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Original Article

Impact of Different Parameters on Handover and Call Drop Performance in UWSNs

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Abstract *- Underwater Wireless Sensor Networks (UWSNs) play an essential role in marine observation and data gathering. However, ensuring reliable communication is challenging due to node mobility and the unpredictable nature of underwater channels. This paper introduces a new method that assimilates the Multi-Verse Optimization (MVO) algorithm to intensify the Hand Over Margin (HOM) essential for establishing continuous connectivity during the mobility of nodes. This paper explains the MVO algorithm and discusses how it can enhance the performance of UWSNs. Another performance metric is Call Drop Ratio (CDR), which measures the proportion of dropped calls during communication. The aim is to enhance the overall network and to curtail the call drops through incorporating the CDR calculations into the MVO framework. This work focuses on specific parameters such as node speed, overlap radius, handover time, and coverage radius, which influence the HOM and CDR to empower the efficiency of network management. Experimental results illustrate that the proposed optimization technique significantly improves the HOM and reduces CDR in UWSNs. This paper concludes with an outline of key observations and suggests potential avenues for future research to further advancements in the application of optimization techniques.*

Keywords *- Underwater Wireless Sensor Networks, Handover margin, Call Drop Ratio, Multi-Verse Optimization Algorithm.*

1. Introduction

These days, to bring down the need for land resources, the discovery of the underwater environment is the most essential goal [1]. UWSNs involve sensor nodes or underwater vehicles that collaboratively monitor marine environments. The network has various applications such as oceanographic data collection, pollution monitoring, offshore area exploration, tactical surveillance, conducting and disaster detection and measurement. The network referred to as mobile UWSNs, when the sensor nodes are underwater, is mobile. High node density and constrained energy resources are the similarities between UWSNs and terrestrial wireless sensor networks. The use of acoustic communication channels, higher latency, node mobility, measured error probability, and 3-D network topology are a few of the differences. This distinctive condition raises several challenges in designing effective UWSNs [2].

Sensor nodes are planted in specific areas to collect the required data. The collected data will be sent to surface sinks for proper interpretation [3]. To monitor the fire and measure the temperature, sound, pressure, etc., within the forests, sensors are deployed in real-world environments. Identifying the exact location where the occurrence of environmental changes is essential. Therefore, the concept of localization is employed [4].

The process of determining the spatial positions of nodes and components within a network is termed localization. This capability is vital for sensor networks, as many of their functions depend on knowing the precise positions of the nodes [5].

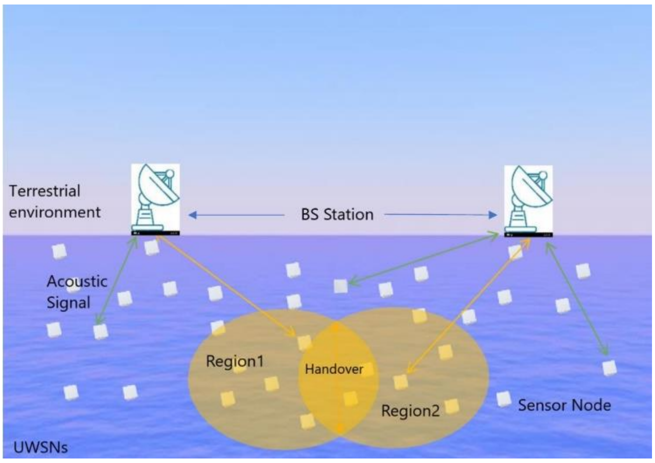

Fig. 1 Underwater wireless sensor networks

The process of determining the spatial positions of nodes and components within a network is termed localization. This capability is vital for sensor networks, as many of their functions depend on knowing the precise positions of the nodes [5]. Node localization technology is very crucial for pinpointing and tracking nodes, thereby improving the significance of monitoring data. Without the location information of the nodes in the sensor network, the data collected at the sink node would be meaningless to the user.

By using the acknowledged positions of anchor nodes, the location of the unknown sensor nodes is determined. There are several methods available to determine the location of sensor nodes, such as Time of Arrival (ToA), Time Difference of Arrival (TDoA), Received Signal Strength Indication (RSSI), and Angle of Arrival (AoA). In addition to localization, other key aspects of UWSNs are the handover margin and call drop ratio, particularly in mobile UWSNs. The handover margin refers to the threshold at which a node or a mobile underwater vehicle switches its connection from one acoustic communication channel to another to maintain a stable link. Properly managing the handover margin is very essential for ensuring seamless communication, especially when nodes move within the network.

