CHAPTER-2
LITERATURE SURVEY

Underwater Wireless Sensor Network has been an upcoming area of research for quite some time. A lot of research is going on in this domain since it has major applications ranging from oceanography to early warning systems for natural disasters (like tsunamis), ecosystem monitoring, oil drilling, and military surveillance. With these areas being of prime importance, researchers are rigorously working to study Wireless sensor networks in the marine settings. A few of the works which have been read and consulted are given below.

2.1 *Channel Modelling*

Communication Channel needs to be modelled for wireless communication between the nodes. Following literature have been studied for the channel modelling both acoustic and optical.

2.1.1 Acoustic Channel Modelling

Andrej Stefanov and Milica Stojanovic, 2011, analyzed the performance of underwater acoustic ad-hoc networks in the presence of interference. The node-to-node channel was modeled using frequency dependent path loss and Ricean fading. They adopted a communication theoretic approach and studied the sustainable number of hops through the network as an indicator of the network connectivity, as well as power and bandwidth requirements. They showed that a desired level of connectivity can be achieved through a judicious selection of the operating frequency, power and bandwidth. Subsequently, they proposed a hierarchical underwater acoustic sensor network architecture in which the sensors and the collector stations operate in distinct layers. The hierarchical architecture is supported by the property of the acoustic underwater transmission medium that for each transmission distance there exists an operating frequency for which the narrowband signal-to-noise ratio is maximized. The sensors and the collector stations are consequently allocated different operating frequencies.

We assume a uniform distribution of both sensors and collector stations over the finite area of the sensing field, and model the channel accordingly. The analysis was performed under the assumption that there is interference from other nodes within the same layer of the hierarchy. Numerical examples illustrate the network performance and demonstrate that the preferred operating frequencies ensure network operation without any cross-interference between the collector network and the sensor network.

Yang Guan et al. 2010, presented a simulation of an underwater acoustic network using the exact same parameters and architecture that was used in an experiment named 'KAM08', conducted in Hawaii 2008. It used the network simulator QUALNET extended with two functional blocks namely "SNR look up" and "SNR BER Converter" to serve as acoustic channel simulation model at the physical layer. This work proposed an adaptive modulation scheme proposed here takes both energy efficiency and loss rate of frames in consideration and choose higher rate modulation for the purpose as it has the advantages of low frame loss rate and high SNR value.

2.1.2 Optical Channel Modelling

Filippo Campagnaro et al. 2017, presented an optical channel model that is based on samples of the total attenuation coefficient and of solar light irradiance taken during the NATO STO CMRE ALOMEX’15 scientific cruise, in different water conditions. The data set includes both strong and mild solar illumination conditions, as well as several different settings for the light absorption and scattering coefficients. We implement the model as part of the DESERT Underwater network simulator, and employ it to show that the throughput of underwater optical links depends not only on the distance between the transmitter and the receiver, but also on the depth at which the devices are deployed. The corresponding insight is empirically validated in dry tests and lake experiments using a proof-of-concept optical modem and helped drive the next stage of the modem development.

Hemani Kaushal et al 2016, focused on understanding the feasibility and how reliable is the high speed optical wireless communication because of various propagation phenomenon that have an impact on the how well the system performs. Apart from giving details about the recent advancements in this field of UWOC, it also studies the channel characterization, modulation schemes, coding technique etc. It also presents a hybrid approach that is acoustic and opto-communication system.

Zhaoquan Zeng, 2015 in his thesis presents a survey of wireless communication taking place underwater with the help of light as the carrier. First it studies all the methods to exchange information among deployed nodes underwater and the compares them with optical mode and how the latter overcome their limitations. The other modes are RF and Acoustic. It also proposes many areas of application of UWSN using optical link, like environmental monitoring, marine life study etc. Along with this, potential limitations of O-UWSN is also discussed like scattering, dispersion, short range etc. They provide a survey of many aspects of O-UWSN like channel modelling, channel modulation, and error detection coding techniques.

