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Design of an Optimal Distributed Energy Efficient Hybrid Optical – Acoustic Cluster Based Routing Protocol (EEHCRP) to Minimize the Energy Consumption in Underwater Wireless Sensor Networks

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Abstract : For ocean exploration high speed data transmission is the emergent requirement. Acoustic sensor networks are available to support large distances but with lower data rates and also consume maximum energy. Optical networks can be used to support high speed data transmission but it cannot be used for larger distances. Underwater Wireless Sensor Networks (UWSN) suffer from large propagation delay, high bit error rates, limited bandwidth, uncontrolled node mobility, water current and limited resources. Hence there is an evolving requirement for design and use of an efficient routing protocol. In the proposed research, design of an Optimal Distributed Energy Efficient Hybrid Optical - Acoustic Cluster Based Routing Protocol (EEHCRP) to minimize the energy consumption in Underwater Wireless Sensor Networks is considered. To overcome these problems we propose an Energy Efficient Hybrid Optical-Acoustic Cluster Based Routing Protocol for Underwater Wireless Sensor Network (EEHCRP).

In this research work we study various network parameters like network throughput, network life time, average energy consumption, end to end delay and data delivery ratio for mobile nodes ranging from 50 to 500. It is observed that there is an average increase of 0.9% network throughput in the proposed EEHRCP protocol compared to CBE2R protocol. The network life time is increased to 51.2 seconds with a decrease in 0.93% of energy consumption and 0.48 % decrease in end to end delay in the proposed protocol EEHRCP compared to CBE2R protocol. There is an increase in 0.95% of data delivery ratio using the proposed EEHCRP protocol compared to E-CBCCP protocol.

Keywords: Underwater Communication; Underwater Wireless Sensor Networks (UWSN), Energy Efficient Hybrid Optical-Acoustic Cluster Based Routing Protocol,Routing Algorithm (EEHRCP).

I. INTRODUCTION

To safeguard the marine life, for pollution control, prediction of natural disaster, climate recording, military etc., .

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Underwater Wireless Sensor Networks (UWSN) have become an important topic of research

The communication methods used by UWSN are completely different from the terrestrial networks [1,2].There are three kinds of communication channel for UWSN viz. radio waves, acoustics waves and optical communication channels. Radio waves suffer from high attenuation underwater and require large antennas due to which it not feasible to use radio waves for transmission underwater. Acoustic channels have been used by many researchers for UWSN but it suffers from low data rate, low bandwidth and also the speed of communication is very less. By using optical channel data rates, bandwidth and speed of communication can be increased but it cannot be used for larger distances. All the three methods of communication channels have their own advantages and disadvantages. So there is a need for a hybrid approach [3-4].

In UWSN the battery life of the sensor nodes is a critical issue that has to be considered for research. Unlike terrestrial wireless sensors nodes underwater sensor nodes cannot be easily recharged. Replacing the batteries of all the sensor nodes underwater is a difficult and an expensive task. Network lifetime can be improved if the nodes' energy is used effectively. [5-7]

In UWSN sensors are deployed at different depth and have different amount of data to be transferred. Some nodes participate to maximum extent in data transmission and hence results in nodes losing the energy level and will die earlier. Due to this, the network life time gets degraded. Maximizing the network lifetime is a research issue that has to be considered. By efficiently managing the energy level of the nodes, the network lifetime can be increased. [8]

To address these problems we propose an Energy Efficient Hybrid Optical-Acoustic Cluster Based Routing Protocol for Underwater Wireless Sensor Network (EEHCRP).

The main motto of EEHCRP is to build an energy efficient routing protocol. The energy level of the nodes is maintained and always the node with a highest residual energy is used for transmission, so that the load on the nodes is balanced and the network lifetime can be increased.

The major contributions in this paper are given below:

- We propose a Cluster Based Routing Protocol where the node with highest residual energy is selected as Cluster Head (CH) and remains active to monitor the activities of the network.
- To achieve the high speed data transmission we make use of hybrid approach of optical-acoustic communication.

