Performance Analysis of AODV Routing protocol in Optical Underwater Sensor Network

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Abstract— Underwater Wireless Sensor Network have applications in Marine Monitoring, Seismic Surveillance, Underwater environment pollution control and various others. In this work we have used a commercial software, Qualnet, which is a discrete event simulator, to simulate a simple network to analyze parameters like average jitter, end-to-end delay etc. for the same. The parameters are analyzed for a network of 100 nodes. The data is routed according to the AODV routing protocol of the network layer and the physical layer is customized with parameters to work with optical links with various data rates for underwater settings.

Keywords—*Underwater Optical Communication, Underwater channel modelling, AODV, Qualnet Simulator 5.0*

I. INTRODUCTION

The Underwater Communication poses different challenges as compared to the communication in terrestrial sensor networks due to harsh environmental settings. While RF can be used as a communication link on the land, it is highly attenuated inside water, thereby not feasible. Currently the most mature technology for the marine environment is the acoustic mode of communication, but it also poses limitations like low data rate [1]. So, to send heavy data like videos, audios etc. optical links are being explored which provide the benefit of higher data rates and faster communication though in a small range [2-11]. To study the performance of a network, we use Qualnet 5.0 as our simulator out of all the various simulators which are available. Since underwater environment are not compatible with built-in protocols of Qualnet protocol stack, we attempt to model the underwater channel for optical links and modify the Qualnet version 5.0 to work with the same scenario. Subsequently study the performance of AODV routing protocol on that network.

II. WORKING ENVIRONMENT

A. Qualnet 5.0 Simulator

QualNet is a network simulator which provides a comprehensive environment for designing protocols, creating and animating network scenarios, and analyzing their performance. It also provides a set of tools with all the components for developing a custom network and for its reliable simulation. QualNet has significantly higher speed, better scalability and fidelity as compared to other network simulators[10]. Its works with a protocol stack which includes the following layers:

- Application Layer: The Application Layer is responsible for traffic generation and application level routing. Protocols written at the Application Layer rely on the Transport Layer to deliver application-level data from the source to the destination. Application Layer protocols implemented in QualNet are Constant Bit Rate (CBR), FTP, and Telnet. Examples of Application Layer routing protocols implemented in QualNet are RIP, Bellman-Ford, and BGP.

- Transport Layer: The Transport Layer provides end-to-end data transmission services to the Application Layer. Protocols written at the Transport Layer receive data from the Application Layer and rely on the Network Layer for data forwarding at the source node, and receive data from the Network Layer and pass data to the Application Layer at the destination node. Examples of Transport Layer protocols include UDP, TCP and RSVP-TE.

- Network Layer: The Network Layer is responsible for data forwarding and queuing/scheduling. The Internet Protocol (IP) resides at this layer and is responsible for packet forwarding. Examples of Network Layer routing protocols implemented in QualNet are AODV, DSR, OSPF, and DVMRP.

- MAC Layer: The Link (MAC) Layer provides link-by-link transmission. Examples of protocols at the Link (MAC) Layer implemented in QualNet are point-to-point, IEEE 802.3, IEEE 802.11, and CSMA.

- Physical Layer: The Physical Layer is responsible for transmitting and receiving raw bits from the wired and wireless channel.

- Communication Medium: The communication medium transmits signals between nodes. In QualNet, a communication medium model has three components: a path loss model, a fading model, and a shadowing model. Path loss models in QualNet include Free Space, Two Ray, and Irregular Terrain Model (ITM). QualNet implements the Ricean fading model. Rayleigh fading is a special case of Ricean fading. QualNet provides models for two shadowing models: constant and lognormal.

B. Network architecture and Specifications

The sensor network is architectured using the GUI of the Qualnet and its properties are specified in Table I. The complete network is placed onto a cartesian coordinate plane i.e 200 × 200 has altitude ranging from 0 m above sea level to

100 m below sea level. One optical channel is considered for communication and its frequency is given as 560 THz, since it is the frequency of green light (λ=490 nm) which is generally used as the source LED in pure sea and clear ocean [11]. The modelling of communication medium is done by specifying Pathloss, Shadowing and Fading Model. For our work, we have chosen Fading model as 'Ricean model', Pathloss model as 'Two Ray' model and the shadowing model as 'None'. According to the results from [11], we choose the Maximum Propagation Distance which is the maximum distance for which a node's transmission is considered for communication, as 50m. Similarly, for medium speed optical communication i.e 1-2 Mbps, [6] states that the communication distance is 30-60 m. Therefore, we take the propagation communication proximity, which is the approximate optimistic optical communication range, as 40m.