Shijian Tang et al. 2014 analyzed the optical characteristics of seawater and presented a closed-form expression of double Gamma functions to model the channel impulse response. The double Gamma functions model fitted well with Monte Carlo simulation results in turbid seawater such as coastal and harbor water. The bit-error-rate (BER) and channel bandwidth were further evaluated based on this model for various link ranges. This provided a plausible and convenient way to evaluate the system performance such as BER and bandwidth based on this simple closed-form model of impulse response.

Zahir Uddin Ahmad, 2013, in his thesis attempted to improve the underwater optical communication in terms of its range, by using multihopping technique. For the work, a cheap communication prototype using “off the shelf” components, such as a microcontroller, optoelectronics etc., was also built for demonstration purpose. More they have also developed a directional MAC protocol has considering the directionality of light propagation. The work validated that the multi-hop approach is a viable solution to improve the communication ranges for O-UWSN.

Laura Johnson et al. 2013, presented a survey of channel modeling schemes has been for underwater optical wireless communications, with reference to variable water composition, variable refractive index and the presence of additional light sources. It was found that numerical solutions to the radiative transfer equation (RTE) provided the best description of the state of a light beam further along the channel by including temporal and spatial distributions of light, as well as polarization.

John W. Giles and Isaac N. Bankman 2005, discussed the basic design issues for underwater optical communications systems. They also consider the effects of environmental noise such as background solar radiation, which typically limits performance of these systems. Also, light sources which show promise for underwater optical transmitters such as laser diodes (LDs) and light emitting diodes (LEDs) are also discussed.

Dansgaard and P. M. Grootes, 1989, devised equations using Monte Carlo calculations, to predict underwater scalar irradiance as a function of depth, solar irradiance, and zenith angle at the surface, and absorption coefficient and ratio of scattering to absorption coefficients in the water. The equations correct for the depth dependence of the attenuation coefficient near the surface, and they predict scalar irradiance to within an error of < 10%.

2.1.3 Opto-Acoustic Channel Modelling

Jingjing Wanga et al. 2017, proposed an optimal hybrid network of optical and acoustic integrated underwater wireless sensor network. They devised a four-tier model to determine that which type of communication link should be setup between the nodes. These levels depicted are based on the SNR level that is received by the receiving node when data is sent by transmitter. The first three levels namely high speed, medium speed and low speed communication use optical mode to communicate because the SNR levels are significant. But when the communicating nodes are not able to exchange information due to very low SNR, then we use acoustic communication. Otherwise in general purposes, for closer ranges use high speed optical communication and for sending the control commands downlink from sink to source nodes, use acoustic communication. A reverse routing protocol was devised to improve the network life cycle and to adapt to all the changes that happen in network topology. This paper proposed a solution to transmit the real-time videos and images over high-speed links for marine exploration.

Seongwon Han et al. 2014, explored the properties of both underwater acoustic and optical communications. Using the simulation results, they determined that acoustic communication was well suited for transmitting small amounts of data over large distances, or to align nodes to prepare for optical communications. It proposed the concept of a hybrid system where a node is equipped with both acoustic and optical modems which outperforms the case in which only the acoustic modem is used from both throughput and energy consumption perspectives. The performance gain from the acoustic modem is seemingly negligible in some cases. As the attenuation of the optical modem depends greatly on the water conditions like transmitting data via optical modem would be virtually impossible in turbid waters. For such cases, despite the high energy consumption and slow data rates, the acoustic modem would be necessary to ensure that the data is transmitted.

2.2 *Node Localization*

Hong Li et al. 2015, studied about the aspect of security and privacy in localization for Underwater Sensor Networks. As the UWSN is used in various applications like pollution monitoring, offshore exploration and oil /gas spill monitoring. For every purpose the location of the nodes needs to be configured. For this we use underwater localization schemes. First is location related information collection phase, second is position estimation phase. There are many security loopholes in a WSN, which the attackers can exploit to interfere with localization process, which could lead to serious consequences in critical applications like military monitoring. This paper discusses the security and privacy issues in localization of underwater sensor networks and then it discusses few secure and privacy preserving localization schemes and discuss their suitability for UWSN.