The rest of the paper is organized as follows: Section 2 presents the related works.

System model is discussed in Section 3. The EEHRCP proposed system is discussed in Section 4. Details of simulation setup, results and discussions are provided in section 5. Conclusions and summary of the research work carried out using EEHCRP are highlighted in section 6.

II. RELATED WORKS

In UWSN due to the harsh and dynamic environment, maintaining an efficient route with energy constraint is a challenging task [9]. Many energy efficient routing algorithms have been proposed, but they fail to maintain the link quality and battery power. As the water pressure is high underwater, it is very difficult to control the node mobility [10]. In this section we discuss some of the energy efficient cluster routing protocols.

Classical Cluster Based Routing Algorithm is LEACH [11]. LEACH is best suited for Wireless Sensor Networks. It cannot be used for UWSN because every node participates is selection of CH and every node broadcasts all the packets to other nodes within the cluster which results in high utilization of energy of the Sensor Nodes.

Zhiping Wan et.al [12] proposed an energy efficient multilayer clustering algorithm where the sink node is placed in the centre and the network is divided into multiple layers. A node which is closer to the sink node is chosen as the cluster head so that it can use its maximum energy in forwarding data packets rather than data fusion. As the node that is closer to the sink is always selected as the CH and it loses its energy to the maximum extent than the other nodes which results in reduced network lifetime.

Kun Hao et.al [13] presentd an EEL (Energy Efficient Location based algorithm) where the location information of the nodes is used to select the next forwarding node. Each candidate nodes calculates their Normalized Advancement (NADV) and the node with the highest NADV are selected as the next forwarding node. The location information of the nodes is updated as and when the topology gets changed.

Muhammad Awais et.al [14] proposed SPB-WDFAD-DBR which uses Dijkstras' Algorithm to find the shortest path between nodes for cluster formation. The nodes selected using Dijkstras' Algorithm are selected as CH. These cluster heads collect the data from all the other non CH nodes in the network, aggregates the collected data and forwards it towards the destination.

Zhuo Wang et.al [15] proposed EAVARP protocol which works in two phases. The first phase is a layering phase where concentric shells are built around the sink node and sensor nodes are distributed on different shells. It is the responsibility of the sink nodes to identify the real time changing topology. The data packets are forwarded to the destination using opportunistic directional forwarding strategy (ODFS). The second phase is the data collection phase where the sender forwards the packet to the next relay node by looking at the neighbor table. Instead of sending a probe message to identify the best route, it considers each node transmission capacity to identify the best route. The problem with EVARP is that, it uses complex mechanism for shell formation.

Mukhtiar Ahmed et.al [16] proposed CBE2R protocol for UWSN. CBE2R has three phases. The first phase is the cluster formation phase where high memory and high powered courier nodes are deployed at different depth as courier nodes. These courier nodes act as CH. The CH sends a join message to the other nodes which are 4 hop distance away from CH. The nodes that receive join message form a cluster. In the second phase i.e the route development phase, the CH develops the route by considering the nodes with high weighted value. Once the route is developed, then the data transmission phase starts where courier nodes collects the data from all other nodes or other courier nodes and then transforms it towards the destination.

Wang, Li [17] proposed minimum cost clustering protocol. The architecture of MCCP comprises of control station located onshore, sink nodes and ordinary nodes which forms the cluster. CH uses hop by hop mechanism to forward the data packet collected from ordinary nodes to the sink nodes. Node movements underwater are controlled by Minimum Cost Clustering Algorithm (MCCA).

Rahman, et.al [18] proposed Reliable and Energy Efficient Protocol (REEP) where the packet forwarding is done based on the calculation of residual energy. It uses only vertical distance for calculation. The problem with REEP is that, if the nodes become sparse than the forwarder drops all the packets which in turn results in reduced network lifetime.

