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# Resource allocation optimization for mitigating multi-jammer in underwater sensor network

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**ABSTRACT**

Wireless underwater sensor networks (UWSNs) are used for coastal area monitoring and military monitoring applications, such as tsunami prevention and target tracking. In UWSNs, jamming is considered to be a serious problem where the intruder affects the lifetime of sensor motes and impacts the performance of the packet transmission. This paper considers that the jammer device is capable of reducing battery life and preventing the trustworthy UWSN mote from communication. Considering the presence of multiple jammers, the existing resource utilization model is not effective. This work presents an efficient resource allocation design to mitigate multiple jammers in UWSNs to overcome research problems. The resource allocation (ERA) model adopts a cross-layer design and can interact in a cooperative manner using direct and hop-based communication to maximize the quality of resource use. Compared to existing resource allocation methodologies, considering the presence of multiple jammer motes, the ERA achieves a much better detection rate, resource utilization, packet drop, and energy efficiency performance.



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## 1. INTRODUCTION

Extreme attenuation of underwater scenarios makes Wireless communication very challenging and it is possible only with microwave bands of short-range broadband channels [1], [2]. Acoustic waves are used in underwater communication environment for increasing the communication range. The presence of noise underwater such as wind, shipping activities, marine life affect these signals highly. Narrow band, propagation delay, multipath fading, reflection, and also effect these waves. Despite such complex propagation scenarios, various industries and military applications use the underwater wireless sensor network (UWSN). In addition, it is also used for tsunami and soil erosion monitoring. It is important to provide an effective safety mechanism in view of these applications as it is used for environment and surveillance monitoring. For the compromised system, which already faces the challenges of a hostile environment, a denial of service (DoS) or jamming attack can have catastrophic magnitudes [3], [4].

Jamming is clearly defined as the specific interference induced by the malicious nodes in the wireless network by reducing the receiver side's signal-to-noise ratio by transmitting interfering wireless signals; furthermore, it is observed that jamming differs from interference or regular noise as it causes the degradation in network performance. At various levels, jamming is induced from hampering communication to altering information in the legitimate communication given. In addition, to understand the underwater-WSN attack or to prevent jamming for efficient communication. There are various types of jammer, such as reactive jammer, proactive jammer, hybrid smart jammer, and specific jammer function; it is also very important to know the types of jammer to achieve the optimal jammer placement. Therefore, through the different researchers, many existing methodologies have been considered and different strategies have been designed to tackle the problem of jamming [5]. In addition, reactive jammers are the type of jamming where jammers remain silent until the sensor device is authentically initialized over the given channel; this is one of the general jamming and widely used; to protect and detect respectively, it requires absolute strong mechanism and efficient mechanism [6], [7].

Extensive surveys show that the existing methodology for resource allocation or channel access presented so far to mitigate the jamming effect is only effective for terrestrial WSN [8]-[10]. In addition, to improve resource utilization, the medium access control (MAC) layer optimization model [5], [11], [12] was carried out. As a result, the [13] routed packet on a pre-selected path is not efficient in a highly dynamic jamming attack environment. In addition, a cooperative communication scheme was presented in [14], [15] to make more efficient use of resources [2], [16]. In addition, [17] showed that cross-layer design was adopted to select hop motes to help enhance the UWSN resource. The main drawback of these models, however, was that they failed to achieve effective use of resources as they avoided spatial re-use. A spatial reuse mechanism was developed in [18] to mitigate near-far node effects [19]-[21], but ignored proper scheduling as well as delay in transmission, thereby increasing the likelihood of a packet collision. In addition, these models are designed to take into account the existence of single jammer scenarios. This paper therefore introduces successful resource allocation (ERA) in UWSN to mitigate multi-jammer adopting cross layer architecture.

The importance of the effective distribution of resources to reduce multi-jammer in UWSN is as follows:

– First, a highly dynamic reactive jamming effect model is presented in this paper.
– The second resource maximization approach proposed considering both direct and hop contact presence.
– The third proposed a bounding model for solving the problem of resource maximization with the existence of multiple users and multiple jammers.
– The outcome of the experiment indicates that the suggested approach decreases packet drops, increases the usage of resources and improves UWSN's energy efficiency.

As follows, the manuscript is structured. The successful resource allocation model for minimizing multiple jammers in the UWSN is discussed in section 2. In section 3, the outcome obtained by ERA over the current resource allocation model is addressed. The work is concluded in the last segment and future job changes are discussed.

