

Beckoning Penguin Swarm Optimization Protocol for Routing in Underwater Wireless Sensor Network

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ABSTRACT

Underwater Wireless Sensor Network (UWSN) plays a significant role in the communication world where it still uses cables. Due to minimum development in the underwater network, the communication is made still using traditional routing protocols that are developed for other specific networks where it won't be giving its better performance. To increase the delivery of packets and decrease the delay and energy consumption, this paper proposes a protocol inspired namely Beckoning Penguin Swarm Optimization Protocol (BPSOP) which is inspired by the natural characteristics of penguin. Foraging characteristics of penguin is applied to find the best route in UWSN. BPSOP is evaluated in NS3 using benchmark performance metrics and results indicate that BPSOP has better potential against existing protocols.

Keywords

Delay, Energy, Packet Delivery Ratio, Penguin, Routing

Introduction

The communications in Underwater Wireless Sensor Network (UWSN) are non-dependent on radio frequency (RF). The attenuation of RF waves increases with the conductivity of water. However, only low-frequency waves (between 30 and 300 Hz) can travel long distances with low power [1]. Hence, short-range waves are the only wavelength used for radio transmission (upto several meters).

For UWSNs, optical communication and acoustic systems are considered as best alternatives for RF-based communication systems. There are some significant variations between these two forms of contact [2]. The way their signals transmit is the first distinction between them. The signals of optical communication are bidirectional and travel at the speed of around 2.55×10^8 m/s through the sea, but acoustic waves travels in omni-directional and with the speed of 1500 m/s[3]. Another distinction is the trade-off they make between transmission range and transmission rate. Acoustic modems intends to send small quantities of data over long distances (a few kbps), but optical modems have the ability to send massive amounts of data over short distances (a few meters). Another point of distinction is energy efficiency. Optical modems save a lot of energy compared to acoustic modems because they can relay multiple times for more bits per joule. Nodes typically have low power supplies (i.e., batteries) and charging them can be unfeasible or difficult or expensive [4], [5].

Acoustic communication has become the widely utilized technology for UWSN communication; its shortcomings have prompted the development of alternatives. Cognitive acoustic networks enable nodes in sensor network to aware of their surroundings and utilization of spectrum, are alternate to acoustic networks used for underwater communication. Integration of optical networks is another choice for improving spectrum efficiency and dealing with acoustic

limitations [6], [7]. Since optical and acoustic communications have common properties, it is possible to combine and act as a hybrid communication networks to get the best of both worlds [6].

The main function of the UWSN routing protocol is to create routes between nodes. In general, UWSN routing protocols are difficult to design while considering different aspects. Because of the marine world, it is a difficult task. UWSN technology differs greatly from terrestrial sensor technology [8]. First, acoustic waves are the most appropriate means of communication in underwater networks, and they are favored over optical and radio waves because they have significant disadvantages in the aquatic channel. Second, most terrestrial sensors are fixed (or static), while underwater sensor nodes can change in response to water flow and other underwater events. As a result of the obstacle faced by UWSNs, current routing protocols in terrestrial WSN cannot be directly adapted, and a new routing solution for UWSN must be applied [9], [10]. Optimization [11]–[14] in finding routes in UWSN will lead to reach better performance.

Literature Review

“Geographic Opportunistic Routing Protocol”[15] proposed to minimize the packet drop ratio and also to face the problem of void. The protocol used the geocasting concept other than multicasting and it has faced delivery of data packets in a low ratio. “Joint Data Gathering and Energy Constraint Problem” [16] is studied and analyzed the problems that arise when the sensor node face meets the low battery energy while sending data to sink node. In this study, a radio frequency circuit was used to reduce the energy, but the problem of delay got increased. “Hybrid Methodology for Static and Dynamic Clustering Operation”[17] proposed to find a solution for the problems that arise statically and dynamically. It utilized the approach of distributed centralization and multi-hop routing which takes care of the level of energy, energy utilization and count of neighbors in nearby clusters. “Hybrid Particle Swarm Optimization based Genetic Algorithm”[18] proposed to address the problem of delay that exists between nodes. The main concept was to charge the nodes in a periodic manner other than charging in a lengthy periodic manner. It aimed to reduce the delay but the delay got increased with an increase in total energy consumption of WSN.

