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ENGOR: CROSS LAYER ENERGY BALANCING ROUTING PROTOCOL FOR UNDERWATER SENSOR NETWORK

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ABSTRACT

As of late, Underwater Wireless Sensor Networks (UWSNs) have pulled in much exploration consideration from both scholarly world and industry, to investigate the immense submerged climate. Nonetheless, planning network conventions is trying in UWSNs since UWSNs have impossible to miss attributes of huge spread postponement, high mistake rate, low data transfer capacity, and restricted energy. In UWSNs, improving energy proficiency is quite possibly the main issues since the substitution of the batteries of such hubs is pricey because of the brutal submerged climate. In the current writing, scientists zeroed in on the productive administration of submerged sensor organizations and earthly remote mixed media sensor organizations. Be that as it may, within the sight of submerged media remote sensor hubs, the measure of information to be sent increments altogether which weakens the general organization execution. Consequently, there is a need to plan a defer ideal powerful geography control conspire for UWMSNs, while expanding the organization throughput and lifetime. Submerged remote sensor organizations (UWSNs) have been appearing as an encouraging innovation to screen and investigate the seas in lieu of customary undersea wireline instruments. Before long, the information social event of UWSNs is still extremely limited in view of the acoustic channel correspondence characteristics. One strategy to improve the material arrangement in UWSNs is through the arrangement of directing shows considering the eminent characteristics of submerged acoustic correspondence and the significantly remarkable association geography. The unmistakable highlights of Underwater Acoustic Sensor Networks (UW-ASN, for example, high engendering delay, deviated channels, high mistake rates, and restricted transfer speed cause critical issues because of the utilization of the acoustic medium as a technique for correspondence. Consequently, planning a proficient submerged convention that utilizes accessible battery assets and gives unwavering quality in an untrustworthy acoustic climate is a difficult errand. Submerged acoustic sensor organizations (UW-ASNs) have as of late been proposed for investigating submerged assets and social affair logical information from sea-going conditions. UW-ASNs are confronted with various difficulties, for example, high proliferation delay, low transmission capacity, and high energy utilization. In any case, the most outstanding test is maybe how to effectively advance the parcels to the surface sink by considering the energy-obliged sensor gadgets. The deft directing idea may give a powerful answer for the UW-ASNs by the participation of the hand-off hubs to advance the parcels to the surface sink. Portable submerged organizations with acoustic correspondences are faced with a few interesting difficulties, for example, long engendering delays, high transmission power utilization, and hub portability. Specifically, moderate sign spread allows different parcels to simultaneously go in the submerged channel, which should be misused to improve the general throughput.

Opportunistic routing (OR) has emerged as a promising paradigm for the planning of routing protocols for underwater sensor networks (UWSNs). But, Despite its advantages, major drawback is that the immutable transmission priority level of the next-hop forwarding nodes. This characteristic can cause an overuse of a singular node (or a couple of of them), quickly depleting its battery, creating network partitions, shortening the network lifetime, and, consequently, degrading the application's performance. In this report, we shed light on the need for mechanisms for rotating the forwarding priority level between candidate nodes.

We propose a baseline new lightweight energy-aware opportunistic routing (ENGOR) protocol, leading to balanced energy consumption and prolonged UWSN network lifetime. ENGOR rotates the transmission priority level of the forwarding candidate nodes by considering the remaining energy, link reliability, and packet advancement of them.

Simulation results reveal that ENGOR effectively extends the network lifetime as compared with other underwater sensor network opportunistic routing protocols.