1.1. Problem Statement

In Underwater WSNs reliable communication is a critical challenge due to dynamic environments, limited bandwidth, and node mobility. Some issues faced are the high call drop ratio and inefficient handover mechanisms. These directly impact the Quality of Service (QoS). Traditional handover mechanisms often fail to adapt to the unpredictable nature of the underwater environment, leading to frequent connection loss and degraded network performance. Therefore, there is a need to develop an optimized handover management strategy that minimizes call drops in UWSNs. This research addresses this gap by employing the Multi-Verse Optimization Algorithm to intelligently tune parameters such as HOM, thereby enhancing handover decisions and reducing the CDR in UWSNs

1.2. Contribution

The paper makes several significant contributions to the field of UWSNs. Here are the key contributions outlined:

- The paper introduces a novel method that utilizes the MVO algorithm to optimize the HOM in UWSNs. This optimization is important for maintaining seamless connectivity as nodes move through the
- underwater environment, addressing challenges such as signal attenuation and interference.
- By focusing on optimizing network parameters, the paper emphasizes minimizing the CDR in underwater communication networks. The insertion of CDR calculations into the MVO framework allows for a more robust analysis of network performance.
- The paper presents a performance analysis of the proposed model, demonstrating how the optimized handover margins lead to improved network reliability. The results show that the optimization technique effectively maintains higher handover margins even at increased node speeds, which is essential for robust underwater communication.

1.3. Paper Organization

This paper covers: Section II reviews existing literature on handover schemes, call drop analysis, and optimization techniques. Section III details the approach taken in the study, including the application of the MVO algorithm for optimizing handover margin and call drop ratio. Section IV explains the experimental results obtained from applying the proposed method. It discusses the impact of different parameters on handover performance and proposed call drop ratios, providing insights into the effectiveness of the optimization technique used. Section V concludes the main findings and contributions of the research. It emphasizes the improvements in handover margins and call drop ratios achieved through optimization.

2. Related Work

The Internet of Underwater Things (IoUT) enhances the maritime industry by reducing energy use and addressing long propagation delays. Sensor nodes prioritize connections without scanning nearby stations, and machine learning predicts handovers without channel measurement [6]. Handover schemes for high-speed wireless communication address challenges like fast handover and Doppler shift. The author proposes innovative methods and technology integrations to enhance efficiency and reliability in future networks [7]. Predicting handovers based on user mobility enhances efficiency and reduces errors in heterogeneous networks by analyzing user movement trends with fuzzy neural networks. The method aims to achieve quicker and more seamless handovers [8]. Mobile Wireless Sensor Networks play a vital role in health monitoring and wildlife tracking, requiring seamless handovers and efficient target tracking. This paper focuses on target tracking and proposes three handover schemes for improved performance in MWSNs [9]. This work analyzes dropped calls—an important QoS indicator in cellular networks and finds that existing models fail to account for significant factors affecting call termination. An original analytical model, validated with real network data, is proposed to enhance performance and improve QoS and revenue [10]. The author examines how combining handover prioritization schemes with retrial queues can minimize call drops. Results indicate that these techniques effectively reduce the number of dropped handover calls [11]. The study assesses the implementation of affordable femtocells in residential settings. It demonstrates that auto-configuration technology significantly reduces their interference with macrocell users, resulting in a minimal 0.45% rise in dropped calls under the most adverse conditions. It also discusses the effect of femtocells on network signalling [12].

2.1. Handover Margin

Handover states the process of shifting an active connection or communication session from one communication link or base station to another through the network. This is essential for ensuring uninterrupted connectivity as the node transitions from the range of the current link to the range of another. The primary goal of a handover is to ensure that communication is uninterrupted, even as the node's physical location changes and the quality of the current link degrades. Handover can be a Horizontal handover between similar types of networks (e.g., from one underwater sensor node to another) and a Vertical handover between different varieties of networks (e.g., from an underwater sensor node to a surface buoy). Handover margin is a threshold or a predefined value that determines when a handover should be initiated. It represents the buffer zone where the system starts considering a handover. HOM is used to avoid sudden drops in connection quality by triggering the handover process before the current link degrades too much. It helps in balancing the trade-off between unnecessary and maintaining a stable connection [13].