Al Salti [19] Energy Efficient multipath Grid-based Geographic Routing (EMGGR) where the network area is divided into logical grid and each grid is a cell identified by XYZ coordinates. The fixed sink node is deployed at the surface and all other anchor nodes are deployed at various depth. EMGGR has three main components Gateway Election, Gateway Updation and packet forwarding. In Gateway election sensor nodes are elected as gateway and are responsible for forwarding data packet to destination. In gateway updation , the network table maintained is updated with latest location values. In packet forwarding mechanism the disjoint paths are constructed and data packets are forwarded in those paths.

Chih-Min Chao et.al [20] proposed DRP which calculates the collision probability for constructing the route path for transmission of data packets. DRP requires a localization algorithm to locate the node and find the distance between them

III. SYSTEM MODEL

In UWSN battery life of sensor nodes is limited and hence it is inconvenient to recharge the sensor nodes. In this paper we propose a cluster based routing protocol which saves maximum amount of energy.

The proposed architecture comprises of relay nodes, anchor nodes, sink nodes and a monitoring station.

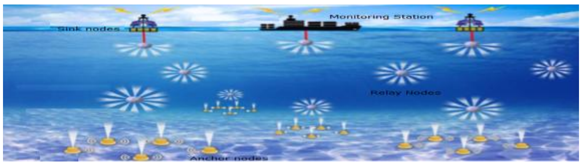

Figure 1: Architecture of EEHRCP

Anchor nodes are placed deep inside the sea it is used to sense the data and transfer it to the relay nodes. The Relay nodes are placed at different depths. Anchor nodes and Relay nodes consists of acoustic transmission, receiving components, optical transmitter, receiver and various sensors (for obtaining the marine life parameters as temperature, salinity, pressure etc.)

Relays are responsible to periodically collect the sensed data from the anchor nodes and then transfer it to the Cluster Heads (CH) (which is another relay node) or sink nodes. It uses optical links to provide high speed data transmission at close range and acoustic links as a backup whenever optical communication is not possible. Sink nodes are placed at the surface of the sea. These sink nodes forwards the data to the monitoring station which is located onshore and is responsible for processing the sensed data and sending the control signals periodically.

In the proposed system different clusters are formed with CH and relay nodes. CH collects the data from the relay nodes and then forwards it to the sink node if it is within the transmission range or else it forwards it to the next nearest CH which is within the range. Initially there is no CH within the network. The node with the highest residual energy is selected as the CH and these collect the data from their neighbors through relay nodes. If sink or anchor nodes are not within the transmission range then it aggregates the data and forwards to the next CH. In this way the data is transferred continuously from anchor node to sink node using CH to CH transmission.

IV. PROPOSED SYSTEM

In this section we discuss the proposed algorithm that is categorized into 4 phases namely:

1. Initial phase
2. Selection of Cluster Head (CH)
3. Transfer of data
4. Switching of mode of transmission

4.1 Initial Phase:

In the initial phase the network is divided into different sectors. Each sector has its own cluster and a node with is randomly selected as a CH. Each CH maintains a table called Cluster Table (CT) which has information about nodes within the cluster. Initially CT is empty. In the first round the CH creates and broadcast an HELLO packet to the predefined N cluster members. The HELLO packet consists of Cluster-ID (CID) which is unique to each cluster and is assigned once at the start and remains same throughout. Cluster Member ID (CMID) which is unique to each and every member node within the cluster, Response time (Rt).

CID	CMID (1)	Rt (1)	CMID (2)	Rt(2)	…..	CMID (n)	Rt (n)

Figure 2: Hello Packet format

Sensor nodes which are within the communication range receive the HELLO packets and checks whether its CMID is present within the HELLO packet, if present it sends a reply with HI Packet and go to sleep mode to save the energy level for specified time duration, else discard and waits for the packet containing its CMID.

HI Packet includes nodes CMID as Source ID, Cluster Head ID (CHID) as destination address, Residual energy (Re), Depth, Distance from CH and Signal to Noise Ratio (SNR). If CH fails to receive the HI packet from any node within the specified timeout then it assumes as packet loss and resends the HELLO packet to only such specific nodes.