INTRODUCTION

Oceans involve more than 66% of the Earth's surface.. These environments, for example, are critically important to human life because of their role in major global production, such as the uptake of carbon dioxide (CO_2) and the regulation of Earth's climate. In this context, the Underwater Wireless Sensor Network (UWSN) [1] has attracted the attention of the scientific and industrial community because of its potential for monitoring and exploring the aquatic environment. UWSN has many possible applications such as monitoring marine life, pollutant content, geological processes on the ocean floor, oil fields, climate, tsunamis and earthquakes; for oceanographic data collection, oceanic and offshore sampling, navigation aid and mine identification, in addition to being used for tactical surveillance applications. Voice communication was considered the only viable method of underwater communication in the USWN. High frequency radio waves are strongly absorbed in water and optical waves are highly dispersed and are limited in short field applications. However, the underwater sound channel produces significant delays and variations from radio frequency (RF) communication, due to the speed of sound in water of approximately 1.5 x 10 ^ 3 m \/ s. (less than 5 orders of magnitude with respect to the speed of light (3 x 10 ^ 8 m \/ s)); temporary path loss and high noise resulting in high bit error rate; very limited bandwidth due to a large drop in audio channel and progressive multipath; shadow zone; and communications power costs are high, around tens of watts. Designing routing protocols for Underwater Sensor Networks (UWSNs) is a difficult task as they are severely affected by unreliable audio links. Traditionally, the UWSN has consisted of underwater sensor buttons, used to sense the environment and events of interest, and surface floats (sinks), responsible for collecting data from magnetic sensors. In these networks, optical and radio frequency communications are generally considered impractical because the optical signal is heavily scattered and the high frequency radio signal is strongly absorbed by the high attenuation. Therefore, the audio channel was considered the only practical technology for underwater wireless communication. However, this technology introduces limited bandwidth capacity, high and variable latency, transient transmission loss and high noise, multi-path dimming, gray area, and high communication energy costs. The aforementioned characteristics of the audio channel make the traditional reactive and active routing protocols designed for wireless networks impossible [1], [2]. In this context, the opportunity routing (OR) model is considered as a possible solution for UWSNs [1], [3] - [6]. Using the OR model, multi-step packet transmission occurs as described below. The send node selects some of its neighboring nodes as the sender of the next step (candidate nodes for the next step), according to certain criteria, such as the expected number of transmissions, the progress of the packets, or latency. The idea is to choose a subset of the most qualified neighbors based on specific criteria. The candidate nodes are then ranked with a different transmit priority, so the low priority node will only forward the packet if the high priority nodes fail. This is to avoid redundancy if a packet is transferred. In OR protocols, the use of multiple nodes that are activated as the next candidate step forward reduces packet loss and therefore packet retransmission. This is because a packet is lost and only needs to be retransmitted if no next step candidate node is received. Therefore, this routing model has proven to be very attractive for loose and power hungry underwater sensor networks.

CHALLENGE

In short, OR routing is beneficial for UWSN because it exploits the broadcast nature of the wireless channel and chooses a set of next hop candidate nodes to help transmit the data packets to the destination. Therefore, using this model, a data packet is retransmitted if no candidate node receives it, reducing the number of retransmissions. This aspect saves energy and improves the use of network bandwidth, reducing the number of possible crashes. In addition, the operating room can cope with the degradation of unreliable underwater audio channels by using a candidate generator set, which will improve package delivery, reducing impact. of temporary path loss and high noise. However, in UWNs, OR is primarily proposed to improve link reliability and increase packet delivery capacity. Less effort has been devoted to solving the power-hungry aspects of underwater sensor arrays [7], although OR saves power due to reduced retransmission of packets. In fact, the OU protocols currently proposed for UWSN lack mechanisms to periodically cycle the transmission priority of these candidate nodes to the next step, in order to achieve balanced power consumption and avoid network partitioning. . The protocols encountered in the document assign the same temporal transmission priority to the candidate nodes. This immutability in the priority of candidates leads to a rapid exhaustion of the battery of central nodes in high demand in the OR solution [8]