The handover process involves four main stages: measuring, triggering, selecting, and performing. In the measurement phase, both the base station and the mobile station assess their downlink and uplink signals on a regular basis. The mobile station also assesses the signal strength of nearby cells, with each measurement causing a delay. The quantity of nearby cells being assessed directly affects how many cycles are required for the measurement. The number of cycles needed for measurement is directly related to the number of neighboring cells being evaluated. By streamlining the list of neighboring cells, the number of required measurements can be decreased, which in turn reduces measurement delays. During the triggering stage, the base station's subsystem must process the measurement time delays in advance and manage the results provided by the mobile station.

The selecting stage is typically very brief and can often be disregarded. In the final stage, the actual handover occurs. The mobile device shifts from the old cell to the new cell. All ongoing connections are redirected to the new base station. The success of this process depends on the complexity of the signaling flow and the processing speed of the network components [14]. Incomplete handover executions pose significant challenges for both current and next-generation networks. To address this, network optimization becomes vital, with localization serving as a key factor. Knowing the precise location of mobile terminals supports better network planning and enhances handover efficiency. By storing statistical data, location servers can identify areas with frequent handovers. In such regions, the handover procedure can be triggered automatically, thereby minimizing signaling overhead [15].

2.2. Call Drop Ratio

Life without a cell phone is hard to imagine today, but call drops can disrupt important conversations. This issue affects people in both urban and rural areas. In many cities, users often need to move to find better signal quality. According to Telecom Regulatory Authority of India (TRAI), telecom operators are now allowed a maximum of 2% call drops. However, many subscribers still experience frequent disconnections. As the number of users rapidly grows, the cell telecom infrastructure has not kept pace, leading to a decline in service quality and increased billing cycles. Rural areas suffer from coverage loss, while urban areas face issues due to the gap between subscriber growth and the development of self-optimizing infrastructure [11].

In cellular networks, call drops occur when a base station is unable to offer available channels to users, whether for a new call or an ongoing one where the mobile station is moving and attempting a handover. Global System for Mobile (GSM) Communication is widely used due to the vital role of communication in daily life. Various issues can cause call disconnections, and delays in identifying the exact cause can lead to poor network service quality, damaging the reputation of the network provider. According to the GSM Association, high demand for GSM communication can lead to network congestion, resulting in call drops. Users expect their network providers to maximize service coverage, optimize network usage, minimize congestion, and balance traffic effectively across different frequencies [16]. Call Drop Rate is a vital connection-level Quality of Service (QoS) metric that indicates the probability of a call being dropped due to a handoff failure. The main goal of most admission control strategies is to keep the CDR within a specified target while maximizing bandwidth utilization and minimizing the blocking rates for new calls within the system [17].

2.3. MVO Algorithm

The Big Bang theory proposes that the universe originated from a tremendous explosion, marking the beginning of all matter and energy. In contrast, the Multiverse theory proposes that multiple Big Bangs have given rise to multiple universes and each universe is governed by its own set of physical laws. This theory incorporates concepts such as white holes (potentially connected to the Big Bang), black holes (which absorb everything), and wormholes (hypothetical tunnels enabling instant travel within or between universes). Universes expand due to eternal inflation, and the inflation rate influences the development of cosmic structures and the conditions necessary for life. According to a cyclic model, these universes interact and stabilize through such phenomena.

The MVO algorithm conducts its search in two fundamental stages: exploration and exploitation. Exploration is carried out through the concepts of white holes and black holes, while exploitation is achieved using wormholes. Each and every solution is considered as a universe with its variables as objects, and the inflation rate of every result is proportional to its fitness function. Generally, the term "iteration" is used to approximate the result, but in the MVO algorithm, the term "time" is used to align with cosmological terminology.

The following instructions are applied during the optimization process:

1. Huge inflation rates increase the possibility of white holes.
2. Huge inflation rates tone down the probability of black holes.
3. Universes that have high inflation rates release objects through white holes.
4. Universes with comparatively low inflation rates pull objects into black holes.
5. Through wormholes, objects can move toward the best possible universe, independent of the inflation rate.

The selection of universes with white holes and black holes is carried out using a roulette wheel mechanism. Through this process, a white or black tunnel is formed, allowing objects to transfer from white holes (representing higher inflation rates) to black holes (representing lower inflation rates). This exchange strategy helps enhance the overall inflation rate of universes across successive iterations [18].