CMID	CHID	Re	Depth	Distance	SNR

Figure 3 : Hi Packet format

The CH uses the HI packet information for 3 reasons

1. To indentify the nodes those are reachable from CH and update its information in Cluster Table.
2. To check the residual energy of the nodes.
3. To calculate the actual transmission delay

4.2 Selection of CH:

In this phase the node with highest residual energy is selected as a CH. Upon receiving the HI packet from all the nodes in the cluster the CH checks the Re field and identifies the node with the highest residual energy as the new CH. CH informs all the cluster members about the new CH by sending a notification packet.

CHID	New CMID	Max propagation delay	Sensing interval	Awake time

Figure 4 : notification Packet format

Upon selecting a new CH, the old CH broadcasts a notification packet which contains information about new CH to all the members within the cluster. The notification packet consists of old CHID as the sender address, new CMID as newly selected CHID, max propagation delay, sensing interval which specifies the duration at which the nodes should wake up from sleep and start sensing the data and awake time which specifies the time at which nodes should wake up and listen for notification packet.

In response to the notification packet, the newly selected CH sends an acknowledgement packet by putting the old CHID as receiver node ID and its own CMID as sender node ID.

Sender Node ID	Receiver Node ID

Figure 5 : Acknowledgement Packet format

On receiving the acknowledgement packet, the old CH goes to sleep mode to conserve its energy and newly selected CH will be awake monitoring the nodes within its cluster.

4.3 Transfer of Data:

Cluster member nodes will be in sleep mode while the CH will be always in the active mode. At the specified time duration the cluster members wakes up listens to the channel and some time duration and when channel is found idle it transmits the sensed data to the CH. The cluster member nodes construct the data packet for sending the data to the CH and goes to sleep mode.

CHID	CMID	Sensed data	Time	Residual energy (Re)

Figure 6 : Data Packet format

The data packet comprises of CHID as Destination address, CMID as source address, sensed data during the time interval t, time of sending the data and residual energy of the node.Upon receiving the data packet the CH sends an acknowledgement to the Cluster member. This process continues until the CH receives the data packets from all the cluster members. The CH then aggregates the collected data from all the nodes and forwards it to the next above level until it reaches the sink node.

4.4 Switching of mode of transmission:

The CH node upon sending the notification packet waits for the acknowledgment and data packet from the cluster members. If the CH node fails to establish the connection with the nodes cluster members for the specified time duration say t1, then it assumes that the cluster member node that might have left the cluster region and tries to communicate with the neighbor node by checking the CT entry. If the CH is not able to communicate with any of the node in the CT then it switches from optical mode to the acoustic model and then sends the notification. The cluster member nodes then transmit the small volume of sensed data to the CH.

4.5 Algorithm for initial phase

1. for *C Cluster € {1,2,……, S} Sectors*
2. for *N nodes € {1,2,……., C} Clusters*
3. *Randomly select a node within each cluster as CH*
4. *Create an HELLO Packet*
5. *Broadcast an HELLO Packet to each member in the cluster*
6. if *CH does not receives an HI packet from all cluster members*
7. then *goto line 4*
8. else
9. *create a notification packet*
10. *broadcast the notification packet and wait for ACK*
11. End if
12. End for
13. End for

4.6 Algorithm for Transfer of Data

1. for *C Cluster € {1,2,……, S} Sectors*
2. for *N nodes € {1,2,……., C} Clusters*
3. *At time t1 the nodes wake up*
4. *Construct the Data packet*
5. *Listen to the channel*
6. if *channel is free*
7. then *Transfer the sensed data to CH*
8. *Wait for ACK*
9. Else
10. *goto line 5*
11. End if
12. if *ACK received within time t2*
13. then *goto sleep mode*
14 else
15. *goto line 6*
16. End if
17. End for
18. End for