“Clustering Algorithm Protocol based on C-means”[19] proposed to form a cluster with the available number of nodes. The communication mode used for this protocol was single-hop which was utilized for the communication of intracluster, and it adopts the mode of multi-hop communication for the inter-cluster. The result shows that the results get weakened because of poor packet delivery ratio. “Multi-Objective Ant Colony Optimization based Secure Routing Protocol”[20] proposed for WSN to minimize the consumption of energy at nodes and also to maximize the trust level of the established routing path, where the pheromone information got decreased and the objective of the research towards reducing the delay. “Routing Protocol for Low-Power Lossy-Networks”[21] proposed to make a proficient cluster with efficient topology in WSN. This protocol was utilized to calculate the optimum count of the cluster, where the clusters formed don’t have the perfect communication to pass the data to the destination.

“Multi Constraint Optimum Path Protocol” [22] is proposed by utilizing the approach of calculus operator to establish the valid path towards the destination in WSN, where the protocol fails to give preference to remaining paths resulting in a reduced network lifetime. “QoS Enabled

Routing Protocol”[23] proposed to reduce the delay and consumption of power for delivering the data packets. It utilized the concept of supervising the clusters by chiefnode, which selects the node depending on available energy and connectivity of the nearby nodes. Results show that much energy is consumed towards electing the nodes for forwarding the packet towards the destination. “Enhanced Version of Election Protocol”[24] proposed to decide the sink node cluster head depending on the level of energy the position of the node, where the head of the cluster finds the path which has minimum distance to accomplish the correct routing path. Results showed that the protocol consumes more energy in accomplishing the routing path than the energy utilized for delivering the data packet.

“Adaptive Queue Learning Protocol based on Reinforcement Strategy” [25] proposed to increase the WSN performance by minimizing the energy consumption in WSN based on IoT, which results in an increased delay between source and destination. “Emphasizing Protocol”[26] proposed to gather the data in wired WSN when there arise link break and data loss. Finally, it was found that the protocol was not fit for wired environments due to the poor ratio of packet delivery. “Node Clustering Protocol based on Cuckoo Search”[27] proposed to balance the energy was used to find the uniformity among nodes to forward the data to reach the destination, which results in failure of links between a candidate node and sink node. “Distribution-based Self Stabilizing Algorithm”[28] proposed for scheduling in WSN, which was a theoretical concept. The result of simulating this protocol shows the network-facing reduced lifetime because of too much consumption of energy. “Hop Constrained-based Self Stabilizing”[29] concept was proposed to reduce the energy consumption in real-time routing, where the protocol initially forms the routing path inside the current cluster by controlling the node count to reach the packet to the node in another cluster. The result shows that the protocol faces increased energy consumption. Optimization based routing protocols[30][11], [13], [14], [31] provides better result when comparing with other types of protocols.

Beckoning Penguin Swarm Optimization Protocol

Characteristics of Penguins

Penguins are more experts at surviving underwater than any other fishes, its moments in water are like other birds flying in the sky. In addition to being good for flying, their wings may be flippers. For a while, the penguins remain submerged in the ocean in order to get down to a greater depth. Anecdotal evidence supports the hypothesis that the penguins can dive over 500m to find food. Swimming underwater is more efficient and less exhausting than sliding over ice. Penguins can swim at high speeds by reducing their heart rate and looking for food at the same time. Many penguins can see patterns and colors because of the retina of their eyes. In addition to krill, penguins eat small fish, cuttlefish, squid, and crayfish. This is how they use their energy, and over a longer period, so they dive deeper.