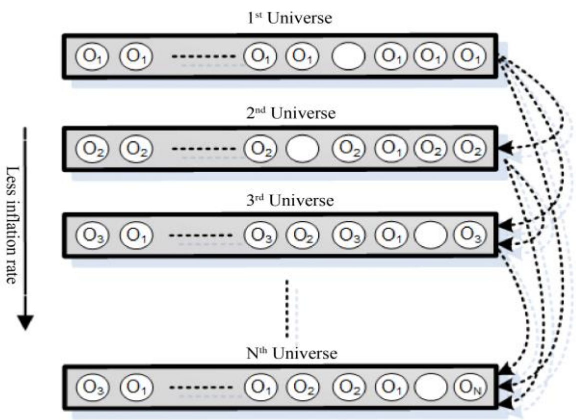

Fig. 2 Process of MVO algorithm [18]

Assume that,

$$U = \begin{bmatrix} x_1^1 & x_1^2 \cdots & x_1^d \\ x_2^1 & x_2^2 \dots & x_2^d \\ \vdots & \vdots & \vdots \\ x_n^1 & x_n^2 \dots & x_n^d \end{bmatrix} \quad (1)$$

Where *d* represents the number of parameters and *n* is the number of universes.

$$x_i^j = \begin{cases} x_k^j & r1 < NI(Ui) \\ x_i^j & r1 \geq NI(Ui) \end{cases} \quad (2)$$

Where x_i^j represents the jth parameter of the ith universe, *Ui* represents the *i*th universe, *NI*(*Ui*) is the normalized inflation rate of the *i*th universe $r1$ is a random number in [0,1], and x_k^j indicates the *j*th parameter of the *k*th universe. A lower inflation rate increases the chance of objects being transferred through white or black hole tunnels. For optimization problems focused on maximization, the normalized inflation rate (*NI*) should be positive. This approach promotes exploration by forcing universes to exchange objects and experience sudden shifts. To ensure diversity and enable exploitation, each universe is equipped with wormholes for random object transfers. Wormholes enable independent random modifications to the objects within universes, regardless of their inflation rates. To enhance local adjustments and optimize inflation rates, wormhole tunnels are continually established between a universe and the best one found so far. The process is described as follows:

$$x_i^j = \begin{cases} \begin{cases} X_j + TDR \times \left((ub_j - lb_j) \times r4 + lb_j\right) & r3 < 0.5 \\ X_i - TDR \times \left((ub_j - lb_j) \times r4 + lb_j\right) & r3 \geq 0.5 \end{cases} & r2 < WEP \\ x_i^j & r2 \geq WEP \end{cases} \quad (3)$$

Where, X_j is the jth parameter of the best universe formed, TDR is a coefficient, Wormhole Existence Probability (WEP) is another coefficient, lb_j and ub_j are the lower and upper boundaries of the j^{th} variable, x_i^j represents j^{th} parameter of i^{th} universe and *r2*, *r3*, and *r4* are random numbers in [0, 1].

WEP defines the likelihood of a wormhole's presence in universes and should increase linearly to enhance exploitation during optimization. Traveling Distance Rate (TDR), on the other hand, controls the distance that an object can be teleported by a wormhole around the best universe found, and it should also increase to improve local search precision.

$$WEP = \min + l \times \left(\frac{max - min}{L}\right) \quad (4)$$

Here, "min" and "max" denote the minimum and maximum values, respectively, while "l" stands for the current iteration, and "L" represents the total number of iterations.

3. MVO Approach Based Proposed Model

The flowchart of the proposed model, as shown in Figure 3, provides a foundation for handover mechanisms and call drop ratios, with the optimization approach.

3.1. For Handover Margin

When the signal intensity at the target node is greater than the signal strength at the source node, the user's equipment switches from the source node to the target node. Only in the event that the destination node's signal is stronger and the source node's signal falls below a predetermined threshold level is the handover triggered.

