SZAR: Shadow Zones Avoidance Routing Protocol for Underwater Wireless Sensor Network

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Summary
In underwater environment the shadow zones (obstacles) reduces the performance of the routing protocols. To overcome on this issue we proposed the Shadow Zones Avoidance Routing (SZAR) protocol which avoids the shadow zones through back-route ACK mechanism and improves the overall performance of SZAR. NS2.30 with AquaSim simulator is used to measure the performance of SZAR over VARP and VHGOR routing protocols. SZAR performs well as compare to VARP and VHGOR.
Key words:
Relay_Node; acoustic; upper_depth; lower_depth

1. Introduction

Underwater Wireless Sensor Network (UWSNs) becomes a powerful technology due to its well-known applications like: tactical surveillance, ocean monitoring, undersea biological life, and underwater minerals, coal mines, gold, silver, oil/gas and many more [1-3]. In undersea the valuable data for oil/gas, gold, silver and coal mines placed at the seabed level and majority of the researchers are engaged to explore this valuable information towards the water surface by deploying the undersea sensor nodes [4-6]. The researchers are specially using the four kinds of nodes in undersea environment to extract the information from the seabed [7-9]. Sink nodes are deployed at the sea surface level, source nodes are deployed at the seabed level, ordinary or forwarder nodes are used to route the packets from source nodes to surface sink nodes. Some researchers are using the relay node or super nodes as powerful nodes to prolong the network life time [10, 11]. Surface sink nodes are connected between each other and with onshore data center through radio frequencies. In undersea environment the acoustic waves are only the source for data forwarding because in underwater environment the radio frequencies and optical waves are unable to forward the packets due to their limitations [12-14]. Acoustic waves have also some limitations like: propagation delay, low bit error rate and fading. Due to underwater environmental conditions like water pressure, water current and biological life of the undersea animals creates the major problem in designing of routing protocols [15-17]. When we design the routing protocols the packets forwarding may also face the shadow zones (undersea mountains and underwater obstacles) issue. This research article focuses the removal of void node under shadow zones through alternate route development mechanism. For alternate route development mechanism we proposed Shadow Zone Avoidance Routing (SZAR) protocol which is detailed described in section 3.

2. Related work

The related work focuses on existing routing protocols which avoids or removes the shadow zones through some mechanisms or methodologies.

Reliable and Energy Balanced Routing Algorithm (REBAR) is proposed in [18] is the location based routing protocol. This routing protocol is based on the single sink. REBAR uses the two models for energy saving of the nodes with sphere energy depletion model and extended sphere energy depletion model with formation of different tiers. REBAR forward the data packets with constant constraint radius. REBAR bypass the void zones through boundary set and non-boundary set mechanisms. Boundary set mechanism recognizes the voids and by pass the voids through alternate route development mechanism. In non-boundary set REBAR smoothly forwards the packets. It is observed from the REBAR that boundary set mechanism is not well defined to bypass the void, the authors of REBAR just given the hypothesis.

Vector-Based Void Avoidance (VBVA) is proposed in [19] removes the void problem through vector-shift and back-pressure. The data forwarding mechanism is based on concave and convex voids. Vector-shift mechanism forwards the packets along boundary of the void whereas through back-pressure mechanism the packets can be forwarded through backward concave void. If there is no void the VBVA behaves like VBF as mentioned in [20]. It is observed that the vector-shift and back-pressure mechanisms cannot perform well, when network becomes sparse due to water pressure.

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Depth Controlled Routing (DCR) is proposed in [21] removes the void through use of centralized algorithm. The centralized algorithm follows greedy geographic mechanism which determines the failure node due to underwater obstacles or void zones, when node becomes fail to forward the packets then DCR will follow the newly calculated depth to forward the packets. It is observed from the working functionality of the DCR, that no proper mechanism has been used for removal of void regions or void nodes.

Void-Aware Routing Protocol (VARP) is proposed in [22] follows the opportunist directional flooding mechanism for packets forwarding. VARP control the mobile nodes through breadcrumb method. In VARP, if any node becomes void due to void region then VARP will trap that area through developing of V-Shape architecture, and packets will be forwarded through development of the new route. It is observed from the operation of the VARP that V-Shape development architecture is just hypothesis; in real scenario this kind of architecture is not possible in underwater environment.

Geographic Depth Adjustment Routing (GEDAR)protocol is proposed in [23] focuses the controlling of depth to remove the void node. The depth adjustment controlling finds the new depth to route the packets if any kind of underwater void zone occurs. The new depth can be adjusted through equipped buoyancy-based module in the node which locates the new depth for route to the packets. The sensor node has ability to check the void zones and if void zone appears on the path of the packets forwarding, the node itself will select the new route for packets forwarding. From the operation of the GEDAR and through existing literature the buoyance-based module type node is not available.