The foraging behaviour of penguins can be used as an optimization concept to decide the route to send data in UWSN. Penguin’s food habits can be influenced to select the best route in UWSN. Like other predators, penguins hunt and capture their prey on the move. In order to do this, they must be able to estimate how long and how far they must go to procure it. Going out on a fishing adventure pushes the penguins to the top of the water at any time. The oxygen levels indicate how long you can last after spending a small amount of time. In order to reduce the

amount of wasted energy and optimize the level of oxygen available for feeding, penguins eat in unison and perform their dives at the same time. Penguins speak to each other using a range of communication styles. No two penguins sound in the world will sound alike when producing these sounds (ex: human fingerprint). Therefore, they made it possible for individual penguins to be distinguished.

In summarizing the penguin findings, the following protocol can be stated:

- ✓ Penguins live in groups. Each group holds a different number of penguins and it varies based on the foraging area.
- ✓ The depth at which each group of penguins begins to gather food depends on information about energy gain and information about the cost.
- ✓ Penguins search for food in groups, and some penguins act as a master for other penguins. Once their oxygen level gets deplete, they start looking for food even though it is scarce.
- ✓ After diving many times for food, penguins share the information gained within their local groups.
- ✓ When the support level for food gets insufficient they move to the surface for making intra-communication with its members and move to another location through inter-communication strategy

Update of Swimming Course

Assume $J = \{J_1, J_2, J_3, \dots, J_M\}$ as set of M penguins that are randomly divided into clusters. Individual cluster J_i holds t number of penguins where individual penguin k is located at in the solution at during the time period u, the kth penguin moves to new position during the time period u+1 and it is mathematically expressed as

$y_j^i(u + 1) = y_j^i(u) + P_j^i \times (rand()) \times (y_{localbestvalue}^i - y_j^i(u))$	(1)
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The swimming behaviour of penguin is described in Eq.(1) or much of their foraging, penguins rely on their eyesight. Surprisingly, penguins pursue the cluster head instruction, i.e., the one who has located the most food, and move along a trail created by the other. The oxygen level determines the penguin's overall fitness, causing the penguin to swim faster on each dive. Moving for the local best solution is referred to as spontaneous maneuvering. Gains on the followed path are used to adjust the resulting traveling speed. If the acceleration coefficient continues increasing, it suggests a positive trend.

Update of Oxygen Reservation

During each dive, penguins reserve the oxygen for its progress towards objective and it is mathematically expressed as:

$P_j^i(u + 1) = P_j^i(u) + \left(f(y_j^i(u + 1)) - f(y_j^i(u)) \right) \times \ y_j^i(u + 1) - y_j^i(u)\ $	(2)
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where f represents the objective function of finding the best route. Swimming time determines the available supply of food for the penguin. For any additional minute that the penguin remains

under the water, it captures a greater quantity of food. During the requirement of more oxygen, it takes longer dive and stores less in its cells. Hence, the reserve of oxygen is regulated by the concurrence of primary amelioration. For best or worse, the oxygen supply rises frequently. The penguin dives repeatedly until the oxygen is exhausted.

Intra communication between clusters

Penguins communicate with each other well, feeding as a cooperative entity. The winner of the previous dive has been the local leader of the next dive. Each dive looks for a new snack, resulting in the penguin's reemergence as the town's leading local gourmand. The problem-solving is an autocatalytic procedure that allows trial solutions to be produced without interruption.

Update of Food Abundance

Food abundance rate (FBR) is linked with every clusters and it represents the energy level of prey that is hunted by members in the clusters. FBR is computed using amount of fish eaten (AFE) by penguins and it is mathematically expressed as:

$AFE(u + 1) = AFE^i(u) + \sum_{j=1}^{e_i} (P_j^i(u + 1) - P_j^i(u))$	(3)
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AFE represents the communication between penguins in the cluster. Highest AFE represents the area where food is enough for all members in the cluster and some penguins migrate from one cluster to another cluster.