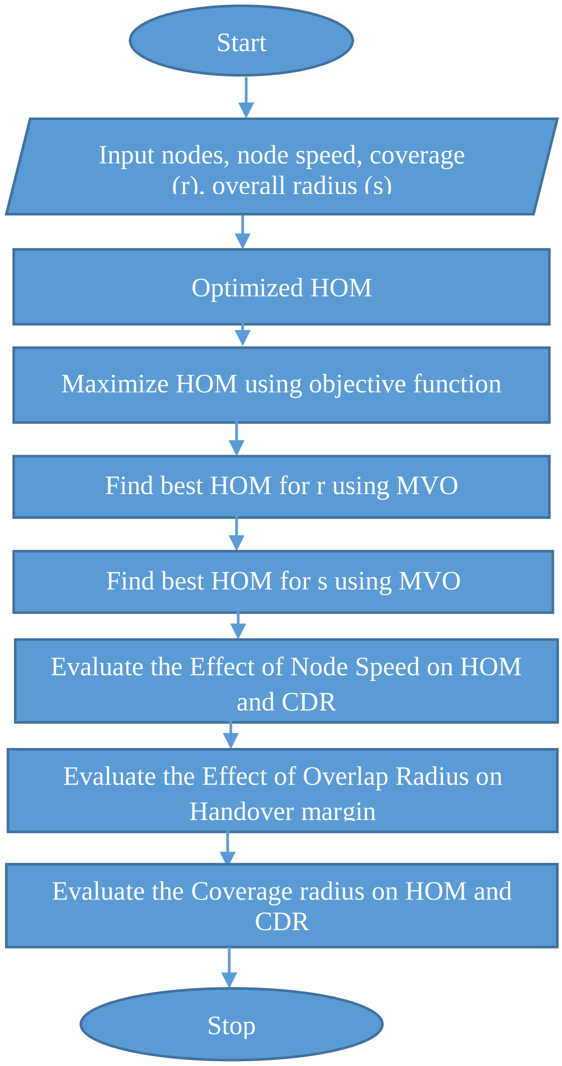

Fig. 3 Flowchart of the proposed model

Setting the threshold too high means the source node signal must fall significantly before a handover is triggered. On the other hand, a very low threshold might cause the user equipment to switch to the target node prematurely, even if the source node continues to provide a strong signal, potentially leading to a weaker communication link and increased risk of call drops [19].

HOM equation is likely designed to determine the point at which a network device, such as a sensor node, should switch its connection from one communication link (or base station) to another as it moves through the underwater environment.

$$HOM = K \log \left\lfloor \frac{r - v_t t}{r + v_t t - s} \right\rfloor \quad (5)$$

Where K is a constant that scales the logarithmic function.could be determined based on network design parameters of the UWSN system. r is the coverage radius between the underwater node and the base station or reference node. v_t is the speed at which the underwater sensor node is moving through the underwater environment. This could be influenced by underwater currents, vehicle movement, or other factors. t is the time elapsed since the node began to move. It helps to calculate how far the node has moved over time. s is the overlap radius of two nodes. This represents the distance or threshold at which the handover should ideally occur. This could be a predefined value based on network design, signal strength requirements, or the distance at which the current link's quality degrades.

The following algorithm gives information about the optimization of handover margin using the MVO algorithm:

Algorithm 1: Handover Margin Optimization

1. Input: num_nodes, node_speed (v), coverage (r), overlap_radius (s), t, K, max_iter, N, lb, ub
2. Output: Optimized HOM
3. Objective Function: Maximize HOM

$$\mathbf{HOM = K \log \left\lfloor \frac{r - v_t t}{r + v_t t - s} \right\rfloor}$$

4. Define parameters and initialize the HOM array
5. Case 1: For each r from 1000 to 2000

   Calculate HOM using the objective function

6. Case 2: For each s from 100 to 500

   Calculate HOM.

7. Case 3: For each vi from 0 to 100
   Calculate HOM.
8. Perform the MVO algorithm up to max_iter
9. Update best_ universes with exploration and exploitation
10. Calculate HOM_final using optimized values

3.2. For Call Drop Ratio

The scenario involving node speed can lead to call drops due to radio link failure, which might occur either from initiating a handover too early or too late. This is not the same as handover failure since a call may still drop in spite of handover failure, particularly if there is a lot of traffic on the target node. Under such circumstances, the handover may take place at the appropriate time and place with adaptive modifications to the HOM and Time-To-Trigger (TTT) to accommodate users with varying speeds. Mathematically, the representation of call drop rate as a function of user speed is possible [19].

Various factors such as the pattern of node mobility, characteristics of the underwater channel, network protocols, energy constraints and handoff management techniques affect the CDR in UWSNs. To ensure the reliable data transmission, efficient communication, and successful deployment of UWSNs in different applications like environmental monitoring, underwater exploration and marine research, maintenance of low CDR is essential.

The mobility model and some applied assumptions provide the formula for the CDR in UWSNs. The formula, which is derived from the random mobility model, is frequently used. This model assumes that the node mobility will be random and independent within the network area. The CDR equation for this model is as follows:

$$P_c = \frac{1 - e^{-\alpha}[1 - \alpha]}{2\alpha} - \frac{\alpha}{2}\int_{\alpha}^{\infty} \frac{e^{-x}}{x}\, dx \quad (6)$$

Where α is a parameter related to the node mobility rate, defined as:

$$\alpha = \frac{2 * r}{v * t_m} \quad (7)$$

r is the coverage radius between the underwater node. v is the average node speed and t_m refers to the time (t) associated with the mobility of the node. The term `$\exp^{(-\alpha)}$` represents the probability that a node remains within the transmission range during the call duration (t). The equation `(1 - α)` represents the probability that a node moves out of the transmission range during the call duration.