4.7 Algorithm for Switching of mode

1. for *CH € {1,2,……, S} Sectors*
2. *Construct the notification packet*
3. *Broadcast the notification packet to all the Cluster Members*
4. *wait for ACK*
5. if *CH fails to establish connection with any of the Cluster member within time t1*
6. then *try to contact its neighbor by looking into CT*
7. *send the notification packet*
8. End if
9. if *CH not able to communicate with any member within the Cluster*
10. then *Switch the mode of transmission to Acoustic*
11. *goto step 3*
12. else
13. *Retransmit the notification packet to specified Cluster member and wait for ACK for time t2.*
14. End if
15. End for

V. SIMULATION AND RESULT DISCUSSIONS

EEHRCP has been developed in Matlab and the performance is compared with CBE2R, E-CBCCP, DRP, and EMGGR. The environment settings of EEHRCP are given below.

5.1 Environment settings

The setting of different parameters when acoustic channel is used is depicted in Table1. The network area is deployed in dimension 1000*2000 m^3, the number of nodes is 1055 with sink nodes located on the surface and anchor nodes located deep inside the sea. The network area is divided into 16 sectors. The minimum distance between the nodes is 80m. Initial energy level of the nodes is 10kJ. Transmission power for the packets is set to 2.8 w. Channel bandwidth is 10 kHz and depth is set to 2.0 km.

Table 1: Parameters used in EEHRCP

Parameters	Value
Network Area	1000*2000 m^3
No of nodes	500
Min distance between nodes	80 m
Number of sectors	16
Sensor node initial energy	10 kJ
Transmission power	2.8 w
Channel bandwidth	10 kHz
Depth	2.0 km

The setting of different parameters when Optical channel is used is depicted in Table2. Wavelength is 532 nm, Beam Width is 3mm, maximum beam divergence is 20, link distance is 20 m and we assume default water quality as clear water with 0.31 $mg.m^{-3}$.

Table 2: Parameters used in EEHRCP for optical channel

Parameter	Value
Wavelength λ	532 nm
Beam Width	3mm
Max beam divergence	20
Link distance	20 m
Default clear water	0.31 $mg.m^{-3}$

5.2 Performance Comparison

EEHRCP protocol has been proposed for underwater wireless sensor networks. The main objective of the protocol is to build an energy efficient optical acoustic routing protocol.

Throughput is the number of packets successfully received at the destination. The throughput of the system depends on the data packet size and speed of the data transmission.

Table 3: No. of Nodes vs. Network Throughput

No. of Nodes	Network Throughput (kbps)				
	EEHRCP	CBE2R	E-CBCCP	DRP	EMGGR
0	0	0	0	0	0
50	60	59	48	45	45
100	110	98	60	55	60
150	150	120	95	68	70
200	160	150	142	70	80
250	198	195	188	120	130
300	295	280	220	150	180
350	350	300	289	192	196
400	400	350	310	210	230
450	410	380	350	280	300
500	430	400	380	310	330

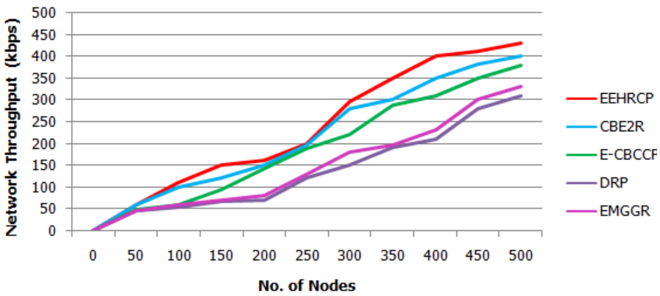

Figure 7: Network Throughput vs. No. of Nodes

Figure 7 shows the Network Throughput (in kbps) and number of nodes for the CBE2R, DRP, EMGGR, E-CBCCP and EEHRCP. It is observed that using optical communication channel the speed of data transfer is increased. The network throughput is constant for 100 nodes for DRP, EMGGR and E-CBCCP algorithms. When the number of nodes increases to 110, there is an increase in network throughput for the proposed EEHRCP protocol compared to CBE2R protocol. Also it is observed that an average of 0.9% increase in network throughput in the proposed EEHRCP protocol compared to CBE2R. The network throughput of EEHRCP is higher than because node mobility is monitered and it uses wireless optical communication which support higher bandwidth than acoustic channel which results in increase in the throughput. DRP uses probability collision mechanism which results in lower throughput. Even the throughput of EMGGR is lower because it make use of complex mechansim for forming 3D grid.

