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Effective Multilayered Energy Harvesting and Aggregation in underwater Acoustic Networks for Performance Enhancement

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ABSTRACT: In wireless networks, there are mobile nodes which are connected to each other using radio or related transmission line without any physical infrastructure. Wireless Network refers to a specific scenario having mobile nodes connected via mobile routers, base stations or satellites using which the overall network can be controlled and monitored. There are number of applications in which wireless sensor networks are integrated. In classical way, the wireless networks are implemented for the ease of mobility, remote accessibility and cross region connectivity. Underwater Acoustic Networks and related energy based lifetime enhancement is one of the key domain of research in marine based engineering. A number of algorithms, protocols and approaches are developed so far for effective optimization of acoustic resources still a huge scope of research is there. In this paper, a novel aspect and approach for energy harvesting is presented using which the effective lifetime of the network can be enhanced. Using this approach, the solar based energy harvesting and optimization can be done with overall cost reduction.

KEYWORDS – UWSN, Underwater Sensor Networks, Energy Harvesting

I.INTRODUCTION

As we wholly classifies that computer science had magnificently positioned the sensor network on earth and on human body but still underwater is unscathed area and our 2/3rd portion of globe is enclosed with seawater. "Underwater sensor networks (UWSN) are the emergent and auspicious announcement framework which empowers a wide range of imperative applications. The characteristics of partial existing bandwidth, huge propagation delay and high bit fault rate (BFR) have posed several essential challenges. Unmanned or Autonomous Underwater Vehicles (UUVs, AUVs) equipped through underwater sensors, are also envisioned to discovery application in exploration of natural below marine resources and gathering of scientific data in collaborative monitoring missions. These potential applications will be complete viable by enabling communications amongst underwater devices. Underwater Acoustic Sensor Networks (UW_ASNs) will entail of sensors and vehicles positioned underwater and network via acoustic links to perform collaborative monitoring tasks.

Underwater acoustic sensor networks enable a broad range of applications, including:

- **Ocean Sampling Network-** Networks of sensors and AUVs can perform synoptic, cooperative adaptive sampling of the 3D coastal ocean environment.
- **Environmental Monitoring-** UW-ASNs can accomplish pollution monitoring (biological, Chemical and nuclear), ocean current and storm monitoring such as tracing of fishes or micro-organisms. Also, UW-ASNs can advance weather forecast, sense climate variation or realize and predict the consequence of humanoid events on marine ecosystems.
- **Undersea Exploration-** Underwater Sensor Networks can sustenance detect underwater oilfields or reservoirs, determine routes for laying undersea cables and assist in exploration for valuable minerals.

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- **Disaster Prevention-** Sensor networks that measure seismic activity from remote locations can provide *Tsunami* forewarnings to coastal ranges, or homework the special effects of submarine earthquakes (seaquakes).
- **Seismic Monitoring-** Frequent seismic monitoring is of inordinate importance in the lubricant extraction from underwater arenas to asses ground performance. Underwater Sensor Networks would permit reservoir management tactics.
- **Equipment Monitoring-** Sensor networks would enable remote regulator and provisional monitoring of expensive equipment instantaneously after the disposition, to assess deployment failures in the preliminary operation or to perceive problems.
- **Assisted Navigation-** Sensors can be castoff to recognize hazards on the seabed, localize dangerous stuns or shoals in shallow seawaters, mooring locations, and submerged wrecks and to accomplish bathymetry profiling.
- **Distributed Tactical Surveillance-** AUVs and fixed underwater sensors can collaboratively monitor areas for surveillance, reconnaissance, and targeting and intrusion detection.
- **Mine Reconnaissance-** The simultaneous operation of multiple AUVs with acoustic and optical sensors can be used to perform rapid environmental assessment and detect mine-like objects.