Update of Cluster Membership

Due to a scarcity of food, the penguin can leave its cluster. When the penguin collects data on the availability of food, it is shared in clusters to maintain the members. The penguin joins the different cluster which has enhanced probability of food availability, this too face risk in foraging. When the food search area is fully explored and avoided by all penguins, then it is noted as zero food availability area. To determine the likelihood of being in the better group i, probability calculation is must and it is expressed as

$Prob_i(u + 1) = \frac{AFE^i(u)}{\sum_{j=1}^k AFE^j(t)}$	(4)
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This type of capacity for proportional diversity promotes inter-group cooperation because of which the promising area can be thought to be searched by the larger group of participants. The Penguin's inter-group cooperation more closely parallels evolutionarily-based competition, which offers the building blocks for excellent solutions.

Results and Discussions

Metrics

- **End-To-End Delay:** It indicates the time difference arrival of data packets.
- **Energy Consumption:** It indicates consumption of power taken by node to deliver the packets.
- **Node Death Rate:** It represents the nodes that are dead due to more energy utilization.
- **Packet Delivery Ratio:** It indicates the delivered packets against the packet sent.

Simulator and Settings

To analyze the performance of BPSOP against EAVARP[32] and E-PULRP[33], this research makes use of NS3 simulator. Simulation settings are given in Table 1.

Table 1: Simulation Settings	
Simulation Parameters	Values
Model of Transmission	ns3::UanPropModelThorp
Model of Noise	ns3::UanNoiseModelDefault
Model of Underwater acoustic channel	ns3::UanChannel
Model of Consumed energy	ns3::AcousticModemEnergyModel
Model of Signal to noise ratio	ns3::UanPhyCalcSinrDefault
Model of Packet error rate	ns3::UanPhyPerGenDefault
Underwater speed of sound	1500m/s
Idle state	158mW
Power of Transmit	50W
Bandwidth	80Hz
Boundary of Network	1km x 1km x 1km
MAC Protocol	CW-MAC802.11DCF
Layer width	≤200m
Runtime	1000s
Size of Packet	64bytes
Packet header size	13bytes
Each node of initial energy	360J
Transmission radius of sensor nodes	≈250m
Data transmission rate	10kbps
Number of nodes	100400
Number of sinks	≥2
Acoustic pressure of layer	101 dB(μPa)
Acoustic pressure of data transmission	103 dB(μPa)

Experimental Results

Energy Consumption Analysis

Figure 1 illustrates the energy consumption of nodes to deliver the packet to destination where x-axis is marked with nodes and y-axis is marked with energy consumption in joules. From figure 1 it is possible to make a clear understanding that BPSOP consumes low energy to deliver the packets than E-PULRP and EAVARP.