Table 4: Comparison Table for No. of Nodes vs. Network Lifetime

No. of Nodes	Network Lifetime(secs)				
	EEHRCP	CBE2R	E-CBCCP	DRP	EMGGR
0	0	0	0	0	0
50	1250	1200	1000	910	930
100	1260	1220	1010	899	899
150	1295	1230	1025	850	855
200	1285	1235	1028	840	855
250	1295	1240	1032	760	810
300	1300	1256	1042	750	800
350	1301	1260	1052	730	820
400	1340	1270	1065	750	850
450	1325	1280	1085	720	860
500	1350	1300	1092	760	900

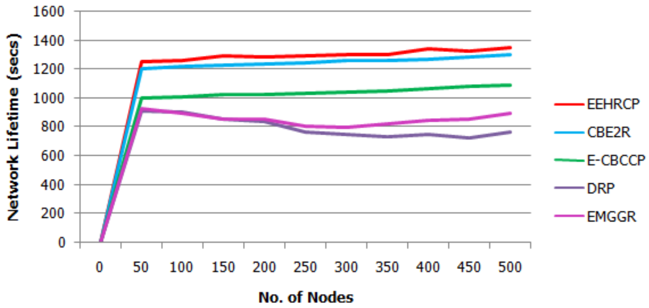

Figure 8: Network Lifetime vs. No. of Nodes

Network lifetime can be defined as the failure time of the first sensor node in the network. From Figurer 8 it is observed that, for 225 nodes there is a decrease in network lifetime for DRP protocol. For the CBE2R, EMGGR, E-CBCCP protocols there is a steady lifetime and remains almost constant. For the proposed EEHRCP protocol for 50 nodes, the network lifetime is 1250 seconds and further increases upto 1350 seconds for 500 nodes. It is observed that, on an average, the network life time is increased in 51.2 seconds for the proposed EEHRCP protocol compared to CBE2R protocol. The network lifetime of EEHRCP increases, as energy levels of the nodes in EEHRCP are preserved by keeping the sensor nodes in sleep mode. The sensor nodes wake up at the regular intervals and transfer the data and move to the sleep mode to preserve their energy levels. In EEHRCP every time the node with highest residual energy is only selected as the CH so that it has to remain active and monitor the cluster activities. In CBE2R all the nodes remain active every time which results in loss of their power due to high water drift even though they do not take part in the communication process.

Table 5: Comparison Table for No. of Nodes vs. Average Energy Consumption

No. of Nodes	Average Energy Consumption (Joules)				
	EEHRCP	CBE2R	E-CBCCP	DRP	EMGGR
0	0	0	0	0	0
50	100	110	150	285	270
100	120	150	200	330	295
150	220	240	230	450	420
200	300	320	350	650	580
250	320	430	410	790	720
300	400	520	489	970	910
350	590	645	592	1180	1020
400	710	720	700	1250	1130
450	700	785	720	1280	1200
500	650	829	750	1300	1250