Zhong Zhou et al. 2011 proposed a scheme, called Scalable Localization scheme with Mobility Prediction (SLMP), for underwater sensor networks by utilizing the predictable mobility patterns of underwater objects. In SLMP, localization is performed in a hierarchical way, and the whole localization process is divided into two parts: anchor node localization and ordinary node localization. During the localization process, every node predicts its future mobility pattern according to its past known location information, and it can estimate its future location based on the predicted mobility pattern. Anchor nodes with known locations in the network will control the localization process to balance the trade-off between localization accuracy, localization coverage, and communication cost. We conduct extensive simulations, and our results show that SLMP can greatly reduce localization communication cost while maintaining relatively high localization coverage and localization accuracy.

Melike Erol et al. 2007 addressed the localization issue in Underwater Sensor Networks (UWSNs). They proposed Dive'N'Rise (DNR) Positioning, the novel idea of using DNR beacons for localization. These beacons get their coordinates from GPS while floating above the water, then they dive into water. While sinking and rising, they broadcast their positions. Sensor nodes are localized by passively listening to DNR beacon messages which reduces the communication cost and the energy consumption. They analyzed localization success and error for static and mobile UWSNs.

Vijay Chandrasekhar et al. 2006, surveyed the different localization algorithms that can be applied to the domain of UWSNs. Localization for terrestrial sensor networks has been studied in detail. However, the problem of localization in underwater sensor networks poses a new set of challenges because of the acoustic transmission medium. Since employment of GPS is not feasible for underwater scenarios, the localization algorithms used for UWSNs can be broadly classified into range-based and range-free schemes. Range schemes include infrastructure based localization scheme, distributed positioning scheme and schemes with mobile nodes/beacons. While the Range free localization algorithms comprise of all hop count based, centroid and area based schemes. The different schemes are compared, and their advantages and disadvantages discussed.

2.3 *Routing Protocols*

Nadeem Javaid et al.2017, worked in cooperative routing in Underwater WSN. The multihop communication was the topic of interest, in which the data received by sink from the source via relay is acknowledged depending on bit error rate. A re-transmission is demanded if bit error rate is below threshold. The channel is Rayleigh faded. The work discussed two possibilities of relay method, the first is the Amplify and Forward (AF) in which the received signal is amplified by the relay node and is forwarded to the destination node. While in the second one, noisy version of received signal is decoded by relay and then forwarded to destination node. The protocol used works in two phases. First phase, is the set up phase in which each node after it gets deployed, shares its ID, depth, Residual energy and SNR of link by a broadcast message within its transmission range. Received Signal Strength Indicator is used as location finder. Neighbors are identified using this. After this, a path is established between source and sink involving Relay Node. The second phase is the steady state phase. The work draws a comparison between RBCRP (Region based cooperative routing in UWSN) and existing IBRT (Incremental Best Relay Technique) and shows that former is better than latter in the terms of throughput and network lifetime.

Petrika Gjanci et al. 2017, worked to devise an algorithm for finding a path which gives maximum value of information in a multimodal UWSN. The transfer of information takes place from the sensor nodes to the sink node via an Autonomous Underwater Vehicle. The AUV develops an optical link with the node to fetch the data while the communication between the nodes is acoustic. It then comes to the surface to transfer gathered information to the collection point. But the path is to be found out such that maximum 'Value of Information' is delivered to the sink by the AUV. The algorithm that has been used is Greedy and adaptive AUV path finding [GAAP]. The value of information with time as we know that the event loses it importance with time from the recorded time of its occurrence.

The observation of their simulation work revealed that the algorithm GAAP was 80% more efficient as compared to OPT in terms of maximum value of information, when a scenario of 4 to 35 nodes is considered. The simulation environment used was SUNSET and a freely available software Gurobi.

