Hybrid Atom Search-Heap Energy Optimization Algorithm for Dynamic Topology in Underwater Acoustic Sensor Network

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Abstract— **Benefits obtained from the water resources are many in terms of renewable energy, food, materials, communication and security. Monitoring, sensing, routing and analysis of underwater happenings is the challenging task in a sparse environment. Due to the dynamic nature of underwater topology, routing among the nodes is a complex task, hence optimal node identification is mandatory for enhancing network performance. The environment and vast area of ocean makes it highly unlikely for humans to explore and monitor as a challenging task and more cost then manual labour. Hence, economical solutions for monitoring and exploration applications in the ocean are possible with Underwater Acoustic Sensor Network (UWASN). This work proposes a meta-heuristic novel hybrid Atom search-Heap optimization (NHASHO) algorithm to enhance the network performance in terms of energy, end-to-end delay and throughput. The NS2 simulation results show that the proposed work outperforms with existing Cat Optimization algorithm (CAO) for dynamically varying underwater topology condition.**

Keywords— Acoustic, CAT Optimization, Routing, Energy, Monitoring, Environment, UWASN, NHASHO.

I. INTRODUCTION

One third of the world is filled with water resources and advances in communication technologies make the monitoring of water resources easier with the help of sensor networks [1] .Various technologies evolved to communicate among the sensor nodes in underwater environments such as RF,optical,magnetic induction and acoustic signals [2]. The natural gas and minerals are available in the bottom of the ocean. Traditionally, ocean resources search with sea vessels such as ships and submarines. However, sea vessels such as ships and submarines require operating crew and fuel, which is costly [3]. The submarine has limitations to maximum depth, it can dive underwater to explore and monitor resources. Hence, the resources in deep ocean monitors with sensor nodes. The sensor nodes are also implemented for disaster awareness and disaster management systems [4]. The disaster occurring in the ocean classifies as natural and manmade. The natural disasters are in the form of underwater earthquakes, and tsunamis, which are caused due to tectonic plate movement, toxic algae, storm surge, and pathogen contamination. The man made disasters in the ocean caused due to oil pollution, dumping of sewage water in the ocean, pesticides, fertilizers, and herbicides [5]. The pollution and natural disaster alert system is monitored with an underwater acoustic sensor network (UWASN).Fig.1 represents the underwater acoustic sensor network architecture.

Through acoustic link each sensor node communicates data through the acoustic transceiver to the sink node [6]. However, the performance of sensor network nodes located in the depth of the ocean is affected due to visible factors and self constrained factors. The external factors include sea mammals, constant change in seabed due to saline water change, and water pressure. The internal factors include sensor node battery lifetime, bandwidth restriction of node, bit error rate due to propagation delay and link disruption due to node movement [7]. The nodes underwater are displaced due to ocean currents. The natural changes in sea disrupt underwater sensor node functioning and link connectivity. Hence, different routing protocols are implemented in UASN to improve link connectivity and improve data reliability [1]

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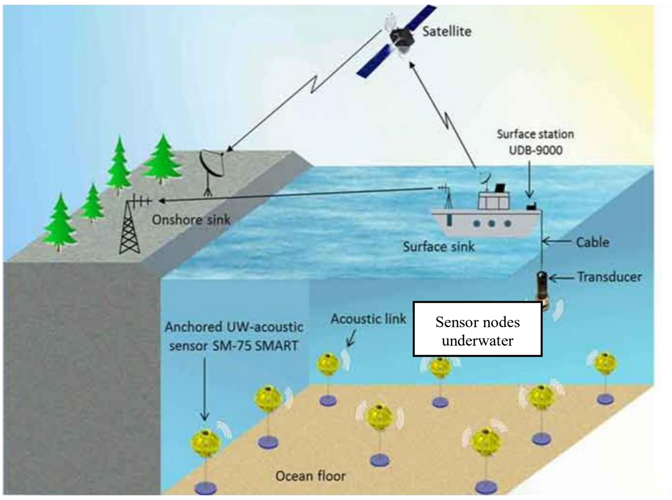

Fig.1 Structure of acoustic communication link in Underwater to buoys node

.The worst situation in underwater acoustic sensor network is how efficiently the sensed information is routed to the buoys node [8].Attainment of remarkable energy efficiency is not only depends on the path chosen by the sensor nodes, but also the routing algorithm designed for the underwater sparse environment. Designed algorithm must overcome network congestion due to link disconnection, harsh environmental condition or due to energy depletion in node [9]. This paper proposes the novel hybrid atom search-heap optimization algorithm (NHASHO) to overcome the above said problem and enhance the network performance.