The product `$(1 - e^{-\alpha}[1 - \alpha])$` gives the probability that a node moves out of the transmission range at least once during the call duration. The factor `(1 / $2\alpha$ )` accounts for the average number of boundary crossings (entering or leaving the transmission range) during the call duration, assuming a random walk mobility model.

The derivation of this equation is based on different assumptions as nodes move according to the random walk mobility model within the UWSN area. Call drops occur when a node moves out of the transmission range of its communication node during an ongoing call. The probability of a node remaining within the transmission range during the call duration follows an exponential distribution. The average number of boundary crossings (entering or leaving the transmission range) during the call duration is proportional to the node mobility rate.

The following algorithm gives the information about the MVO-based approach to optimize the call drop ratio:

Algorithm 2: Call Drop Ratio Optimization
1. Input: num_nodes, r, s, t, Vi_values, max_iter, N, lb, ub 2. Output: Optimized CDR 3. Objective Function: Minimize CDR $$P_c = \frac{1-e^{-\alpha}[1-\alpha]}{2\alpha} - \frac{\alpha}{2}\int_{\alpha}^{\infty}\frac{e^{-x}}{x}\,dx$$ 4. Define parameters and initialize CDR Array 5. Case 1: For each Vi in Vi_values Calculate alpha and CDR 6. Case 2: For each r from 1000 to 2000 Calculate alpha and CDR 7. Run MVO algorithm: Initialize fitness for each universe 8. For each iteration: Find the best and worst universes Update universe positions Apply boundaries and evaluate fitness 9. Get optimized best_CDR value for the network parameters

4. Result

The results section provides a detailed examination of the effects of various simulation parameters on two key performance metrics, HOM and CDR in UWSNs. The simulation is conducted over an area of 1 km x 1 km using MATLAB, with key parameters being the node speed, overlap radius, handover time, and coverage radius. These parameters are varied (as shown in Table 1) within specific ranges to study their impact on the HOM and CDR.

Table 1. Simulation parameters

Parameters	Values
Max. Universes (N)	100
Node Speed (v_i)	0-100 m/s
Overlap Radius (s)	100m-500 m
Handover Time (t)	1 sec -2sec
Coverage Radius (r)	1000 m-2000m

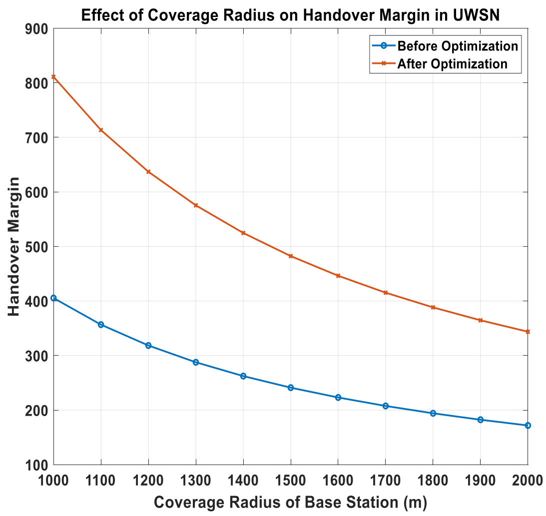

Fig. 4 Effect of coverage radius on handover margin

Figure 4 presents the impact of coverage radius on the HOM in UWSNs. The optimized scenario consistently shows a higher handover margin compared to the non-optimized scenario across all coverage radii. At a coverage radius of 1000 meters, the optimized HOM is approximately 800, whereas the non-optimized HOM is about 400. As the coverage radius increases to 2000 meters, the optimized HOM decreases to around 400, while the non-optimized HOM drops to about 150. MVO optimization approach seems to scale better with increasing coverage radius, maintaining a higher HOM even as the radius grows. UWSNs face challenges like signal attenuation, mobility, multipath propagation, high latency, and underwater constraints. The optimized approach considers these different underwater factors when setting the HOM. This trend highlights the optimization's effectiveness in maintaining higher handover margins, thereby improving the network's robustness and reliability.