Void Handling Geo-opportunist Routing (VHGOR) protocol is proposed in [24] focuses the two types of the voids, one is convex void and other is concave voids. These kinds of voids can be handled through quick hull algorithm. Through convex voids the convex hull mechanism is used to find the alternate route for packets forwarding, if there is no any convex void then VHGOR will use the switch to the concave void through recovery mode to route the packets. When void occurs either convex or concave the ACK signal will be sent back to the forwarder node. VHGOR uses the multi-hop routing mechanism for packets forwarding. It is observed from the performance of the VHGOR that convex and concave through quick-hull mechanism cannot perform well due to underwater environmental conditions of water.

3. Shadow Zone Avoidance Routing (SZAR)

SZAR protocol is consists of three phases:
3.1 Node deployment phase
3.2 Route development and packets forwarding phase
3.3 Shadow zone avoidance mechanism.

3.1 Node deployment phase

The node deployment mechanism is shown in Fig. 1.

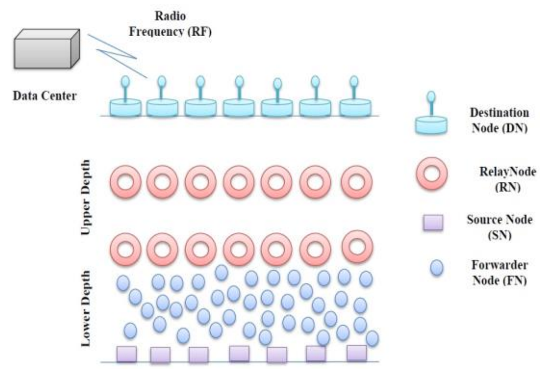

Fig. 1 Node Deployment mechanism

Fig. 1 focuses the four types of the nodes: one is Destination Nodes (DNs), second is Relay Nodes (RNs), third is Source Nodes (SNs), and fourth is Forwarder Nodes (FNs). DNs are deployed on the water surface and are connected with onshore data center through Radio Frequency (RF) signaling. DNs are also connected between each other through RF signaling. The water depth from sea surface to seabed is divided into two layers, one is upper depth and other is lower depth. In upper depth we have deployed RNs in dynamic way. RNs can only move in the upper depth of water. On seabed level the SNs are deployed and are the data collector nodes, which can collect the valuable information like gold, oil/gas, diamond, and underwater coal mines. FNs are deployed only in the lower depth and are able to make a route for packets forwarding from SNs to RNs and from RNs to DNs. DNs further forward the packets to the onshore data center. In underwater environment the acoustic channel is only the source for packets forwarding.

3.2 Route development and packets forwarding phase

In route development and packets forwarding phase, if the SNs has data then it forwards the hello packets to all the FNs and when all the forwarder nodes will receive the hello will make the single path according to the fields defined in hello packet format as shown in Fig. 2.

S_ID	F_N_ID	Min_Hop	Min_Dist	RN_ID	DN_ID

S_ID: Source Node ID
F_N_ID: Forwarder Node ID
Min_Hop: Minimum number of Hops
Min_Dist. Minimum Distance (m)
RN_ID: Relay Node ID
DN_ID: Destination Node ID

Fig. 2 Hello packet format

The description of the hello packet format field is described as below:

i. Source Node ID (S_ID): This field consumes the two bytes and keeps the address of the relevant source node.
ii. Forwarder Node ID (F_N_ID): This field consumes the two bytes and keeps the address of the FNs.
iii. Minimum hops (Min_Hop): This field also consumes the two bytes and calculates the minimum number of hops from SNs to RNs.
iv. Minimum Distance (Min_Dist): This field consumes the two bytes and calculates the minimum distance from SNs to RNs.
v. Relay Node ID (RN_ID): Relay Node ID keeps the two bytes and keeps the address of the relevant RNs.
vi. Destination Node ID (DN_ID): This field consumes the two bytes and keeps the address of the relevant DNs.

The single route selection for packets forwarding is based minimum number of hops and shortest distance from SNs which are placed at seabed level through hello packet format with minimum number of hops from SNs to upper depth RNs. RNs further involve the other RNs to relay the packets towards DNs. The packets forwarding route is shown in Fig. 3.

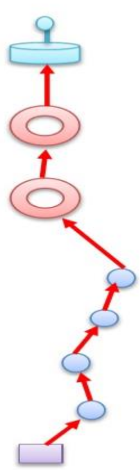

Fig. 3 Packets forwarding route from SN to DN

3.3 Shadow zone avoidance mechanism

Along the packets forwarding route if any kind of shadow zone will appear the FN will forward the ACK signal through back-route mechanism with help of other FNs to the SN, and source node will re-intimate the new route development mechanism. This process is shown in Fig. 4 and operation is shown in Fig. 5 (Flow chart).