Mobility model is considered as the nodes in the water body are subjected to movement due to the turbulence in the environment. Therefore, we take the mobility model as the Random Waypoint model. The corresponding parameters are mentioned in the Table I. We have chosen the position granularity i.e the distance by which node moves 1mm in a single step for a simulation of 5 days. The network works on different protocols for different layers. While Network layer uses IPv4 and MAC layer uses CSMA, the Routing protocol chosen is AODV (Ad-Hoc On Demand Distance Vector). Network architecture consists of 100 nodes. Subsequently, the parameters of network communication are analyzed for these networks. The following figure shows the architecture of the network.

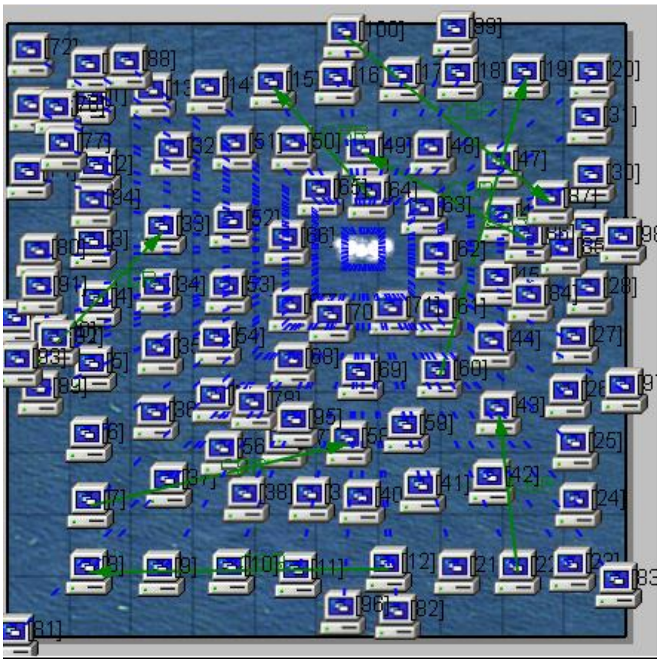

Fig. 1 Network Architecture with 100 nodes in 2D

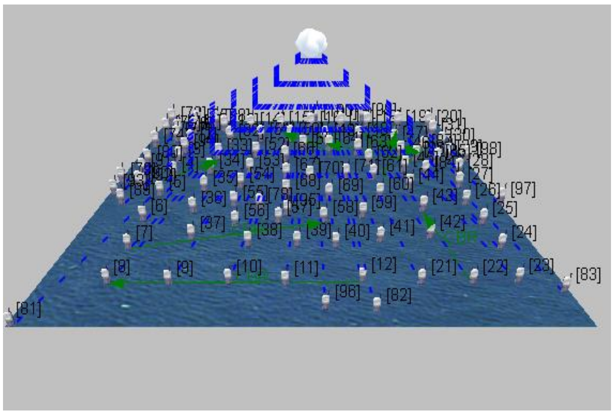

Fig. 2 Network Architecture with 100 nodes in 3D

The nodes are specified with the parameters mentioned in Table-I. All the nodes are randomly placed on the cartesian plane resembling the real time scenario, connected in a wireless subnet. The communication takes place in this subnet from source node to the destination node. These source and destination are identified by the CBR links ends. Constant Bit rate (CBR) is an application layer protocol which acts as a traffic generator. It is a UDP based client server application, data is sent from a client to server at a Constant Bit Rate. We have used UDP over TCP as it does not have much overhead unlike latter, therefore for the resource constrained embedded designs it is better to be used.