## 2. EFFICIENT RESOURCE ALLOCATION DESIGNING FOR UNDERWATER WIRELESS SENSOR NETWORK

The successful resource allocation design for mitigating multi-jammers in UWSN is discussed in this section. First, the cross-layer architecture introduced in our previous work [22], [23] is adopted by this work. Secondly, the existence of several jammers in UWSN addresses the issue of resource maximization. Finally, an ideal method to boost packet transmission and UWSN's energy efficiency is provided.

### 2.1. System model, reactive jamming and cross layer design

Let's assume a UWSN with L reliable underwater motes where these motes can interact with each other [22], [23]. In addition, there are T orthogonal frequency channels that will connect with each other using the underwater motes. In addition, the network shows a variety of jamming motes. To minimize the efficiency of trustworthy motes, these jammer motes have limited power to carry out jamming effects. The power of the jammer motes will influence or jam all of the available channels in UWSN using as (1),

$$j_p = \left(j_p^t\right)_{t\in T}, \tag{1}$$

where j_p^t describes the specified power on certain channel t, which can be described as (2),

$$C^F j_p \leq j_p^{\uparrow}, \tag{2}$$

where C represents an C*|L| vector of 'C', and $j_p^{\uparrow}$ depicts the full power potential of jammer mots for jamming effects in UWSN. The reactive jamming method can therefore be defined using the (3),

$$j_p^t = \frac{V_p^t}{\sum_{t\in T} V_p^t} * j_p^{\uparrow}, \forall t \in T. \tag{3}$$

where the sensed noise and interference level p on channel t are represented by $V_p^t$.

This work takes into account a multihop UWSN communication where the sensor system transmits its packet to the destination cooperatively via intermediate nodes within a communication range close to [22], [23]. The hop motes are picked here at each slot time. UWSN motes that do not conduct any sensing activity at a given slot time are optimally and cooperatively selected as hop motes for other UWSN motes for carry-out transmission. Optimistically, the UWSN mote access range by optimizing the possibility of jammed motes and packet transmission channel access. The contention window parameter of a slotted multichannel carrier-sense multiple access (CSMA) is adjusted to optimize the channel access probability. For keeping collision probability less, in this work the contention window (CW) is kept sufficiently large. Let consider $i_l^t,\ t \in T$ describing the channel sensing probabilities of UWSN mote $l$ on channel $t$ and then the UWSN mote might incur certain delay for carrying out communication for being as an intermediate UWSN mote for neighboring mote due to nonzero probability of node $l$. Thus we have as (4).

$$\sum_{t\in T} i_l^t \leq 1. \tag{4}$$

### 2.2. Effective resource design for multiple jammer mitigation in UWSN

The effective resource allocation architecture for mitigating multi-jammers in UWSN is discussed in this section. As the policy space of a trustworthy UWSN mote, this work uses channel accessible probability and can be interpreted as follows (5) and (6),

$$i_l = (i_l^t)_{t\in\tilde{G}} \tag{5}$$

with,

$$\tilde{G} = T \cup \{0\}, \tag{6}$$

where the channel accessing probabilities of channel t are represented by $i_l^t$, and $i_l^0$ represents the probabilities that l does not check for any UWSN channel accessibility. In this case, the model ensures that the limit described in is followed. In (7), (8) and, respectively (9).

$$i_l^t > 0, \forall l \in L, \forall t \in \tilde{G} \tag{7}$$

$$i_l^t \leq 1, \forall l \in L, \forall t \in \tilde{G} \tag{8}$$

$$C^F i_l = 1, \forall l \in L. \tag{9}$$

The size of trustworthy UWSN motes belonging to l∈L can be estimated using the (10),

$$W_l(i, j_p) = \sum_{t\in T} i_l^t \psi_l^t(i, j_p) W_l^t(i, j_p), \tag{10}$$

where $\psi_l^t(i, j_p) W_l^g$ defines UWSN motes l channel accessibility success probabilities, $i_l^t$ defines channel accessibility sensing probabilities, and $W_l^t(i, j_p)$ defines actual channel size available through both communication modes (i.e, direct and though hop) with the presence of jamming effects $j_p$ and channel sensing probabilities i.
The expected traffic is obtained by direct communication using the (11),

$$W_{l,t}^{direct}(j_p) = X \log\left(1 + \nu_{l,t}^{t2v}(j_p)\right), \tag{11}$$