CONTRIBUTION

In this report, we designed a new lightweight opportunistic routing protocol for submarine sensor networks, called ENGOR-Energy Conscious Opportunity Routing. The proposed protocol aims to extend the service life of the network. In this case, it is defined as the proportion of active nodes that change over time. When establishing the candidate pool and prioritizing process, ENGOR will consider the remaining power, the progress of each neighbor (packet advancement) and the reliability of the link to its neighbors. The idea is to balance the power consumption between adjacent nodes in the forward node by rotating the priority of adjacent nodes during the network running time. Therefore, you can improve application performance and network life by avoiding network partitions. The simulation results show that the proposed ENGOR protocol can effectively extend the life of the network, thus surpassing the well-known opportunistic routing protocol proposed for UWSN. The flow of my research is organized as follows. The first part looks at related work, especially DBR and VAPR, which are the two protocols used in our comparison. The second section briefly describes the submarine sensor network architecture and the estimation of the transmission of submarine data packets. Section 5 presents our proposed routing protocol: ENGOR. The fifth part introduces the results of ENGOR simulation and the other two protocols. Finally, Section VI introduces our conclusions and future work.

LITERATURE REVIEW

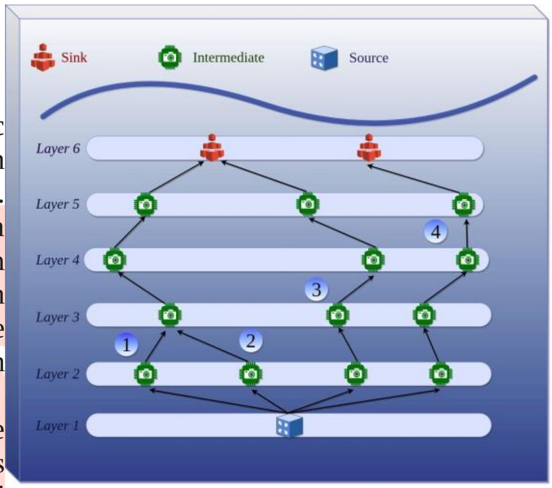
Opportunity routing has been proposed for UWSN. However, there is no job considering the problem of assigning the same transmission priority to candidate nodes. In Vector-Based Routing (VBF) [4], data packets are routed along a virtual pipe with a predetermined radius. The virtual pipeline is formed by a vector transmitted from the source and destination node positions on the sea surface. A node, upon receiving a packet, transmits it if its distance to the transmission vector is below a predetermined threshold. To avoid unnecessary transmission, node transmission takes precedence over the packet holding time, which is calculated locally based on its desired coefficients. The desired coefficient of each node is based on its projection on the route vector. The closer the node is to the routing vector, the greater its desired coefficient and the lower its packet retention time.