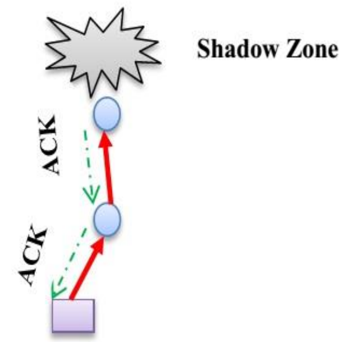

Fig. 4 Shadow zone along packets forwarding route

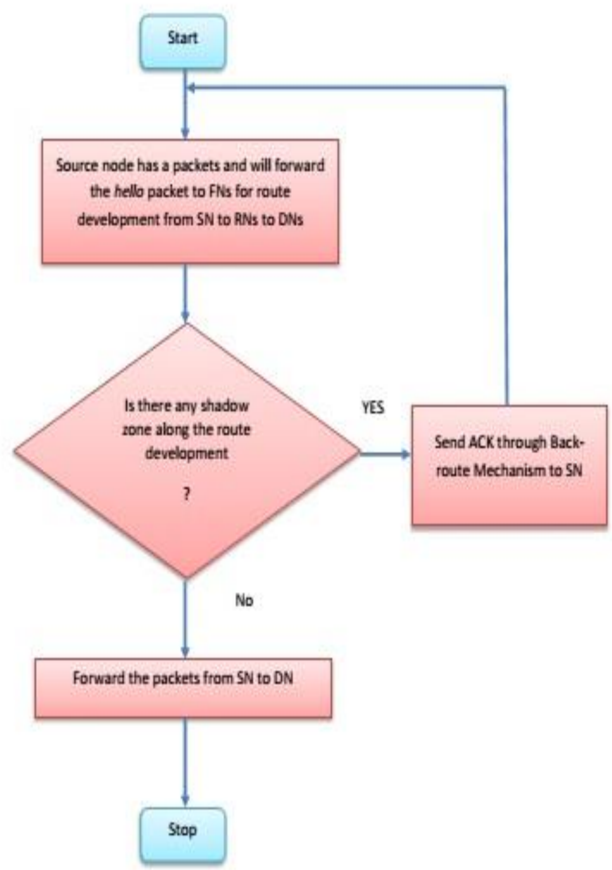

Fig. 5 Process Flowchart for Shadow Zone

4. Performance Analysis

For performance analysis the NS2.30 with AquaSim package simulator is used. NS2.30 simulator parameters are shown in Table 1.

Table 1: NS2.30 Simulation parameters

Parameters	Values
Network Size	1500m x 1500m
No. of Nodes	350
Data Packet size	64 byte
Initial Energy	70 J
MAC Protocol (Shin & Kim, 2008)	802.11-DYNAV
Energy consumption for transmitting	2w
Energy consumption for receiving	0.75w
Energy consumption for idle listening	8mw
Transmission range	100 m to 150 m
Surface sink distance difference	100 m
Simulation time	1000 sec

In simulation parameters, we have considered the 2D deployment with network size of 1500x1500 meters for the deployment of the FNs in lower depth of the water. The transmission range is set up to 150 meters in lower depth of the water, whereas RNs are the powerful nodes which prolongs the battery power of the FNs. We have deployed overall the 350 nodes and measure the simulation results on 50, 100, 150, 200, 250, 300, and 350 nodes. The energy parameters are defined in Table 1. We perform the simulation on following parameters.

4.1 Data Success Ratio

The data success ratio focuses the number of packets received on DNs and number of packets sends by SNs. The Data success ratio is shown in Fig. 6.

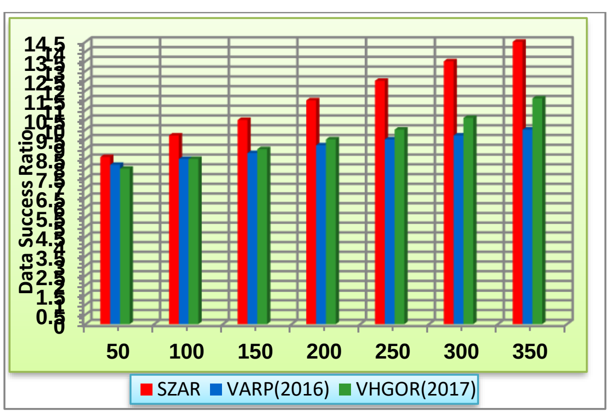

Fig. 6 Data Success Ratio of SZAR over VARP and VHGOR

Data Success Ratio of SZAR is higher than VARP and VHGOR because SZAR divides the water depth into two parts and one is upper depth and other is lower depth which controls the node mobility. In SZAR the use of courier node also enhances the data success ratio. On other hand VARP and VHGOR cannot control the node mobility.

