”, Sensors, vol. 18, issue. 11, 3859.
30. G. Han, Z. Tang, Y. He, J. Jiang, J. A.Ansere,“District Partition-based Data Collection Algorithm with Event Dynamic Competition in Underwater Acoustic Sensor Networks”. IEEE Transactions on Industrial Informatics, 1–1, 2019
31. Xingwang Wang, Debing Wei, Xiaohui Wei, Cui, Junhong, Miao Pan, “HAS4: A Heuristic Adaptive Sink Sensor Set Selection for Underwater AUV-Aid Data Gathering Algorithm”. Sensors. 18. 4110.
32. Sunil kumar S. Manvi, Manjula R. Bharmagoudra, “Agent based Secure Routing for Underwater Acoustic Sensor Networks”, International Journal of Communication Systems, Vol. 30, Issue.13, PP. 1-19, 2017
33. Guangjie Han, Xiaohan Long, Chuan Zhu, Mohsen Guizani, Fellow, WenboZhang, “A High-Availability Data Collection Scheme based on Multi-AUVs for Underwater SensorNetworks”, IEEE Transactions on Mobile Computing, Early Access Article, 2019

## AUTHORS PROFILE

Arun Kuimar Yadav is a research scholar in Department Of Computer Science and Applications,Kurukshetra University, Kurukshetra, Haryana, India. His area of interest is Underwater Adhoc Networks, MANET Security, Cryptography etc.

Dr. Ashwani Kush is working as Associate Professor and Head in Department in Computer Science, IIHS, Kurukshetra University, Kurukshetra. He has completed his Ph.D. on topic “Optimization of Routing Protocols in Ad hoc networks”. His Research interests includes Ad hoc networks routing, ad hoc network security, ad hoc network energy efficiency, e-governance, Underwater Acoustic Networks. He is a professional Member of ACM USA, CSI India, FIM-USA , IACSIT, IEEE, India, and IAENG, Malaysia. He is reviewer of ACTA Press Canada, UBICC Korea, IAENG Malaysia,IACSIT Singapore, and IJCBR India.He has published more than 130 research publications in various International /National conferences and journals