- Yan et al. [3] proposes the DBR (Depth Based Routing) protocol, where routing decisions are made based on node depth information. During each jump, the packet is eagerly transported to the surface of the sea, to be received for a certain number of sound buoys. During the transition, the nodes closest to the surface become the qualified nodes to transmit the packet. The candidate transmission coordination is given by a priority based on the timer, which is determined from the difference between the depth of the sender and the candidate node (progress). The greater the difference in depth (the package facing the sea), the shorter the retention time. The candidate receiving a packet from a node with a higher priority will prevent transmission of the packet, if scheduled. The main limitation of DBR is the hidden terminal problem. Since the candidates are determined based solely on the progress of neighboring nodes, there is no guarantee that all selected nodes will hear transmission from each node. In addition, there is no mechanism to notify low priority nodes of a successful transmission because a high priority node is used to avoid a hidden terminal issue.
- HydroCast [1] and VAPR [5] are two opportunity routing protocols on which information-based transmission decisions are made. Both use a similar method of conjecture to make the selection and prioritization of the set of candidates. The difference is that the VAPR uses directional beacons to identify eligible candidates to avoid max local problems, while HydroCast greedily chooses them as in the DBR. At each jump, the neighboring nodes which lead to a positive progression of the sea are grouped according to their priority and their distance from each other, to prevent the terminal problem from being hidden. Each node's priority, represented by its Normalized Advance (NADV), is determined from the node's process multiplied by the probability of successfully receiving the packet. The cluster with the highest expected packet advance level (EPA) is selected as the candidate pool. The priority of transmission of packets between candidates is provided by a function based on a linear timer so that the low priority nodes retain the packet while it does not reach the priority node. Therefore, the node will stop its transmission if it receives a packet from a high priority node. Otherwise, it forwards the packet after the retention time.
- Xie et al. proposed VBF routing protocol. In VBF, data packets are routed along a virtual "routing pipeline" with a predetermined radius, calculated from the positions of the sender and destination nodes. When a node receives a packet, it checks its distance from the transfer vector and continues to forward the packet if the distance is less than the preset threshold or discard it. If the network density is high, many nodes participate in the transfer process. This ensures that there are redundant paths for data transmission, improving packet transmission rates. However, it also increases the network's energy consumption. To deal with this drawback, the authors have proposed a self-adaptive algorithm. In this algorithm, each node computes its desired coefficients to measure a node's packet transmission ability. This element is given as a function of the distance between the current node and the forward node, the node's projection on the routing vector, and the angle between the vectors from the forwarder to the destination and from the forwarder to the current node. If the desired coefficient is less than a specified threshold, the node will schedule the packet transmission according to its priority. Lee et al. Hydrocast's proposed routing protocol also exploits the pressure level (depth) information of the nodes to route packets to sound buoys (wells) above sea surface. Hydrocast also uses an opportunity routing model where the priority of the next hop is given by the trade-off between the packet's progress to the surface and the cost of the link to reach the neighboring node. . To deal with redundant transmissions, the authors proposed a greedy heuristic method to define a group of next-stage forwarders without hidden terminal issues. When a node determines that it is in an empty communication area, it searches for a node with a depth less than its depth by flooding the control and explicitly maintaining a path to the node.
- O\u2019Rourke et al. propose a multimodal communication approach. In the proposed approach, a sensor node equipped with an audio communication modem, a surface-level radio frequency communication modem, and a depth correction system, calculates the power costs and latency. of the network. Balanced data is based on the amount of data to be sent and the cost of area; then the sensor node will decide which technology to use to send

the data. When a decision button appears, nodes that form radio links to the destination will be notified by audio communication with the surface. The authors proposed and evaluated algorithms to determine the set of surface nodes. The downside of this approach is that all nodes must have both an audio and RF transmission modem. Additionally, for the typical deepest surveillance application scenario, the multimodal communication approach can lead to high end-to-end latency due to the time required to move sensor nodes to the surface of the device. the sea to transmit the collected data.

Vapor Pressure Sensitive Routing (VAPR) uses depth information from nodes to transfer data packets to the sea surface. VAPR is a geographic and opportunity routing protocol in which the stage relay next is configured to continue the specified packet forwarding from the greedy pressure policy. In the VAPR, each node detects empty nodes from the accessibility information of the sound buoy broadcast in the network by periodic signaling. Each node uses this information to build a directed path (up or down) to a surface sound buoy. The next set of step transitions are selected in the adjacent transition direction, that is, the directions whose transition direction matches the current transition direction (up or down).

Unlike all other OR routing protocols, we offer the ENGOR protocol, which rotates the transmission priority of the candidate nodes to achieve a balanced power consumption. ENGOR takes into account energy, link reliability and packet progress of eligible neighbors to determine the transfer candidate nodes and their transmission priority, in order to achieve Balanced energy consumption and extended network life.