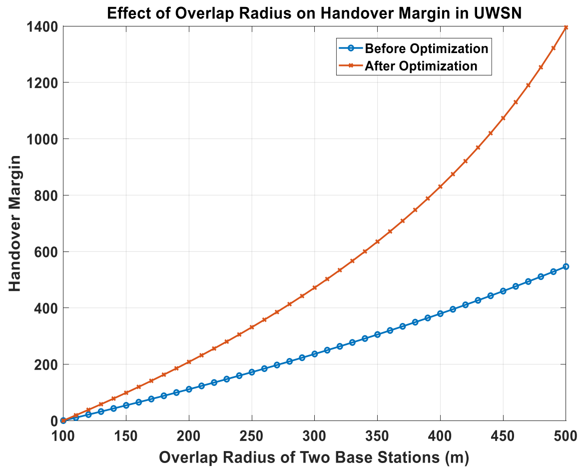

Fig. 5 Effect of overlap radius on handover margin

Figure 5 shows the effect of the overlap radius on the handover margin in UWSNs. The optimized scenario significantly outperforms the non-optimized scenario across all overlap radii. At an overlap radius of 100 meters, the optimized HOM is around 200, while the non-optimized HOM is just above 0. As the overlap radius increases to 500 meters, the optimized HOM rises sharply to approximately 1400, whereas the non-optimized HOM increases to about 600. With larger overlap radii, there is more time and space for making handover decisions. The optimization technique likely incorporates mechanisms that enable better prediction and coordination of handovers, reducing interruptions and improving connectivity. This leads to higher HOM, as the optimized scenario utilizes the additional data to make more intelligent, well-timed handover choices, enhancing overall network performance.

The relationship between node speed and handover margin is depicted in Figure 6. Before optimization, the HOM decreases linearly from 300 at 0 m/s to 150 at 100 m/s. After optimization, the HOM starts higher at approximately 450 and decreases to about 250 at 100 m/s. The MVO optimization algorithm likely involves dynamic adjustment of handover thresholds based on node speed, ensuring that HOMs remain as high as possible without compromising network stability. The fact that the optimized scenario maintains higher HOM values across all speeds shows its ability to handle mobility more efficiently, minimizing the risk of dropped connections or degraded performance due to rapid node movement. The gradual decrease in HOM as speed increases in both scenarios reflects the challenge of mobility, but the slower rate of decline in the optimized scenario indicates that the algorithm effectively mitigates the negative impact of higher speeds on network performance.

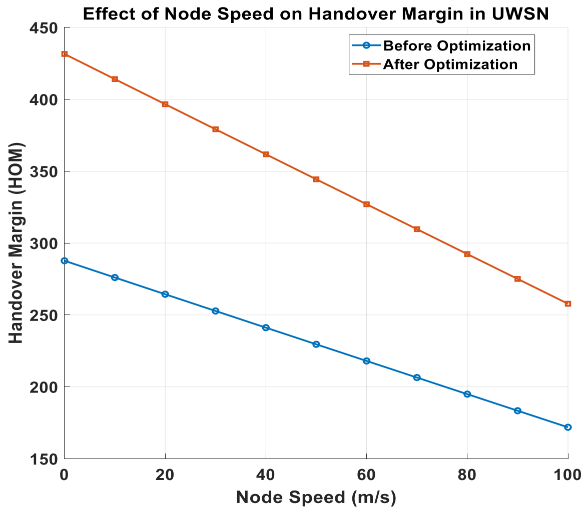

Fig. 6 Effect of node speed on handover margin

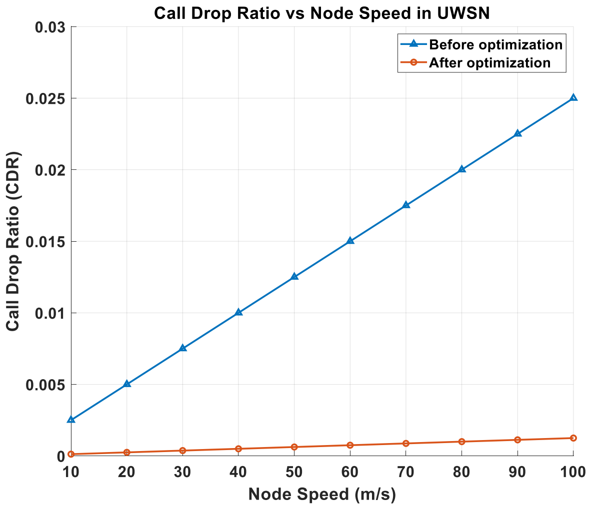

Fig. 7 Effect of node speed on call drop ratio

The comparison between the optimized and non-optimized CDR as a function of node speed in UWSNs is illustrated in Figure 7. The data demonstrates a significant improvement in the call drop ratio when optimization is applied. The CDR increases linearly with node speed for the non-optimized case, reaching approximately 0.025 at a node speed of 100 m/s. In contrast, the optimized case maintains a near-constant CDR close to zero across all node speeds. This indicates that the MVO optimization technique has potential for supporting more demanding underwater applications that require consistent connectivity.