A. DESIGN AND CHALLENGES

- Node Deployment
- Limited Energy, Computational Capacities and Memory
- Network Dynamics
- Energy Efficiency
- Data Aggregation
- Node/Link Heterogeneity
- Fault tolerance and reliability

B. ENERGY HARVESTING

A sensor network is a set-up of collaborating embedded maneuvers (sensor nodes) with proficiencies of sensing, computation and communiqué, is castoff to sense and gather statistics for application particular investigation. Untethered sensor nodes castoff in these dispositions facilitates mobility and disposition in hard-to-reach localities. A foremost restriction of untethered nodes is limited battery capacity-nodes will drive for a finite interval, merely as long as the battery persists. Finite node lifetime implies finite lifetime of the applications or additional cost and complexity to regularly change batteries. Nodes could probably use huge batteries for lengthier lifetimes, but will have to treaty with increased size, weight and cost. Nodes may also determine to use low-power hardware like a low-power processor and radio, at the cost of slighter computation capability and lower transmission ranges.

Numerous resolution techniques have been projected to exhaust the possibilities of the lifetime of battery-powered sensor nodes. Some of these contain energy –aware MAC protocols (SMACBMACXMACpower aware storage, routing and data dissemination protocols duty-cycling strategies adaptive sensing ratetiered system architectures and redundant placement of nodes.

While all the upstairs procedures optimize and adapt vigor usages to get the best out of the lifetime of a sensor node, the lifetime remains bounded and finite. The above methods help prolong the application lifetime and /or the time interval amongst battery substitutions but do not preclude energy-related inhibitions. With a finite energy cradle, seldom can all the performance parameters be optimized simultaneously, e.g., higher battery capacity implies increased cost, and low duty cycle implies decreased sensing a reliability, higher transmission range implies higher power requirement and lower transmission range Implies transmission paths with more number of hopes resulting in energy usage at more number of nodes.

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A substitute procedure that has been pragmatic to statement the problem of finite node lifespan is the usage of energy harvesting. Energy harvesting denotes to harnessing vigor from the atmosphere or former energy cradles (body heat, foot strike, finger strokes) and transforming it to electrical energy. The harnessed electrical vigor powers the sensor knobs.If the harvested vigor source is huge and periodically / endlessly obtainable, a sensor knob can be motorized perpetually.Further, built on the periodicity and magnitude of harvestable vitality, structure parameters of a node can be tweaked to raise the node and network recital.Since a anode is energy-limited only till the next harvesting opportunity (recharge cycle), it can optimize its energy usage to maximize performance during that interval.For example, a node can increase its sampling frequency or its duty-cycle to increase sensing reliability, or increase transmission power to decrease length of routing path.

As a result, energy harvesting techniques have the potential to address the tradeoff between performance parameters and lifetime of sensor nodes. The challenge lies in estimating the periodicity and magnitude of the harvestable source and deciding which parameters to tune and simultaneously avoid premature energy depletion before the next recharge cycle.

C. PROJECTED DEPLOYMENT TECHNIQUE

Network is positioned with an assumption of heterogeneous deployment of nodes in terms of energy and bandwidth. For energy efficiency we use data aggregator, which is use as the gateway. So it is evident that we have used a hierarchical arrangement in our network. The benefit of a hierarchical system over a flat system is that it is more energy efficient and easy to collect data. We are deploying the sensors at three levels, which are mentioned below:-

- Bottom Level of Ocean
- Middle Level of Ocean
- Top Level of Ocean

As to deploy any network some hardware things is required and in consider of deployment in underwater we are using the following hardware to design our network:-

- Aquanodes
- Data Aggregator
- AUV's
- Surface Sink
- Satellite

II. LITERATURE REVIEW

To propose and defend the research work, a number of research papers are analysed. Following are the excerpts from the different research work performed by number of academicians and researchers.

- Kang MJ et. al. (2017) proposed the perspectives of higher performance in terms of both energy and delay times with aspects of reduction in delay time of wireless motes

- Ramanan, K. et. al. (2017) derived Energy Efficient Optimization Techniques (DEEORT) scheme is introduced. DEEORT obtains the better performance in terms of energy consumption rate, energy drain rate, routing over head and routing delay.

- Cai, W. et. al. (2017) designed a 0-5 GHz RF SOI switch, with 0.18um power Jazz SOI technology by using Cadence software, for health care applications. This paper introduces the design of a RF switch implemented in shunt-series topology.