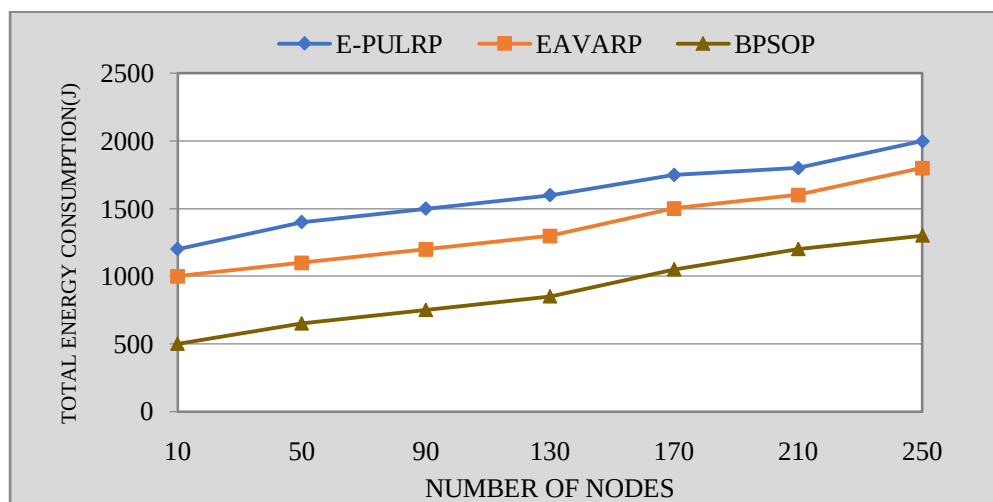


Figure 1.Energy Consumption vs. BPSOP

End-to-end Delay Analysis

Figure 2 illustrates the end-to-end delay in delivering the data packets, where x-axis is marked with nodes and y-axis is marked with delay in milliseconds. From figure 2 it is possible to make a clear understanding that BPSOP faces low delay than E-PULRP and EAVARP.

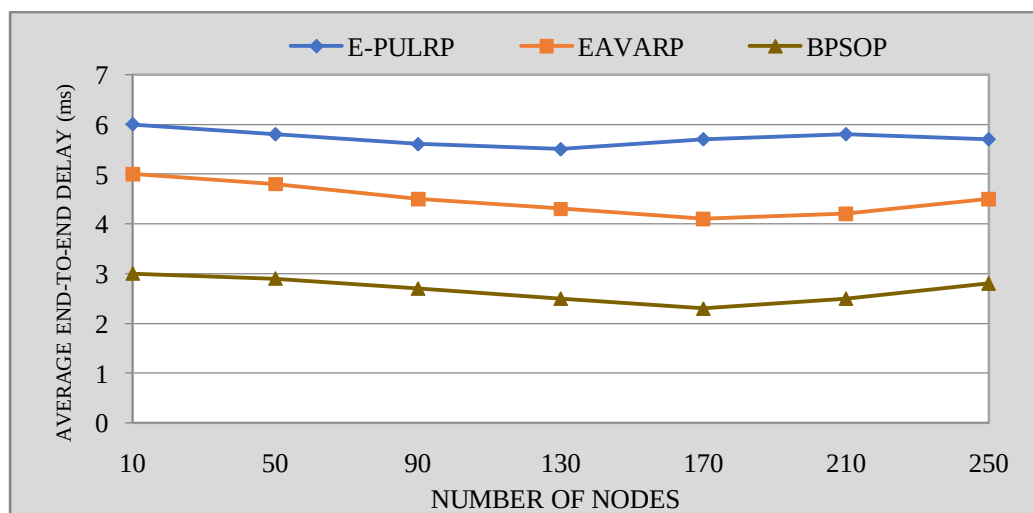


Figure 2.End-to-End Delay vs. BPSOP

Node Dead Rate Analysis

Figure 3 illustrates the node dead rate in the network where x-axis is marked time in milliseconds and y-axis is marked with dead rate of nodes. From figure 3 it is possible to make a clear understanding that BPSOP faces low dead rate of nodes than E-PULRP and EAVARP.