Table I: Network specifications

1.	Scenario Properties–> General	Value
1.a	Simulation Time	5 days
1.b	Real Time	45 minutes
1.c	Background Image	GUI image of water
2.	Scenario Properties–> Channel Properties	
2.a	Coordinate System	Cartesian X=200m Y=200m
2.b	Altitude Range (in m)	Above Sea level=0 Below Sea level=100
2.c	Weather Mobility Interval	100 msec
2.d	Number of Channels	1
2.e	Channel Frequency	560 THz
2.f	Pathloss Model	Two Ray
2.g	Shadowing Model	None
2. h	Fading Model	Ricean
2.i	Propagation limit	16.53 dBm
2.j	Maximum Propagation	See Table II

	Distance	
2.k	Propagation Communication Proximity	See Table II
3.	Node Properties–> Mobility and Placement	
3.a	Mobility Waypoint	Random Waypoint
3.b	Pause Time	2 min
3.c	Minimum Speed	0 m/sec
3.d	Maximum Speed	0.1 m/sec
3.e	Position Granularity	0.001 m
4.	Network Layer Protocol	IPv4
5.	Routing Protocol	AODV
6.	Subnet Properties–> Physical Layer	
6.a	Radio Type	Abstract
6.b	Data Rate [6]	Case 1: 10 Mbps Case 2: 2 Mbps Case 3: 100 Kbps
6.c	Transmission Power	20 dBm
6.d	Reception Sensitivity	0 dBm
6.e	Reception Threshold	-40.76 dBm
6.f	Packet Reception Model	SNR based Reception Model
6.g	SNR threshold	10 dB
6. h	Temperature	305 K
6.i	Noise Factor	0 dB
6.j	Energy Model	Mica-Motes

The above data has been taken to construct a network scenario. Maximum Propagation Distance is the maximum distance for which a node's transmission is considered for communication. Similarly, Propagation Communication Proximity should be set to the approximate range.

Table II: Range based on Transmission Rate

Transmission Rate	Maximum Propagation Distance	Considered Propagation Communication Proximity [6]
10 Mbps	Infinite	30 m
2 Mbps	Infinite	50 m
100 Kbps	Infinite	80 m

III. EVALUATED NETWORK MODELS

The specifications are used to characterize network considered. The effect on the network performance parameters like Average Jitter and End to End delay. The network has the nodes that make up a subnet with the all the details about each layer and its protocol specifically defined.

Since the transmission power is taken as 20 dBm which is equal to 0.1 W as it is the lowest value of LED source power [11]. Corresponding to this value we calculate the propagation limit of the scenario. It is the threshold power below which the signal is not delivered to the nodes. This parameter is meant for optimizing the performance. We calculate it using the Beer-Lambert's law as follows.

$$I(z) = I_0 \exp(-c(\lambda)\cdot z) \quad (1)$$

where,

z = distance from source at which signal power needs to be calculated = 40 m

λ= wavelength of source light =490 nm (to be used for pure sea and clear ocean water) [12-13]

$c(\lambda)$=attenuation coefficient = 0.02 m^{-1} (for λ=490 nm)[11]

I_0 = Transmission power of LED= 0.1W

Therefore, we get 0.045 W= 16.53 dBm.

At the application layer the CBR is defined between 8 node pairs to study the network. It defines us the source node of information and the destination node. All the rest nodes are the part of the subnet and may act as hops for the information transferred.

Table III: CBR Links

Source Node	Destination Node	Number of Hops
Node 7	Node 8	1
Node 12	Node 8	1
Node 22	Node 43	0
Node 60	Node 19	2
Node 64	Node 15	0
Node 86	Node 49	1
Node 92	Node 33	0
Node 100	Node 87	0

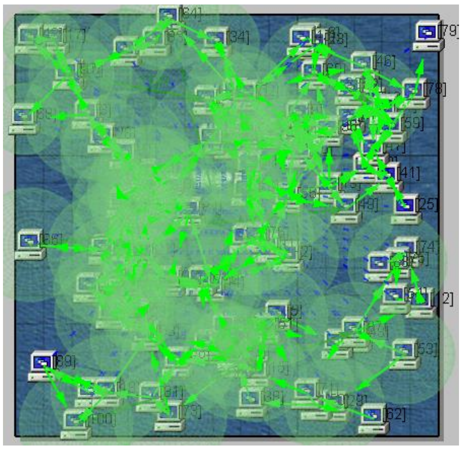

Fig 3. Information transfer in the subnet

IV. RESULTS AND PERFORMANCE ANALYSIS

We perform the simulation for the network with 8 CBR links which characterize a constant bit rate route from source to destination.
The CBR client description is as follows.