- Anandh, S. J. et. al. (2017) work on efficient node density based cluster construction with the enhancesments overall network lifetime. Density of nodes computed and density is high in the sense that there may be more number of unreachable nodes for the cluster head and avoids the hot-spot problem in which information loss can be prevented and saves energy.

- Wu, Y. et. al. (2017) investigates a joint power allocation and relay selection scheme for energy efficient cooperation with energy harvesting-wireless sensor networks (EH-WSN). The work proposes a simple heuristic algorithm to improve the energy efficiency of each node in a clustering based EH-WSN joint optimization algorithm has a promising future in real applications.

- Liu, X. et. al. (2017) propose a novel joint design of sensor nodes clustering and data recovery and WSNs organized in two-layer manner take both the energy-efficiency and data forecasting accuracy

- Kuo, T. W. et. al. (2016) work on the problem of constructing a data aggregation tree that minimizes the total energy cost of data transmission in a wireless sensor network. The work proposed algorithms have good performance in terms of energy cost.

- Jan, M. A. et. al. (2016) underlined the two different cluster-based hierarchical routing protocols are proposed. The scheme is computationally efficient, incurs less connection overhead and safeguard against various types of replay attacks.

- Tahir, M., Khan et. al. (2016) proposed a scheme whereby a small number of High-Energy nodes gather location information and residual energy status of the sensing nodes and transmit to the Base Station. The authors eliminates CH advertisement phase in order to conserve energy and derived an energy model, also known as EEC, for our algorithm and depicts the total energy consumption in the network.

- Ren, J., Zhang et. al. (2016) propose an analytic model to estimate the entire network lifetime from network initialization until it is completely disabled. The work determine the boundary of energy hole in a data-gathering WSN estimate the traffic load, energy consumption, and lifetime of sensor nodes

- Zeng, B. et. al. (2016) proposes an Improved Harmony Search Based Energy Efficient Routing Algorithm (IHSBEER)

- Dong, M. et. al. (2016) presents an analysis strategy to meet requirements of a sensing application through trade-offs between the energy consumption (lifetime) and source-to-sink transport delay under reliability constraint wireless sensor networks. The work presents novel data gathering protocol named Broadcasting Combined with Multi-NACK/ACK (BCMN/A) protocol is proposed.

- Abdul-Salaam, G. et. al. (2016) proposed and discuss a taxonomy of types of data collection in WSN. The authors present in details a thematic taxonomy of energy conservation techniques

- Wang, J. et. al. (2016) presented the new algorithm iteratively partitions a directional sector zone and source nodes are included in an itinerary. The work underlines the length of an itinerary is controlled by the angle of the directional sector zone

- Hu, Y. et. al. (2016) presented the new scheme is Target Detection with Sensing Frequency K (TDSFK) and distributes the sensing time that currently is only on a portion of the sensing period into the entire sensing period. The work improve the network lifetime by more than 17.4% and reduce the weighted detection delay by more than 101.6%.

- Yao, Y. et. al. (2015) stems from our insight that recent research efforts on open vehicle routing (OVR) problems and develop one data collection protocol called EDAL stands for Energy-efficient Delay-aware Lifetime-balancing data collection

- Yang, Q. et. al. (2015) design the ε-full area coverage optimization (FCO) algorithm and select a subset of sensors to provide probabilistic area coverage network lifetime can be prolonged

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- Amgoth, T. et. al. (2015) proposed an energy aware routing algorithm for cluster based WSNs. The work underlines the algorithm based on a clever strategy of cluster head (CH) selection
- Kiani, F. et. al. (2015) underlined new clustering method applied to the network The work done for network established using connected graph. New protocol improved in different parameters including network lifetime, packet delivery, packet delay, and network balance.
- Wu, D. et. al. (2015) adding an EH module to the existing node structure using novel EH-WSN. The authors changed the design of the network eliminating the major constraint and increased battery capacity.

A. **Research Objectives :**

The following aims and objectives of the research work are

1. To develop an efficient algorithmic approach for cluster head selection in the wireless sensor networks
2. To develop the module for integration with the algorithm for simulation of the energy optimization based on the fuzzy logic
3. Removal of Redundant Links to improve the lifetime of the dynamic cluster head
4. To perform clustering/aggregation of sensor motes and dynamic selection of the cluster head
5. To optimize the energy level of the wireless sensor nodes in the region under simulation.
6. The proposed algorithm can be generalized for multiple applications
7. To improve the efficiency and performance of the sensor nodes in terms of lifetime and maximum usability under the condition.