II. RELATED WORKS

In UASN, due to link disruption, packet collision at the relay nodes and other independent variables affects energy utilization [10]. Unbalanced traffic scenario maximizes the chances of occurrence of energy depleted nodes. The nodes in the underwater environment operate in critical conditions such as low solar visibility, high water pressure and High Ocean current[11].The underwater nodes are energy constrained and acoustic links are bandwidth constrained that leads to poor network connection and also the sensor nodes are often physically damaged by aquatic mammals and other damping force . The algorithm based on Energy Prediction (EPA) maximizes the chance of node communication link and coverage area. The EPA-algorithm benefits Markov Chain Monte Carlo [12] for estimating independent variables such as temperature, viscosity, pressure and humidity. The UWASN's dynamic poor topology, underwater current and sedimental drift the performance of the network is affected. Link disconnection occurs in UWASN, if any node runs out of energy or is physically damaged [13]. Due to the link disconnection, packet exchange between the transmitter node and the node at the receiver side becomes a failure often. Sensors embedded and battery operated nodes are distributed under critical and sparse environmental conditions not able to perform well for a long range and life span also short. Hence, the flexible and intelligence decision making is described through routing protocols and installed in to the all sensor nodes. The designed routing protocol choose the optimal relay node to avoid congestion and reduce the packet collision thereby increase the life span of the network. Calculating and analyzing the node's trust values, minimize the energy consumption and overcome the faulty nodes in the network [14]. Additionally, traditional optimization algorithms have a slow computation process, cannot calculate search space completely, overwhelmed to premature convergence. Hence, energy optimized routing algorithm is best solution to overcome the above said problems and analyze the exploration space thoroughly to yields best solution without sacrificing the quality in terms of search time [15].

The traditional and other recent protocols so designed for terrestrial communication is not well suited for underwater environmental condition. Due to the attenuation effect of RF signal and scattering effect of optical signal the protocols designed for such topology not able to find the optimal node and also affected by long computational time in underwater network[16], [17]. The differences are bandwidth usage dependency, propagation delays; transmit power, attenuation and noise. The hardware such as acoustic modem is energy constrained and that must depends on efficient power saving mode than the terrestrial link during signal reception, transmission and sleeping condition, thereby require energy efficient routing protocol [18]. The effects of these relations have to be analyzed deeply. Based on this scenario, the efficient and localization based routing protocol is proposed NHASHO to show better performance in terms of energy, throughput and end-to-end delay.

The routing algorithm designed in previous literature considers only the sensor parameter and static topology. Due to dynamic nature of topology the nodes in underwater often displaced and leads to link failure. Computational time also very high to select optimal node that further increases the delay and hence energy utilization. The efficient routing algorithm is required to tackle the dynamic topology and also Doppler drift in underwater. Also the algorithm must have minimum normalized routing overhead and low energy consumption.

III. EXISTING METHODOLOGY

Sensor network in underwater meets many challenges like variable sound speed, low bandwidth, low bit rate, variable propagation delay, high error probability and asymmetric power consumption. The fundamental properties of under ocean like temperature decreases with depth, pressure increases with depth and salinity increases with depth. The dependent properties like density and decreases with depth, velocity of sound increases with depth ,propagation loss increases with frequency and viscosity decreases with temperature. Based on these properties the Cat optimization algorithm (CAO) is proposed. The CAO algorithm operating in two modes namely seeking mode (exploration mode) and tracing mode (exploitation mode) [19].The algorithm does not considers the water column variation in underwater. But, due to the water column variation node to wait and analyze the channel selection , which consumes time to a greater extent. To enhance network performance the water column variation and water current are considered in the proposed novel hybrid atom search-heap optimization algorithm (NHASHO).