where $X$ represent bandwidth of different frequency channel, and $\nu_{l,t}^{t2v}(j_p)$ is computed as (12),

$$\nu_{l,t}^{t2v}(j_p) = \frac{j_l R_l \cdot (s_l^t)^2}{\left(\delta_{v(l)}^t\right)^2 + j_p R_{pv(l)} \cdot \left(r_{pv(l)}\right)^2} \tag{12}$$

where $j_l$ represents the level of UWSN mote l communication power, $R_l^t$ represents the operating channel environment fading parameter and R l represents the operating channel environment path loss, $\left(\delta_{v(l)}^t\right)^2$ depicts receiver side noise v(l) on specific frequency channel t.

Cooperative hop-based communication can be established in a similar manner to direct communication. Let's take into account that every mote that wants to transmit a packet will have m ∈ L∕l as a hop device with 〖i〗_m^0 probabilities. The cooperative hop motes are therefore created using the (13),

$$W_{l,t}^{coperative}(j_p) = \frac{X}{2} log\left(1 + \min\left(\nu_{lm,t}^{g2h}, \nu_{l,t}^{g2v} + \nu_{ml,t}^{h2v}\right)\right) \tag{13}$$

where $\nu_{lm,t}^{g2h} = \nu_{lm,t}^{g2h}(j_p)$ is the signal-to-noise ratio (SNR) between source motes and cooperative hop motes and $\nu_{ml,t}^{h2v} = \nu_{ml,t}^{h2v}(j_p)$ is the SNR between co-operative hop motes and destination motes. The total expected capacity accessible by UWSN mote l on a specific frequency channel t is therefore obtained using the (14).

$$W_l^t(i, j_p) = \left(\sum_{m \in L/l} W_{l,t}^{coperative}(j_p) + \sum_{m \in L/l} W_{l,t}^{direct}(j_p)\right) \tag{14}$$

There may be several hop motes or paths for each source mote to transmit a packet. This work aims to optimize the objectives of resource utilization that can be represented using the (15),

$$(i, j_p) = \log\left(W_l(i, j_p)\right), \tag{15}$$

and to optimize the resource usage of sensor devices without affecting other valid sensor devices, the proposed quality specifier parameter can be expressed as (16).

$$\begin{aligned} &Given: \ j_p \\ &\underset{i \in (0,1)^{|L|}}{\text{Maximize}}\, E_l(i, j_p) = \sum_{l \in L} E_l(i, j_p) \\ &Subject\ to: (7), (8), (9) \end{aligned} \tag{16}$$

To increase the performance of the methodology of resource allocation, in (17) Constraints are overcome. Let's consider E^* as an optimal global solution problem, and ʋ ∈ [0,1] as the optimal solution predefined. The efficiency specification of the proposed allocation of resources is thus to ensure ʋ-optimal strategy i ensuring ʋ-optimal strategy I as (17),

$$E(i) \geq \upsilon E^*. \tag{17}$$

the ε can be configured here as closer to 1 at the higher overhead of the computation. Let be defined as the global solution's $\mathcal{U}_t$ upper limits and $\mathcal{L}_t$ as the global solution's lower limits with respect to the resource maximization function mentioned in (17). It can then be defined as (18).

$$\mathcal{L}_t \leq E^* \leq \mathcal{U}_t. \tag{18}$$

Then, by optimizing $\mathcal{L}_t$ and $\mathcal{U}_t$, the suggested approach searches iteratively for ε-optimal strategies. This is done to ensure that, until both limits get closer between them as (19),

$$\mathcal{L}_t \geq \upsilon . \mathcal{U}_t. \tag{19}$$

in this way, in the presence of multiple jamming nodes, the proposed successful resource allocation approach achieves superior output than the state-of-the-art model, which is experimentally proven in the next section below.

## 3. SIMULATION RESULTS AND ANALYSIS

This segment discusses the experimental setup and simulation parameter, performance metric used for studying results executed with the aid of allotted aid allocation version over current resource allocation model [18] below the presence of multiple jamming sensor devices. MAcoSim simulator is used for wearing out performance evaluation [24]-[26]. Various sensor mote sizes of 50 and 100 are used to experiment. With a scale of 16 m * 16 m, these motes are randomly placed around UWSN. In addition, the size of the jammer mote varies from 4, 6, and 8 and is located within the 16 m * 16 m area. For a given slot, each jammer will transmit 8 bits of a packet, and each mote will generate UWSN traffic by transmitting 3 bits of packets. To obtain simulated results, 100 iterations are considered and performance achieved is calculated using resource usage, packet drop rate, energy efficiency, and detection rate.