A. Problem Formulation :

- The classical research work done in the existing work and research papers mainly focus on the energy optimization techniques using classical and prominent algorithmic approaches.
- The classical (existing) work develops a model and paradigm for the density and degree based measurement and select of the cluster head and there is only one cluster head in taxonomy.

B. Research Gaps :

- The classical works do not focus on the threshold and fuzzy factors for the cluster head selection
- The existing work lacks on the development and deployment of fault tolerant networks.
- In case of failure or faults in the current CH, the entire network fails. This problem can be avoided using fuzzy and the proposed approach.
- The base work is required to be extended using Monte Carlo simulation as well as fuzzy formulation.

C. Research Methodology :

- Sensors are deployed to form the dynamic clustered head and reconfiguration of the network
- The fuzzy formula based dynamic selection of the cluster head is implemented
- The proposed work is providing the feature and dynamic nature to the cluster head
- The work is fault and failure tolerant due to shuffling of the cluster head.

D. Key Aspects :

- The classical research work done in the existing work and research papers mainly focus on the energy optimization techniques using classical and prominent algorithmic approaches.
- The classical (existing) work develops a model and paradigm for the density and degree based measurement and select of the cluster head and there is only one cluster head in taxonomy.

E. Identification of research perspectives :

- The classical works do not focus on the threshold and fuzzy factors for the cluster head selection
- The existing work lacks on the development and deployment of fault tolerant networks.

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- In case of failure or faults in the current CH, the entire network fails. This problem can be avoided using fuzzy and the proposed approach.
- The base work is required to be extended using Monte Carlo simulation as well as fuzzy formulation.

III. RESULTS AND DISCUSSION

A. CUMULATIVE GRAPH OF PREVIOUS OR CLASSICAL AND PROPOSED APPROACH

1. Read WSN Node (Mote) {WSN[i]; i<=n}
2. Generate Dynamic Graph of the Nodes
3. Measure the Density of each node based on the ratio of the number of links between and to neighbours of u over the degree of u: $\rho\ (u) = (\mathrm{V}, w) \in E \mid \mathrm{V} \in \{u,\mathrm{N}(u)\}\ ,\ w \in \mathrm{N}(u)\ /\ \delta\ (u)$
4. Add Random Number to the measured density of each node to avoid any biasing
5. Allocation of the Cluster Head shall be based on the Threshold Value.
6. The Threshold Value shall be compared with all nearby densities and minimum difference in the densities shall be the factor.
7. Suppose the densities are -> d1, d2, d3 …... Now, a dynamic threshold based the average of all these will be taken.
8. Then, the most near value to the threshold shall be considered as Cluster Head
9. The comparison parameters / graphs shall be

- Energy Optimization / Conservation between Previous or classical and Proposed Approach
- Overhead Factor between Previous or classical and Proposed Approach

B. PERFORMANCE EVALUATION METRICS

Source Code of MATLAB Attached herewith having previous or classical and proposed approach implementation. Biograph Toolbox, Plotting Library is used with Core Programming of MATLAB to perform the implementation

The following simulation scenarios and implementation aspects are generated using BioGraph Toolbox in MATLAB. Using biograph toolbox, the scenarios of different nodes are generated by which the simulated environment is generated for the wireless sensor network. Using the simulated environment, we can view the connection or association in the nodes.