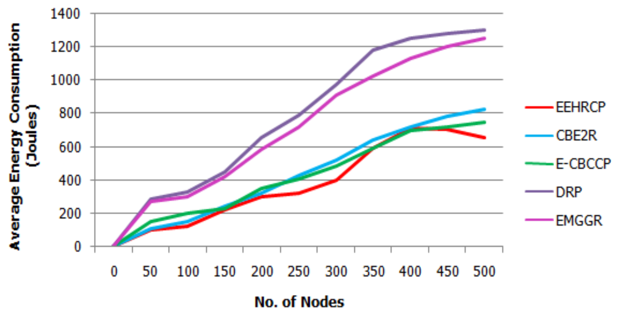

Figure 9: Average Energy Consumption vs. No. of Nodes

Average energy consumption can be defined as the average difference between the initial level and final level of energy in the nodes. From Figure 9 it is observed that for the DRP protocol, there is a steep increase in the avrage energy consumption and is maximum of the protocols. Compared to E-CBCCP and CBE2R protocols, the average energy consumption of EMGGR protocol is higher. On an average there is a decrease in 0.93% of energy consumption in the proposed protocol EEHRCP compared to CBE2R protocol. The energy consumption of EEHRCP is lower, as the energy levels of the nodes are preserved putting them in sleep mode. CBE2R makes use of powerful courier nodes to transfer data but the sensor nodes at the lower level may lose energy due to pressure and high water drift even though they do not take part in transmission process. The energy consumption of EMGGR is higher because it make use of complex grid calculation for selecting the next forwarding node and if the forwarder node leave the grid than the packets are dropped continuously which may also result in energy consumption. In DRP the node mobility is not monitered properly and the packets are dropped continuously if the nodes move out of the reach which results is energy consumption by the nodes without any successful transmission of data.

Table 6: Comparison Table for No. of Nodes vs. End-to-End Delay

No. of Nodes	End-to-End Delay (secs)				
	EEHRCP	CBE2R	E-CBCCP	DRP	EMGGR
0	0	0	0	0	0
50	10	11	12	14	13.5
100	8.5	9	11.8	13	12.5
150	6.2	7	11.5	12	10.5
200	4.8	5	10	11	8.5
250	4	4.5	8.5	9	7.2
300	3.6	4.2	8	8.5	7
350	3.8	4	7.8	8	6.9
400	3.4	3.8	7.5	7.8	6.5
450	3	3.4	6	7.3	6.3
500	2.5	3.2	5.5	7.2	5.8

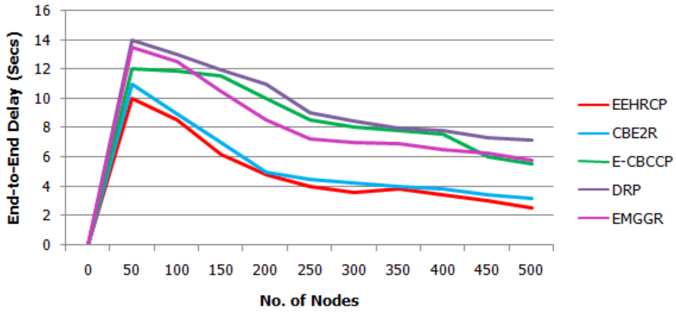

Figure 10: End-to-End Delay vs. No. of Nodes

End-to-End delay can be defined as average time taken by all the packets from different sources to reach the destination. From Figure 10 we can observe that the end to end delay of DRP protocol is maximum compared to EMGGR, E-CBCCP, CBE2R and EEHRCP protocols. There is 0.48 % decrease in end to end delay with the proposed EEHRCP protocol when compared to CBE2R protocol. Also it is observed that the end to end delay is minimum for EEHRCP protocol, among the other protocols considered in this research work. The end-to-end delay of EEHRCP is lower when compared with all other protocols since it uses an hybrid approach using optical communictaion channel where the packets are transfered at a higher speed and thus results in lower packet loss. As we know that the speed of light is faster than sound, all other protocols uses acoustic channel which results in increased delay.