The ENGOR protocol

In this section, we describe in details the proposed opportunistic routing protocol. We highlight how ENGOR rotates the transmission priority level of the nodes to achieve a balanced energy consumption. Similar to most of OR protocols, ENGOR relays on two main procedures: candidate set selection and candidates' transmission prioritization. Both techniques will be presented in the following. Such as any geographic routing protocol, ENGOR suffers from the communication void region problem. This problem has been extensively studied in [19] and it is not handled in this report. In this work, we deal with the energy efficiency of UWSNs since it is a central aspect of UWSNs [20]. Existing OR protocols in UWSNs assign the same priority level to the candidates. The non- rotation of the transmission priority level is critical in non-mobile UWSN architectures used in long-term monitoring applications as it may lead to an overuse of some nodes, unbalanced energy consumption and, consequently, network partitions and short network lifetime.

- CANDIDATE SET SELECTION PROCEDURE

ENGOR takes into account link reliability, remaining power, and packet progress from neighboring nodes in selecting the next hop handover candidate set. ENGOR relies on the following three main steps to create this set. 1. Periodic signaling: Each submarine sensor node transmits a signaling packet periodically. The beacon packet contains the sender's ID, remaining power, and in-depth location information. Additionally, by listening to the beacon transmission, a node can estimate the pairwise distance to the sender from received signal strength indicator (RSSI) or time of arrival (ToA) techniques, such as 'used by the algorithms for locating the nodes of underwater sensors [21]. Each time a node receives a tag, it updates its neighbor table. 2. Selection of candidate nodes: The procedure for selecting the candidate transmission set of the following ENGOR step is given in algorithm 1. Let us call the sensor node whose data packet is sent and Ni its neighbor table . The node calculates the ability of its neighbors to select the most suitable nodes as candidates for transfer (lines 2 to 7). In doing so, a neighbor is only considered a candidate node if it advances the packet to the surface sound buoys (lines 3 to 6). The packet increment of a neighbor j is calculated as the difference between the depth of the current sending node and j is Pj = depth (i) - depth (j). Next, the confidence of neighbor j is calculated (line 5). We use link reliability, packet progress, and residual energy to determine the capacity of a neighboring node. This counts in row 5 as:

$$F_j = P_j \times p(d_j, m) \times \left(\frac{E^j_{\text{rem}}}{E^j_{\text{init}}} \right), \qquad (8)$$

where Pj > 0 is the packet advancement of the neighbor j; p(dj, m) is the delivery probability of a data packet of m transmitted from node to node j; Ej is the remaining energy of j; and E nit is the initial value of energy of j.

Algorithm 1 Next-hop forwarding candidate set selection

1: ▷ i: a node having a data packet to be sent.
2: **for** $j \in N_i$ **do**
3:     **if** $P_j > 0$ **then**
4:         $F.node \leftarrow$ j
5:         $F.fitness \leftarrow fitness(P_j,\ p(d_j, m),\ E^j_{rem},\ E^j_{init})$
6:     **end if**
7: **end for**
8: sort($F.fitness$, '$descend$')
9: $P_d \leftarrow 0;\ \Gamma \leftarrow \emptyset$
10: $priority \leftarrow 1$
11: **while** $P_d < \gamma$ **do**
12:     $\Gamma \leftarrow \Gamma \cup \{F(priority).node\}$
13:     $P_d \leftarrow$ update()
14:     **incr** priority
15: **end while**
16: **return** Γ

The nodes enabled to be candidates are sorted according to their fitness value(Line 8). Finally, the set of candidate nodes is determined from the potential candidate nodes. The number of nodes in the candidate set is critical. A small candidate set may result in low link reliability. Conversely, a large candidate set also can be detrimental to the application as it will incur in high delay. In the ENGOR protocol, potential candidate nodes are added to the candidate set until it reaches the desired link reliability γ. These nodes are included according to their fitness value (Lines 11–15). The link reliability of a considered set (Line 13) is determined as:

$$P_d = 1 - \prod_{j=1}^{|\Gamma|}[1 - p(d_j, m)]. \tag{9}$$

1. Transmission priority level of candidate nodes: It is worth mentioning that ENGOR intrinsically deals with the problem of having the same transmission priority level of the candidates. ENGOR periodically changes the priority of the candidate nodes by considering the residual energy of them, when calculating their fitness value through Eq. 8. Accordingly, the lower the remaining energy of a node, the lower its fitness value, even if it is the best candidate in terms of packet advancement. In this way, a high priority will be assigned to a node having a high level of remaining energy.