C. SIMULATION OF CLASSICAL APPROACH

Implementation of Cluster Head Selection in Wireless Sensor Networks
Generation of Sparse Matrix for Connectivity of the Wireless Sensor Nodes

0	1	0	0	0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0	0	0	1	1
0	1	0	1	0	0	0	0	0	0	1	0	1	0
0	0	1	0	1	0	0	0	1	1	1	0	0	0
0	0	0	1	0	1	0	0	1	0	0	0	0	0
0	0	0	0	1	0	1	0	1	0	0	0	0	0
0	0	0	0	0	1	0	1	1	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0
0	0	0	1	1	1	1	1	0	1	0	0	0	0
0	0	0	1	0	0	0	1	1	0	1	0	0	0
0	0	1	0	0	0	0	0	0	1	0	1	1	0
0	0	0	0	0	0	0	0	0	0	1	0	1	1
0	1	1	0	0	0	0	0	0	0	1	1	0	1
1	1	0	0	0	0	0	0	0	0	0	1	1	0

Generation of Sparse Matrix for Implementation of Low Battery Nodes Removal
Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 158.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 92.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 120.1302 Evaluation of the Overhead Factor in the Previous or

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classical Approach overhead = 169.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 157.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 173.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 143.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 81.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 162.1302 Evaluation of the Overhead Factor in the Previous or classical Approach overhead = 171.1302 overheadfactor = Columns 1 through 8 158.1302 92.1302 120.1302 169.1302 157.1302 173.1302 143.1302 81.1302 Columns 9 through 10 162.1302 171.1302 Maximum Overhead Factor in the Previous or classical Approach -> 173.1302 Minimum Overhead Factor in the

Previous or classical Approach -> 81.1302 Average Overhead Factor in the Previous or classical Approach -> 142.7302 alloverhead = 81.1302 142.7302 173.1302

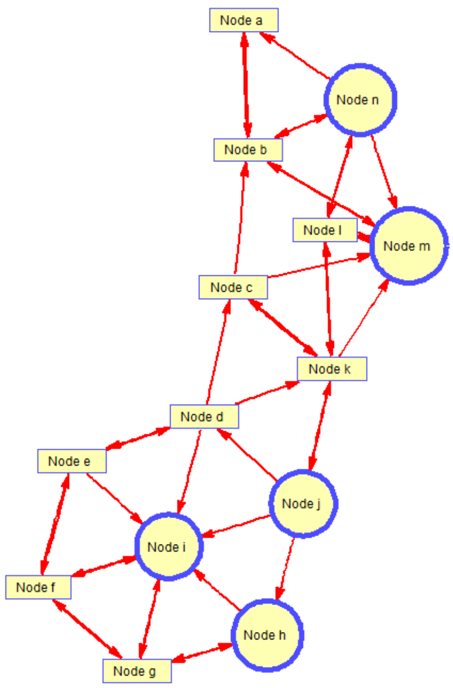

Figure 1: Navigation and Density analysis Phase

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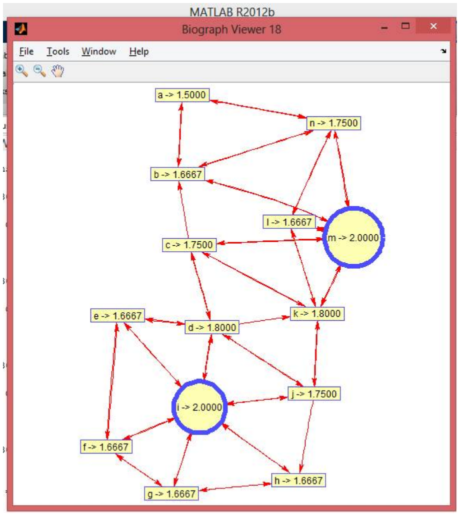