Table 7: Comparison Table for No. of Nodes vs. Data Delivery Ratio

No. of Nodes	Data Delivery Ratio				
	EEHRCP	CBE2R	E-CBCCP	DRP	EMGGR
0	0	0	0	0	0
50	8.2	7.4	7.8	7.2	6.9
100	8.9	7.9	7.5	7.6	7.4
150	9	8.4	8.8	8.2	7.9
200	9.8	8.9	9	8.4	8.4
250	10	9.4	9.5	9.2	8.9
300	10.4	9.7	10.3	9.3	9.5
350	10.8	9.9	10.5	9.4	9.5
400	11.3	10	11	9.8	9.3
450	12	10.2	11.1	9.9	9.8
500	12.3	10.3	11.5	10	9.7

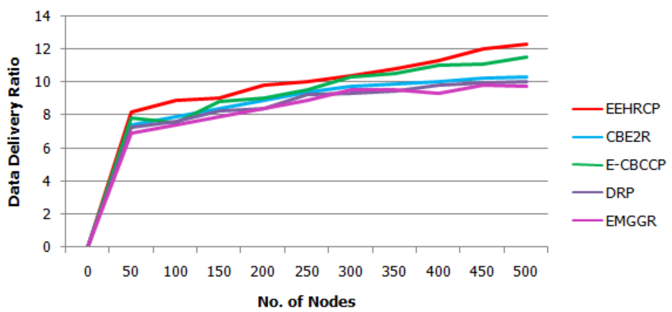

Figure 11: Data Delivery Ratio vs. No. of Nodes

In proposed protocol EEHRCP the nodes are divided into different sector and the CH is responsible for collecting the data from all sensor nodes and forwards it to the upper level towards the sink. The CH is active all the time monitoring the channel and whenever it finds the channel free it transfers it packets to the next level with high speed optical communication channel.

The data delivery ratio can be defined as ratio of packets generated to successfully deliver at the destination. Figurer 11 shown above provides simulation study of data delivery ratio and the number of nodes. The data delivery ratio is minimum for EMGGR protocol compared to all other protocols considered in this research. The data delivery ratio of EMGGR, DRP and CBE2R are almost constant. There is an increase in 0.95% of data delivery ratio using the proposed EEHRCP protocol compared to E-CBCCP protocol.

VI. CONCLUSION

The battery power of the nodes cannot be easily recharged in underwater environment so there is a need for an energy efficient routing protocol for UWSN. EEHRCP is an energy efficient routing protocol where the battery levels of the nodes are saved by making the nodes to sleep when they do not actively participate in the communication. The CH has to be active during the communication process which results in energy consumption so in the next cycle the node with highest residual energy is only selected as CH so as to reduce the average energy consumption. High speed underwater wireless transmission is achieved by using optical communication. But optical channel cannot be used deep inside the sea so EEHRCP uses a hybrid approach of optical- acoustic which results is high speed transmission for larger distances.

In this research work we study various network parameters like network throughput, network life time, average energy consumption, end to end delay and data delivery ratio for mobile nodes ranging from 50 to 500. It is observed that there is an average increase of 0.9% network throughput in the proposed EEHRCP protocol compared to CBE2R protocol. On an average, the network life time is increased to 51.2 seconds for the proposed EEHRCP protocol compared to CBE2R protocol. In EEHRCP every time the node with highest residual energy is only selected as the CH so that it has to remain active and monitor the cluster activities. On an average there is a decrease in 0.93% of energy consumption in the proposed protocol EEHRCP compared to CBE2R protocol.

The energy consumption of EEHRCP is lower, as the energy levels of the nodes are preserved putting them in sleep mode. There is 0.48 % decrease in end to end delay with the proposed EEHRCP protocol when compared to CBE2R protocol. Also it is observed that the end to end delay is minimum for EEHRCP protocol, among the other protocols considered in this research work. The end-to-end delay of EEHRCP is lower when compared with all other protocols since it uses a hybrid approach using optical communication channel where the packets are transferred at a higher speed and thus results in lower packet loss.

As we know that the speed of light is faster than sound, all other protocols uses acoustic channel which results in increased delay. The data delivery ratio is minimum for EMGGR protocol compared to all other protocols considered in this research. The data delivery ratio of EMGGR, DRP and CBE2R are almost constant. There is an increase in 0.95% of data delivery ratio using the proposed EEHRCP protocol compared to E-CBCCP protocol.

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