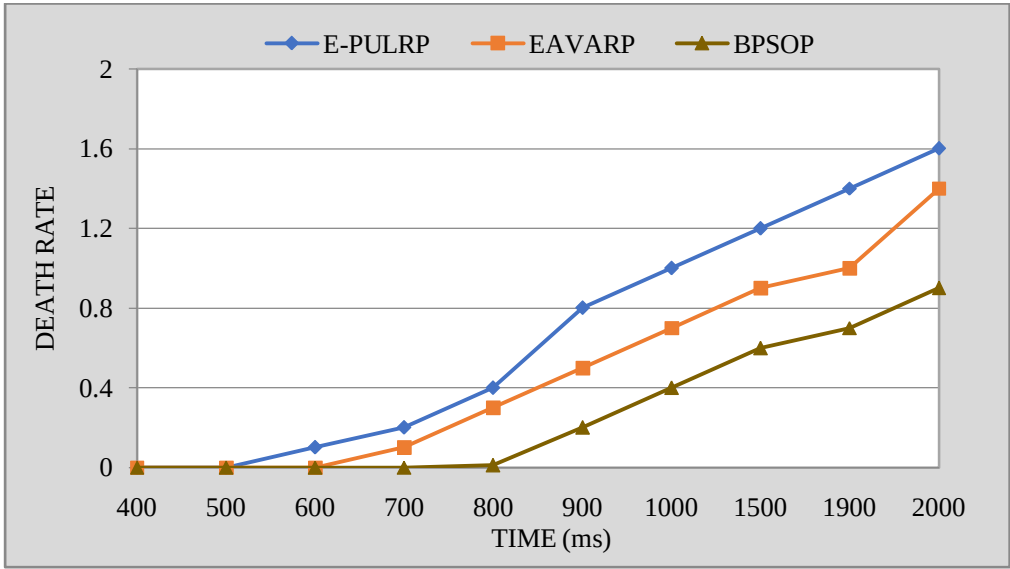


Figure 3. Node Dead Rate vs. BPSOP

Packet Delivery Ratio Analysis

Figure 4 illustrates the packet delivery ratio of protocols, where x-axis is marked with nodes and y-axis is marked with packet delivery ratio in percentage. From figure 4 it is possible to make a clear understanding that BPSOP attains better packet delivery ratio than E-PULRP and EAVARP.

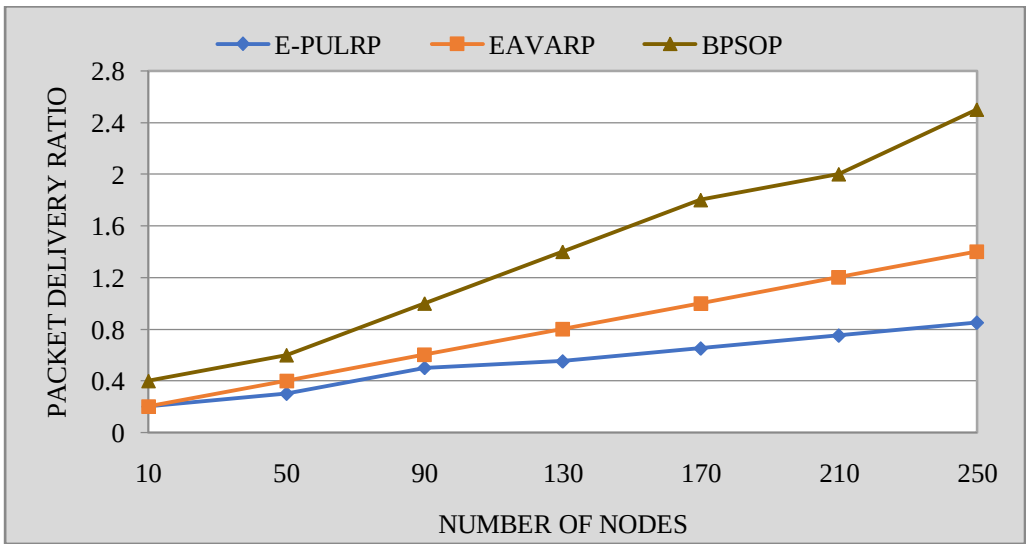


Figure 4. Packet Delivery Ratio vs. BPSOP

Conclusion

This paper has proposed a bio-inspired protocol namely Beckoning Penguin Swarm Optimization Protocol (BPSOP). BPSOP intends to find the best route in UWSN which will reduce the delay and energy consumption. Foraging behavior of penguins is applied to find the best route and oxygen reservation behavior is utilized to maintain the route effectively till all the packets get delivered. BPSOP is evaluated in NS3 using standard performance metrics. Results makes an indication that it has better performance in all consider aspects and well suited for UWSN.

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