2. Data packet transmission: After the above steps, the current send node will broadcast the data packet. In doing so, it includes the identifier of the candidate transmitting nodes and the maximum distance Dmax between itself and the candidate. The node IDs are included in the packet header in their ascending order of priority. The maximum distance between the sender and the candidates is used to coordinate the pool of candidates as described in the next section. As in [1], [5], we use the Bloom filter to reduce the cost required to match the id of candidates [22]. The Bloom filter is a membership test data structure in which false positives can be limited by adjusting the size of the filter. For example, as shown in [23], a filter size of 19 bytes is sufficient to represent 15 items and obtain a false positive rate of less than 1%.

- CANDIDATE TRANSMISSION COORDINATION

Candidate's transmission coordination is one of the most challenging issues in opportunistic routing. The interested reader might refer to [2] for a detailed discussion about techniques, advantages and disadvantages of control-based coordination by means of either acknowledgment or RTC/CTS packet, and timer-based coordination.
ENGOR uses a timer-based coordination to prioritize the candidates' transmissions. In timer-based techniques, a time slot is assigned to each candidate according to their priorities. This approach can be implemented locally, without the use of extra control packets, which is desirable in the underwater acoustic channel environment. Accordingly, each

candidate node holds the data packet, proportionally to its priority, for a certain amount of time (or slots). When this time expires, the candidate node will broadcast the data packet if it does not hear the transmission of the same packet coming from a high priority node. The main drawback of this approach is the high delay that can be experienced by the packet. For instance, if we consider only the progress to determine the priority of the nodes, probably most of the packets will be forwarded by low priority nodes since the link quality to reach the high priority node will be usually low given the long distance between itself and the sender. In this case, the packet will be always delayed given the low priority of the forwarder node.

1. Packet holding time: In a timer-based coordination, a node should wait a proportional time relative to the time required by its high priority predecessor to receive, process and forward the packet, and the transmissions of the high priority node to reach it. Only after not hearing the transmission of the high priority node, a node must forward the packet. To determine the holding time, the candidate set selection mechanism should guarantee that all nodes of the set are neighbors, either knowing their distances and hearing each other or including this information into the data packet. To avoid long preambles in ENGOR, the packet holding time, based on the priority of the nodes, should consider the greatest distance between the sender and the candidates. Thus, upon receiving a data packet, the candidate node holds the packet for a certain time T_h given as:

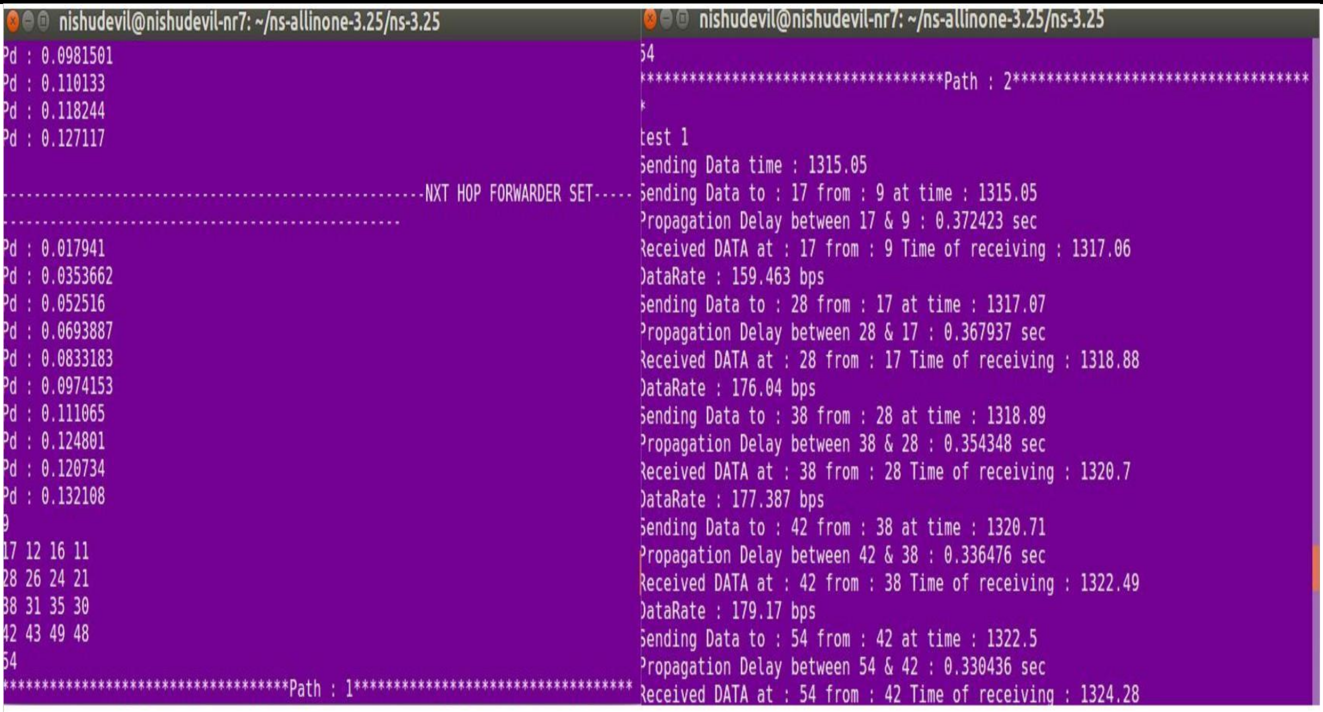
$$T_h(p) = \begin{cases} \dfrac{R - D_{\max}}{v}, \text{ if } p = 1 \\ \dfrac{R + p \times D_{\max}}{v}, \text{ if } p > 1, \end{cases} \tag{10}$$

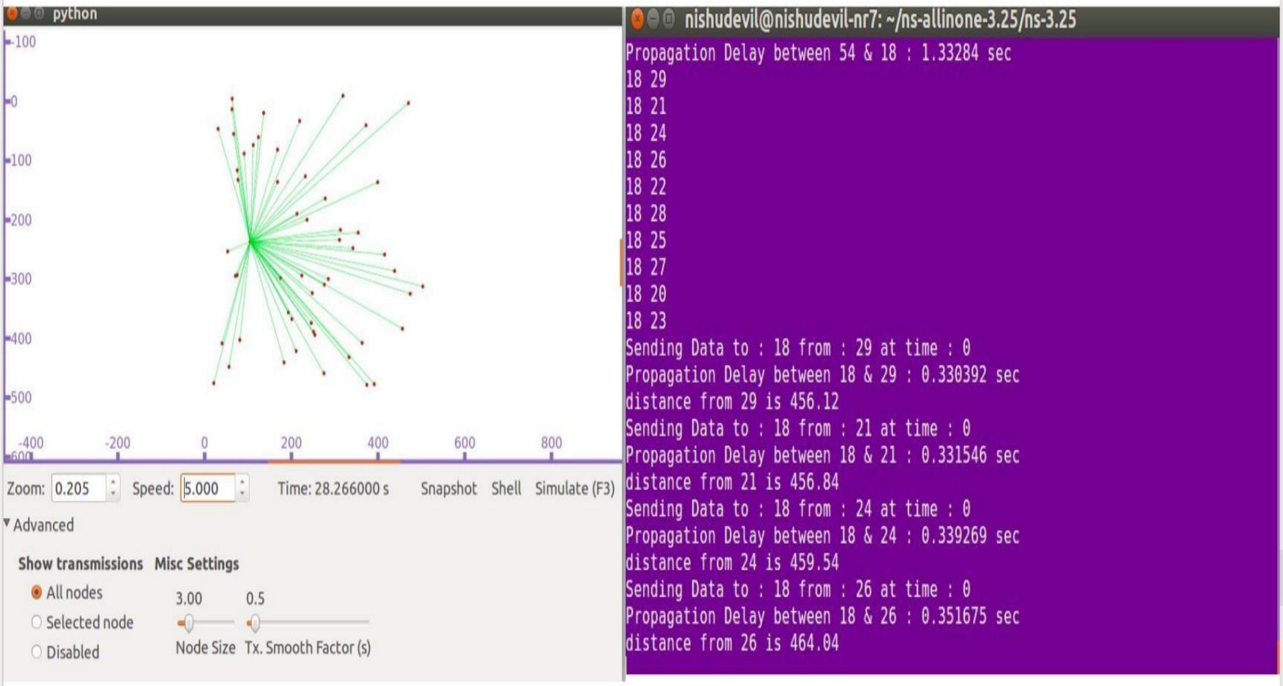
where R is the communication range, D_{max} is the maximum distance between the sender and the candidates, p is the priority of the candidate according to its position in the header of the packet, and v is the sound propagation speed in the water, approximately 1500 m/s.