The multi-universe search process prevents the algorithm from getting stuck in local optima, allowing it to find globally optimal solutions for minimizing CDR, even under varying speed conditions. This ensures that CDR remains low across a wide range of node speeds.

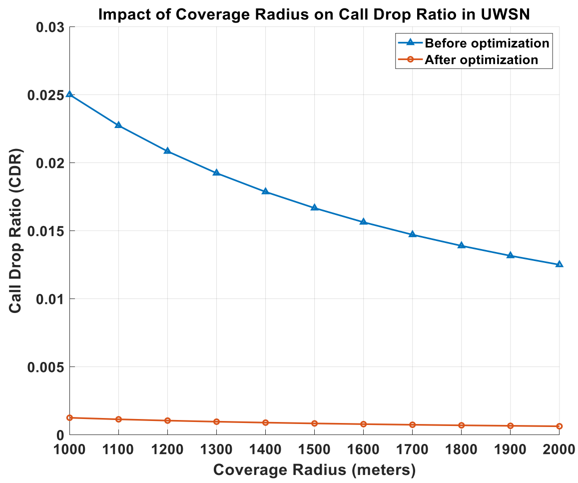

Fig. 8 Effect of coverage radius on call drop ratio

Figure 8 illustrates the impact of coverage radius on the CDR in UWSNs. The data shows a significant reduction in CDR when optimization is applied. For the non-optimized case, the CDR starts at approximately 0.025 for a coverage radius of 1000 meters and decreases gradually to around 0.013 at 2000 meters. The optimized scenario maintains a near-zero CDR across all coverage radii. MVO's multi-universe approach likely makes it more robust against variations in underwater conditions that may occur across different coverage radii, thus ensuring more reliable communication within the network.

The Table 2 below summarizes the comparison between optimized and non-optimized methods using the MVO algorithm for Handover Margin and Call Drop Ratio.

Table 2. Comparison criteria

Comparison Criteria	Optimized (with MVO)	Non-Optimized
Effect of Node Speed on Handover Margin	Handover margin is dynamically adjusted with MVO, maintaining efficient handover as node speed varies.	Static handover margin, leading to possible handover failures or unnecessary handovers at higher node speeds.
Effect of coverage radius on Handover Margin	MVO seems to scale better when sustaining a higher HOM even as the radius increases.	Non-optimized scenario consistently shows a lower handover margin.

Effect of Overlapping Radius on Handover Margin	As the overlap radius increases, HOM rises as the optimized scenario utilizes the well-timed handover choices.	The handover margin is continuously lower in the non-optimized case.
Effect of Node Speed on Call Drop Ratio	Lower call drop ratio at varying node speeds due to optimized handover margin adjustment, resulting in smoother transitions.	Higher call drop ratio with increased node speeds, as the handover margin is not adjusted for optimal connectivity.
Effect of Coverage Radius on Call Drop Ratio	Reduced call drop ratio within varying coverage radius, as MVO adapts the handover margin to maintain connectivity.	Higher call drop ratio in areas with inconsistent coverage, as fixed handover margin does not adjust for coverage radius changes.

5. Conclusion

This study has explored the impact of different parameters on handover margin and call drop ratio performance in UWSNs. We have used the MVO optimization technique, which significantly enhances the underwater networks by improving HOM and CDR. The optimized HOM is consistently higher than the non-optimized, demonstrating better scalability with coverage and overlap radii, and handling high node speeds more effectively. As the results show, at a high node speed of 100 m/s, the optimized parameters have decreased the CDR from 0.025 to 0.001, resulting in approximately a 96% reduction in the call drop rate. In contrast, at the maximum coverage radius of 2000 meters, the reduction is 92.30% due to optimization. This optimization approach can potentially enhance various applications of UWSNs.

Future work could explore the application of this optimization technique to other performance metrics in UWSNs, as well as investigate its effectiveness in different underwater environments and network configurations. Additionally, comparative studies with other optimization algorithms could further validate the efficacy of the MVO approach in UWSNs optimization.

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