Table IV: CBR Client details

Bytes Sent	12000
Packets Sent	24
Throughput (bits/sec)	4000

Corresponding to this we have the CBR server which shows the parameters i.e. Average jitter and End to End delay of the nodes.

The CBR server evaluated results are as follows:

Table V: Case 1: Data Rate = 10 Mbps

Propagation Distance	Average Jitter	Average End to End Delay
20 m	0.0017	0.011
50 m	0.0026	0.024
100 m	0.0058	0.065
150 m	0.0138	0.09
200 m	0.0221	0.13

Table VI: Case 2: Data Rate = 2 Mbps

Propagation Distance	Average Jitter	Average End to End Delay
20 m	0.0017	0.012
50 m	0.0019	0.024
100 m	0.0037	0.038
150 m	0.0088	0.069
200 m	0.014	0.098

Table VII: Case 3: Data Rate = 100 Kbps

Propagation Distance	Average Jitter	Average End to End Delay
20 m	0.0018	0.0116
50 m	0.0019	0.019
100 m	0.0019	0.024
150 m	0.0042	0.0368
200 m	0.008	0.054

The above tables show the values of parameters that describe the link formed between source and destination. The average jitter and the end to end delay are studied and plotted for various data rates in Fig 4. and Fig 5.

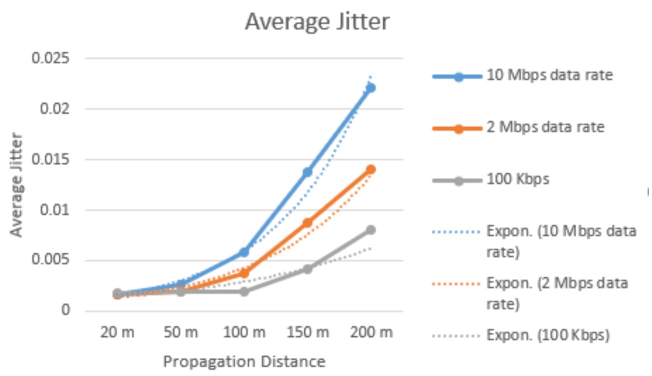

Fig 4. Average jitter vs propagation distance (range)

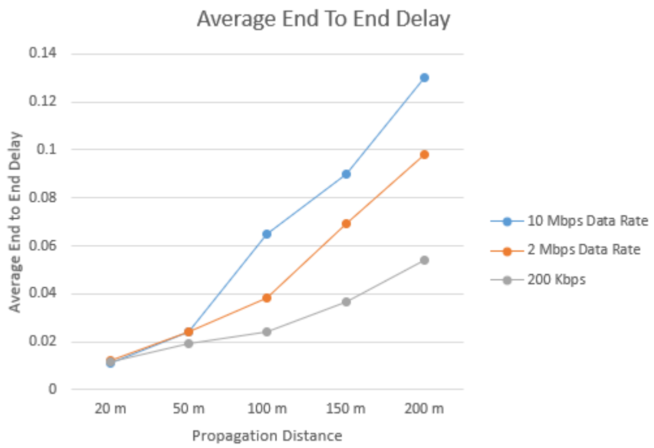

Fig 5. Average End to End Delay vs propagation distance (range)

V. CONCLUSION

This paper focuses on analyzing performance parameters of an AODV based Optical Underwater Wireless Sensor network. Previously work have been done to analyze the performance

AODV routing protocol in terrestrial network but subjecting it to underwater environment helps study it better. Therefore, we have characterized the network as the underwater sensor network and then studied the parameters like average jitter and end to end delay. This has been done for various propagation distances each for the data rate 10 Mbps, 2 Mbps and 100 kbps. Studying the results, we can say that as the we increase the propagation distance the average jitter and the end to end delay increase more rapidly for higher data rates as compared to lower ones. So, we can conclude that, in order to get an optimized network and an efficient system, we should use higher data rates for smaller communication range and lower data rates for longer range communication range. Since higher data rates i.e in Mbps mean more information transfer, so when we need heavy data that is needed to be transferred we can use short range optical communication.

VI. REFERENCES

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