IV. PROPOSED METHODOLOGY

Optimal node selection is an important consideration in underwater sensor networks for data forwarding. Among the cluster of nodes a priority queue is generated to select the optimal node in energy constrained sensor networks. Every node has routing table with heap based tree structure indicates routing metrics such as energy consumption, distance and delay. Based on these metrics the optimal node will be selected as cluster head if it is having greater metrics than the other nodes. Find optimal node, with highest energy selected as head. The Atom search optimization with heap optimization called novel hybrid atom search- heap optimization perform better in comparison with the existing Cat optimization algorithm. Movement of atomic particles is considered as an important parameter along with heaps taken to develop algorithms to optimize the network performance. Based on atom search algorithm each node maintains two parameters in routing table namely location and speed of the node. Due to water column variation and water current in underwater the nodes often displaced that leads to packet drop.

The acceleration of the node in underwater is described by

$$a = (fi * ci)/Weight \quad (1)$$

fi→ Relative force

ci→ Constrained force

Velocity and location is updated based on the following parameters

$$V(t+1) = r^n Vi(t) + a(t) \quad (2)$$

$$L(t+1) = L(t) + V(t+1) \quad (3)$$

Where, Rn→ random number

V(t)→ Velocity of Node

L(t)→Location of the Node

Fig.2 shows the flow diagram of NHASHO algorithm. Initially all the sensor nodes are deployed and distributed at various depths in virtual environment. Fitness function of each sensor nodes calculated and stored in routing table. Optimal nodes identified based on fitness function for better routing and updating is broadcasted to nearby clusters. The features of atom search algorithm and heap optimization take in to the account , then novel hybrid strategy described with NHASHO algorithm to betterment of underwater acoustic sensor network.

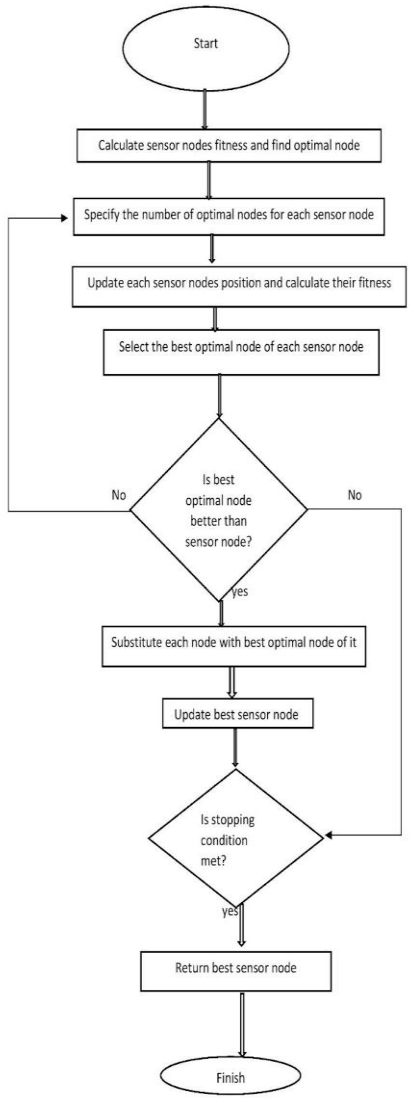

Fig.2 Represents NHASHO working flow chart

V. RESULTS AND DISCUSSION

The NHASHO algorithm is tested using NS2 simulation software with aqua-sim patch to visualize the underwater environment virtually. The battery operated sensor nodes are placed at different depth . The performance metrics of NHASHO algorithm is analyzed and compared with Cat optimization algorithm(CAO).