4.2 End-to-End Delay

End-to-End Delay can be defined the average delay at DNs. The end-to-end delay of SZAR is shown in Fig. 7.

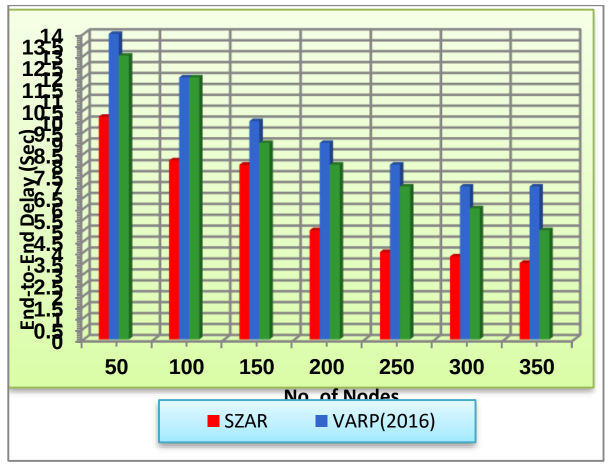

Fig. 7 End-to-End Delay of SZAR over VARP and VHGOR

The end-to-end delay of SZAR is lower than VARP and VHGOR because the powerful RNs reduce its end-to-end delay. On other hand VARP and VHGOR cannot use the powerful RNs.

4.3 Average Energy Consumption

Average Energy Consumption can be measured the sum of the initial and final energy of the nodes for entire network. The average energy consumption of the entire network with different nodes for SZAR is shown in Fig. 8.

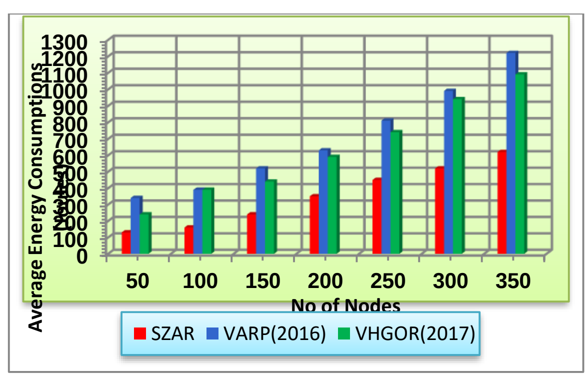

Fig. 8 Average Energy Consumption of SZAR over VARP and VHGOR

The average energy consumption of the SZAR is lower than VARP and VHGOR because the powerful use of RNs nodes and controlled node mobility reduces its average energy consumption. On other hand VARP and VHGOR cannot controls the node mobility due to water pressure.

4.4 Network throughput

Network throughput can be measured the aggregate data arrived at the DNs of the entire network. The network throughput for SZAR is shown in Fig. 9.

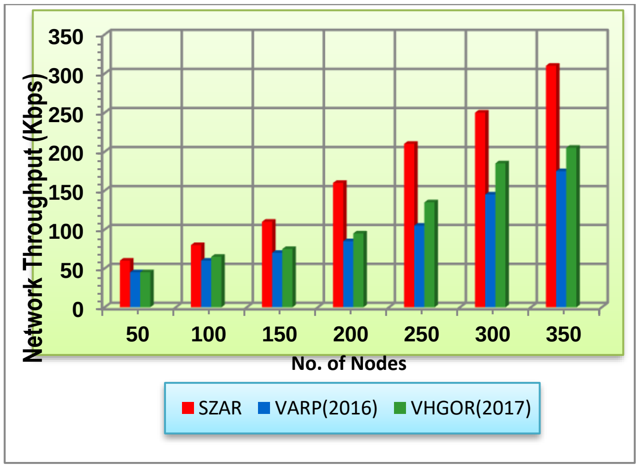

Fig. 9 Network throughput of SZAR over VARP and VHGOR

Network throughput of SZAR is higher than VARP and VHGOR because SZAR removes the void node from shadow zones in efficient way and use of RNs also enhances the network throughput through efficient route development mechanism. On other hand VARP and VHGOR cannot use the efficient data forwarding mechanism.

5. Conclusion

This research article focuses the Shadow Zone Avoidance (SZAR) routing protocol. In SZAR the nodes are deployed in upper and lower water depths which control the node mobility. The use of RNs in upper depth enhances the performance of the overall network. The optimal route selection mechanism through FNs also enhances the performance of the SZAR. The efficient use of back-route mechanism through ACK on appearance of shadow zones also improves the performance of the SZAR. For performance analysis the NS2.30 network simulator is used to compare the results of the SZAR with VARP and VHGOR. From simulation response it is clear that SZAR is well performer over VARP and VHGOR.

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