2. Packet Transmission Suppression*:* The suppression of unnecessary transmissions will directly affect the network performance. In VBF [4] and DBR [3], a low priority node will cancel the transmission of a scheduled packet if the node hears the transmission of the same packet by a high priority node. In both protocols, it is expected to have a high number of redundant packets due to the hidden terminal problem.
   In order to reduce redundant transmissions, HydroCast [1], VAPR [5] and GEDAR [6] try to reduce the hidden terminal problem by choosing nodes distant among themselves. Thus, a candidate node can hear the transmissions of their neighbors. However, this is not enough to avoid the hidden terminal problem given the signal attenuation and the noisy environment.
   ENGOR employs an active suppression mechanism. When a high priority node forwards the packet, all low priority nodes hearing the transmission cancel the packet transmission. Furthermore, the sender node, upon receiving its transmitted packet from the forwarding node, sends a short suppression message containing its id and the id of the transmitted data packet. Thus, nodes that do not hear the transmissions of the high priority node will cancel their transmissions after receiving a suppression message.

RESULTS & IMPLEMENTATION

The performance evaluation was performed by simulations using the NS3 emulator. This is a versatile and high-fidelity underwater sensor network simulator based on the NS-2.30. NS3 simulates attenuation of audio communication, such as audio signal attenuation and packet collisions in underwater environments. Regarding the network topology, we assume that sensor nodes are randomly deployed over the region of interest. To deploy the sound buoy, we divide the surface of the interest in a grid of four squares with sides equal to 500 m. In each square, 16 sound buoys are deployed randomly. We simulate a random 150 and 350 node deployment of an underwater sensor in an area of interest. In the graph, all results correspond to the mean values of 50 trials (seeds) with 95% confidence intervals.





CONCLUSION & FUTURE SCOPE

In this report, we have covered the immutability of the transmission priority of candidate nodes in the opportunity routing protocols. We have proposed a new opportunity routing protocol for underwater sensor networks, taking into account the remaining power, the reliability of the link, and the packet progress to select candidate nodes and prioritize them for transmission download. Our goal is to achieve an energy balance to extend the life of the network, by switching the transmission priority of candidate nodes. In the proposed ENGOR protocol, the transmission priority of the same node may differ over time, to prevent the same node from acting as a relay until its battery is depleted. The simulation results confirm that the proposed protocol can effectively extend the life of the sensor nodes. The results are immediate, the performance of the network has been improved. As part of future work, we intend to study the performance of ENGOR of other important features of the operating room, such as the average number of candidates in the population.

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