Fig.3 represents the throughput Vs number of acoustic sensor nodes. Underwater sparse environment the nodes are displaced with respect to water current there by variation in network throughput.The NHASHO algorithm outperforms over the

CAO due to optimal node selection based on routing table information

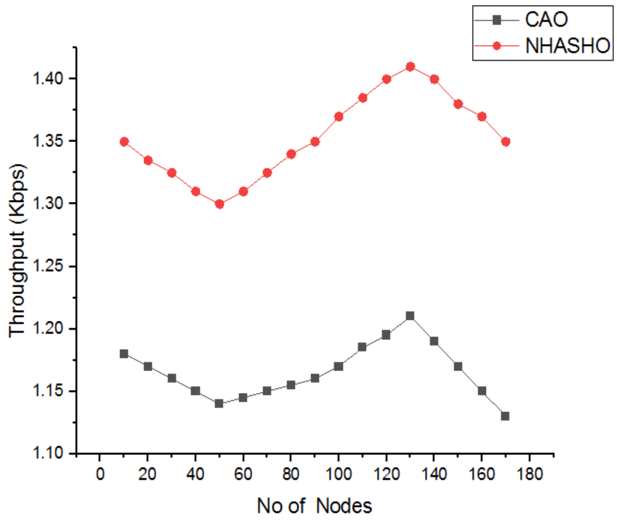

Fig.3 Throughput Vs No of Nodes

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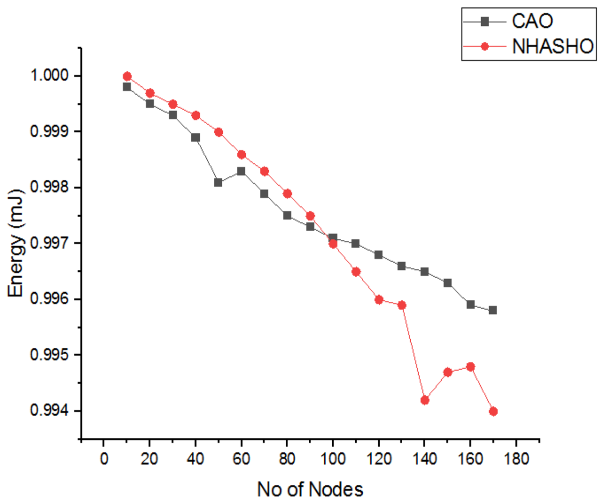

Fig.4 Energy Vs No of nodes

Fig.4 represents the energy Vs number of acoustic sensor nodes. Sensor network underwater is energy constrained,so the effective utilization of battery energy is important task.The routing algorithm so designed NHASHO capable of reducing the time delay to selecting the optimal node there by increase the energy efficiency in comparison with CAO.

Fig.5 indicates the end-to-end delay with respect to number of acoustic sensor nodes. Delay for the proposed algorithm is low when compared with CAO due to the less computational time and low normalized routing overhead.

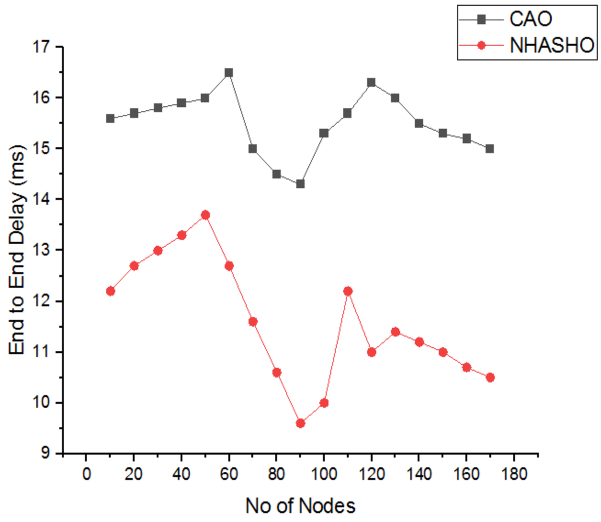

Fig.6 Delay Vs No of Nodes

VI. Conclusion

Monitoring of underwater resources is the important task with the energy constrained underwater acoustic sensor network(UWASN).The acoustic link will perform better when compared with RF and optical link For dynamically changing underwater network topology the sensor nodes are often drained due to long processing and optimal node selection process. For this sparse environment the proposed novel hybrid atom search-heap optimization algorithm (NHASHO) outperform in terms of energy, throughput and delay. The proposed work is restricted with minimal number of nodes and small geographical area. Future work considers large geographical area with larger number of nodes for better performance with machine learning algorithm.

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