Figure 2: Selection of the Cluster Head after Density analysis Phase

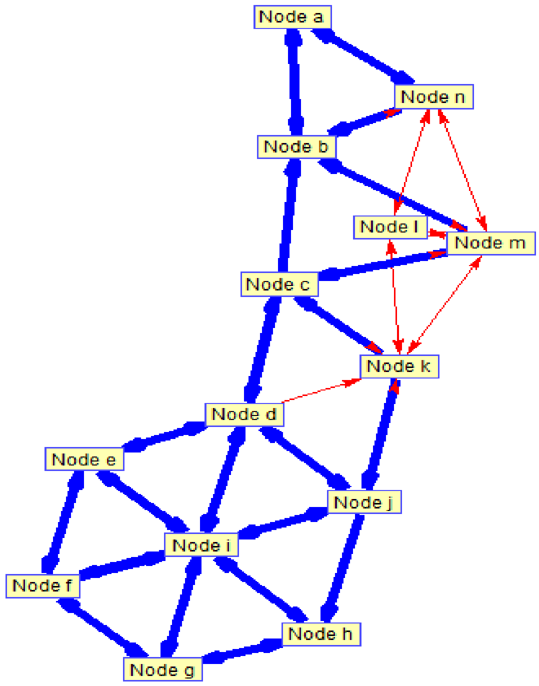

Figure 3: Biograph representation and Navigation Mode of the WSN

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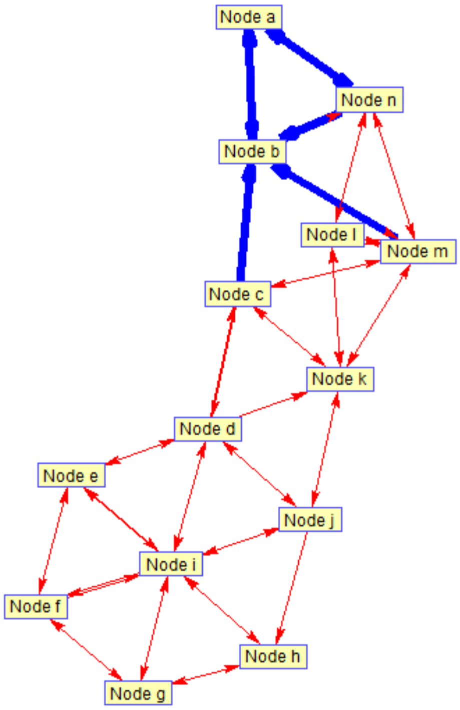

Figure 4: Biograph representation and Navigation Mode of the WSN

D. SIMULATION OF THE IMPROVED / PROPOSED ALGORITHMIC APPROACH

Implementation of the Proposed Cluster Head Selection and Low Battery Nodes Removal in Wireless Sensor Networks

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Density Measurement of each node Degree of each Node deg = Columns 1 through 8 1.5000 1.6667 1.7500 1.8000 1.6667 1.6667 1.6667 1.6667 Columns 9 through 14 2.0000 1.7500 2.0000 1.6667 2.0000 1.7500 meandeg = 1.7536 deg = Columns 1 through 8 2.6873 2.8540 2.9373 2.9873 2.8540 2.8540 2.8540 2.8540 Columns 9 through 14 3.1873 2.9373 3.1873 2.8540 3.1873 2.9373 Selection and Formation of the Cluster Head - 1 pool1 = 1.5000 1.6667 1.7500 2.0000 1.6667 2.0000 1.7500 2 Selection and Formation of the Cluster Head - 2 pool2 = 1.8000 1.6667 1.6667 1.6667 1.6667 2.0000 1.7500 alloverhead = 59.7475 87.4475 137.7475

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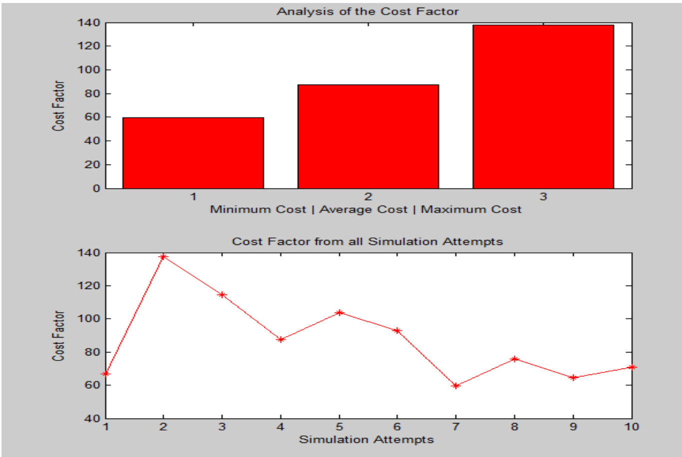