Figure 1 shows the performance of resource use achieved by ERA given the varying size of the jammer mote. It can be seen from the outcome that the total clear-to-send (CTS) packet sent is 129 and 129 while the jammer mote size is 4 and 8. Then, the total request-to-send (RTS) packet sent is 41 and 41 while the jammer mote size is 4 and 8. Similarly, the total packet obtained correctly is 35 and 34 while the jammer mote size is 4 and 8. As a result, it can be seen on average considering that varied jammer mote size 41 RTS packets are sent to a UWSN network from which 35 packets have been successfully received on the receiver side. From this, we can interpret that in UWSN there are 15.85% duplicate packets created by the jammer.

Figure 2 shows packet transmission overall performance accomplished through the proposed ERA model with a presence of multiple jammer sizes of four and 8 keeping UWSN mote kept at 100 and an experiment is performed. From experience, it is noticed that when the mote size of the jammer is 4 and 8 the number of transmitted dispatched packets is 161 and 163, respectively. Then, when the mote size of the Jammer is 4 and 8, the number of the projected beam is 84 and 108, respectively. Then, when the size of the jammer is 4 and 8, the range of received packages is 133 and 135, respectively. Likewise, when the size of the jammer mote is 4 and 8, the number of discarded enclosures is 120 and 124, respectively. From the result, it can be considered that the size of the jammer mote increases the projection of the beam being dropped, and very limited work is performed by current methodologies for comparing performance thinking about the presence of multiple jammers. This, work is the first of its kind to evaluate this type of assessment considering the presence of multiple jammers in UWSN surroundings.

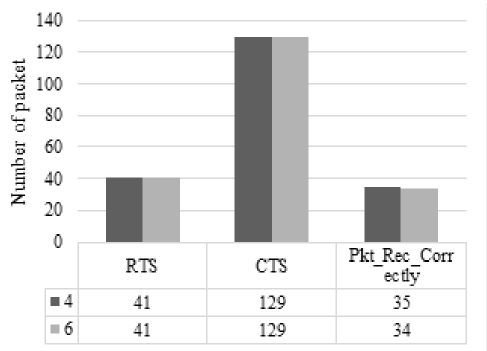


Figure 1. Resource utilization performance considering varied number of jammer device

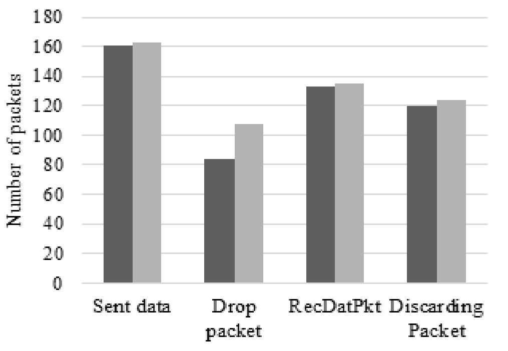


Figure 2. Packet transmission performance considering varied number of jammer device

Figures 3-5 demonstrate the performance of energy efficiency achieved by the proposed ERA with and without the presence of jammer motes considering the varying size of jammer mote, varying size of sensor mote, and varying slot size. The first experiment is performed by varying jammer mote to 4 and 8, maintaining constant slot size and mote size of 5 $\mu s$ and 100, respectively and average energy consumed with and without jammer Mote is noted and illustrated graphically in Figure 3. Out of Figure 3 when compared to ERA without the presence of jammer mote considering varying jammer mote size, an average energy overhead of 10.64% is achieved by ERA with the presence of jammer mote.

The second experiment is carried out by varying mote to 50 and 100, maintaining constant slot size and jammer mote size of 5 $\mu s$ and 8, respectively, and the average energy consumed with and without jammer mote is noted and shown in Figure 4. Out of Figure 4 As compared to ERA without the presence of jammer mote, an average energy overhead of 9.737% is reached by ERA with the presence of jammer mote considering varied mote size. The third experiment is carried out by varying slot sizes to 5 $\mu s$ and 10 $\mu s$, maintaining a constant mote and jammer mote size of 100 and 8 respectively, and the average energy consumed with and without jammer mote is noted and shown in Figure 5. Out of Figure 5 In contrast to ERA without the presence of jammer mote given varying slot size, an average energy overhead of 3.96% is achieved by ERA with the presence of jammer mote.

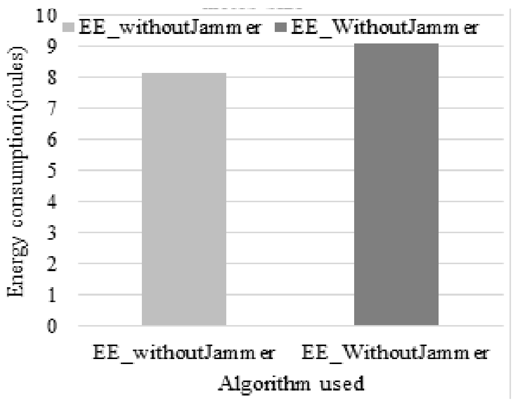


Figure 3. Energy efficiency performance considering varied number of jammer motes

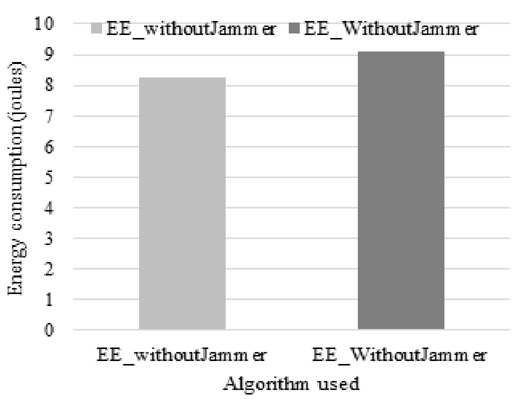


Figure 4. Energy efficiency performance considering varied number of UWSN motes

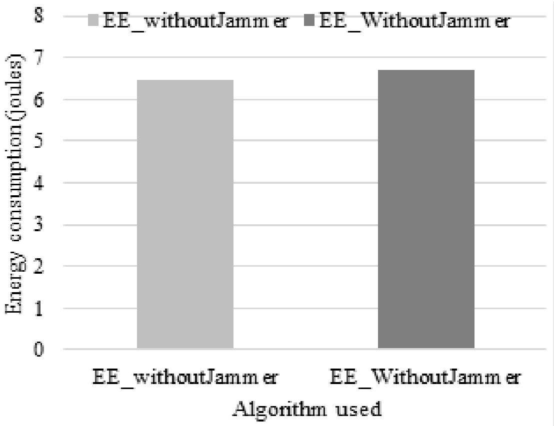


Figure 5. Energy efficiency performance considering varied slot size

The ERA model shows a much higher outcome than current methodologies [18]. Table 1 shows a comparative analysis. Table 1 shows that the proposed ERA model produces a much higher outcome than the existing resource allocation, given the existence of multiple jammers.

Table 1. Performance comparison of DRA with respect to existing resource allocation model [18] under UWSN environment

| | [18] | Proposed ERA |
|---|---|---|
| Drop rate | 33.33%-57.15% | 1.62-6.81% |
| Detection accuracy | - | 90.39% |
| Resource utilization | 90.0% | 95.46% |
| Energy overhead | - | 8.11% |

## 4. CONCLUSION

Under the presence of multiple jammer mote, this work provided an effective resource allocation model for jammed UWSN users. The ERA model will more accurately detect jammer nodes and assign resources to the jammed node in a more optimal resource maximization constraint for fashion meeting. In addition, cooperative cross-layer architecture helped to use resources more effectively by keeping the scale of the contention window higher. The Age model achieves a packet drop rate of 1.62%-6.81% from the results achieved, where current methodologies achieve a drop rate of 33.33%-57.15%. In addition, current methodologies achieve 90% resource utilization when the ERA achieves a 95.46% resource utilization efficiency. The 90.39% detection rate is then achieved by the proposed ERA method. In addition, the suggested ERA induces 8.11% energy overhead considering varying mote, jammer mote, and slot size, which is negligible considering the performance of resource utilization achieved by ERA. In addition, such energy performance evaluation has not been considered in any previous work. The ERA can be very productive from the results obtained when adopted in a highly complex jamming system with multiple jammers. Future work would consider using more heuristic and optimal solutions to further improve UWSN sensor motes for life.

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