Figure 5: Bar and Points View of the Overhead Factor in Proposed Approach

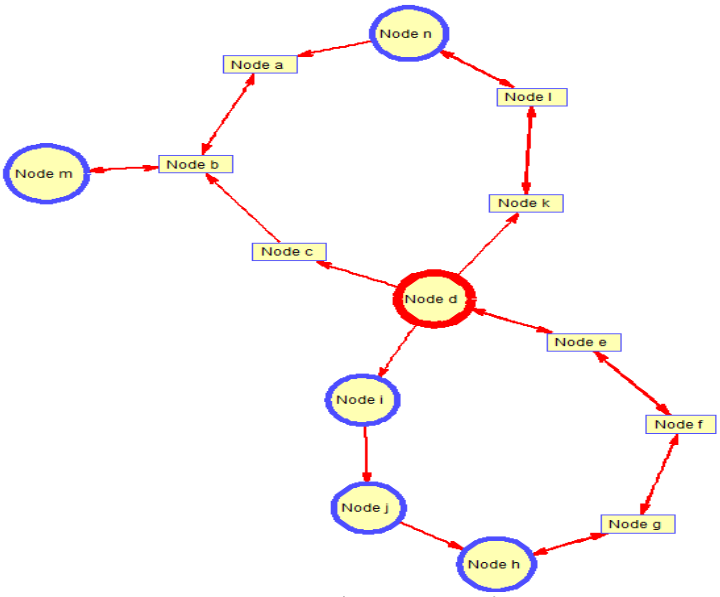

Figure 6: Wireless Network after removal of redundant links

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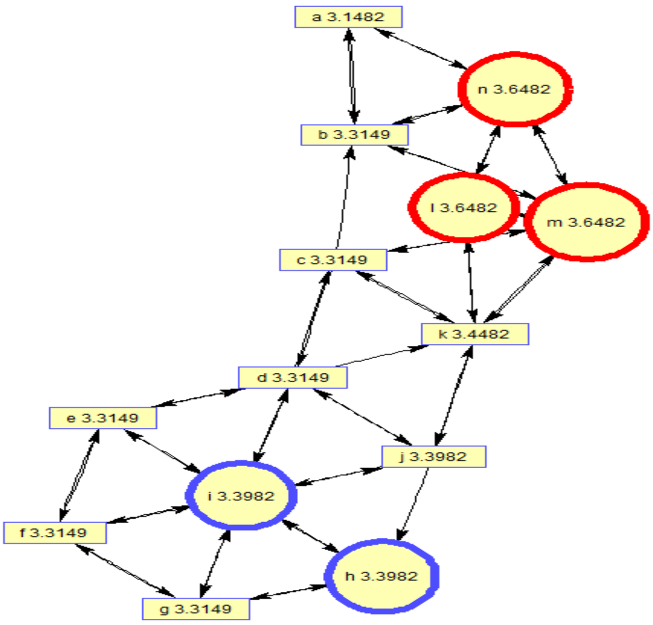

Figure 7: Overall View of the Wireless Network before removal of redundant links

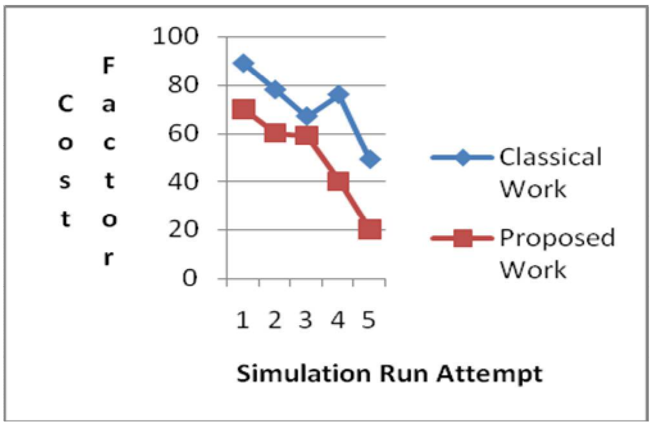

Figure 8: Cost Factor Line Plot Analysis of the Approaches

It is evident from the graphical results that the cost factor in the proposed research approach that is very less when compared to the existing algorithmic approach. The execution time in the classical work is taking higher units as compared to the proposed work.

Existing Base Work	Projected Approach
53	73

Table 1: Classical and Improved Approach

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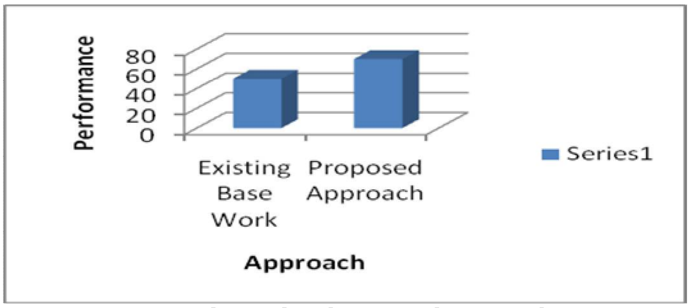

Figure 9: Classical and Projected Approach

Existing Base Work	Projected Approach
93	63

Table 2: Classical and Improved Approach

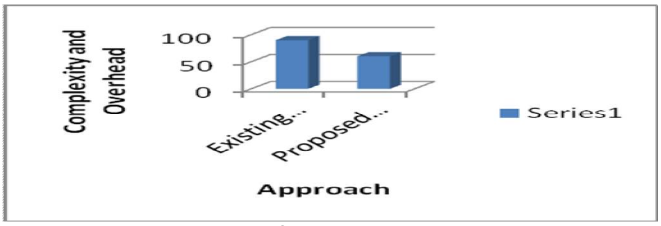

Figure 10: Comparison of Classical and Projected Approach

Existing Base Work (Overall Effectiveness)	**Projected Approach (Overall Effectiveness)**
52	61
62	90
72	91
52	71

Table 3: Difference between Classical and Improved Approach

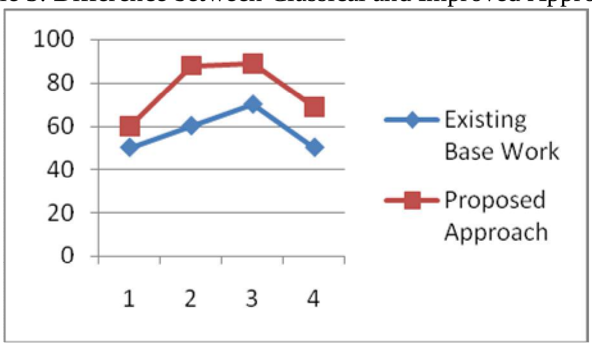

Figure 11: Effective Comparison of Classical and Proposed Algorithm

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IV. FUTURE SCOPE

In this research work, the multilayered approach for energy harvesting and optimization is done using the mathematical foundations integrated with the underwater sensor networks. Using the projected approach in association with the tidal energy, the overall performance of the system is escalated and higher degree of optimization is achieved. As the underwater sensor networks function below the sea level, there is need to optimize the energy of underwater acoustic networks with higher degree of accuracy, this work is having key focus on this segment.

V.CONCLUSION

The energy optimization is one of the leading domain and still in research. There exist another approach hyper-heuristic that can be integrated for deep learning of energy optimization and predictive analysis. The key demarcation line between Metaheuristics and hyper-heuristics is that nearly all the implementations in Metaheuristics makes search in the search space in the span of solutions of problem. The hyper-heuristics takes the cases and search space within the range and domain of heuristics. In addition and for further improvements, the nature inspired approaches and soft computing approaches can be used to achieve the global optimization. As deep Learning is one of the constituent of soft computing having core tasks associated with classification, recognition which are generally related with the artificial intelligence. Generally, these operations are performed using some Metaheuristics approach in which the global optimization or simply effective results can be fetched from a huge search space of solutions.

For future work, the prominent soft computing approaches which can be used for further optimization include

- Fuzzy Logic
- Support Vector Machines
- Swarm Intelligence
- Metaheuristics
  - Ant Colony Optimization
  - Cuckoo Search
  - Bees Algorithm
  - Particle Swarm Optimization
  - Firefly Algorithm
  - Bat Algorithm
  - Simulated Annealing
  - Flower Pollination Algorithm
- Bayesian Network
- Evolutionary Approaches
- Nature Inspired Algorithms
- River Formation Dynamics

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