G. Han et al. 2015, provided the comparison between various routing protocols used for Underwater WSN. They have classified the protocols into three broad categories. First is, Energy-based routing which is an Energy Optimized Path Unaware Layered Routing Protocol (E-PULRP). The whole network is divided into layers with each node of a layer allowed to communicate to sink via equal number of hops. In the communication through multihopping, the choice of relay nodes is based on the latter's distance from the sink node i.e node, closer to the sink and significantly away from source becomes the next hop. The lifetime of network increases by allowing non-active nodes to sleep. But in this protocol the mobile nature of nodes is not considered, therefore making it unsuitable for real time underwater applications. Another energy based protocol is QELAR which is specifically suitable for mobile UWSNs. However, this demands the nodes to keep a lot of information in store due to the Q-Learning algorithm it uses, therefore, it is not possible to apply QELAR on a large scale UWSNs. Second category is Geographic information-based routing. It is the position or location based routing approach is also used in various protocols which continuously updating of the location of the neighbouring nodes is done to communicate data. Different protocols like Hop-by-Hop Dynamic Addressing Based (H2-DAB), Depth-Based Routing (DBR) and Delay Sensitive Depth-Based Routing (DSDBR) protocol have been discussed. Third category is Hybrid Routing protocol. Comparison between all the three categories have been drawn in this work.

Vinod Kumar Verma et al. 2014, evaluated one of the commonly used proactive protocol–Ad hoc on demand distance vector. They proposed an improved assessment about the AODV protocol over different terrain condition like attitude above & below sea level etc. Here in the paper the performance of AODV protocol is judged on the basis of different layer's performance of network model like Application, MAC, Transport, physical layer as well as Battery model in its association. Also, it is contributing towards the assessment parameters as byte delivery fraction at client & server side, No. of packet dropped, no. of beckon received and synchronous loss in the consideration with various energy models in its association. This paper is presented to aid the researchers for their assessment towards the behaviour of proactive type of routing protocol. The simulation results showed the temporal assessment of AODV routing protocol under proposed real time constraints.

Vinod Kumar Verma et al. 2013, presented preliminary work to address scalability concern over AODV protocol in wireless sensor network. Firstly, they discussed the scalability design issues with related work in context of wireless sensor networks (WSN). Following, they designed and illustrated wireless sensor network model. Finally, significance of scalability on the behaviour of application, MAC, transport and physical layer performance are described.

Muhammad Ayaz et al. 2011, conducted a survey on routing techniques in underwater wireless sensor networks. When we deploy a UWSN, there are various levels of nodes. The fixed nodes are placed on sea beds, mobile nodes within water and sink node up at the surface level. As the distance between the deepest level nodes are floating nodes is larger, multi hop has to be used for communication. Thereby to make this happen the optimal route of transfer of information is to be found out, which is done by define a routing protocol. This paper conducts a survey of various routing protocols and provides a comparison.

Naveed B. Qadri & Ghalib A. Shah et al. 2010, analyzed the performance of ad-hoc routing protocols in underwater acoustic network environment. Acoustic propagation in water is characterized by high and variable delays, fading effect, Doppler spread and multi path which in turn lead to a limited bandwidth and high error rates. Also, battery life and storage capacity of nodes is limited. So, to overcome these limitations and make communication in underwater networks viable, they used performance metrics like packet delivery ratio, average end-to-end delay, throughput, routing overhead and energy consumption of the sensor nodes. AODV, DSDV, DSR and OLSR were compared for their performance at different traffic conditions, number of nodes and depths. From simulation results they concluded that among the discussed protocols, AODV could be used for denser networks but with less traffic and DSDV is suitable for higher traffic conditions with optimal number of nodes.

2.4 *WSN Surveys*

Shu Yinbiao et al. 2015, in a white Paper for IEC, present the use and evolution of WSNs is discussed within the wider context of IoT. A review of WSN applications has been done, with a focus on infrastructure technologies, standards and applications featured in WSN designs. This paper also discusses the challenges and future trends in WSN.

V.P. Dhviya et al 2014, analyzed various Simulation Tools for Underwater Wireless Sensor Networks. The study of simulators is important because they have been devised to ease the system design and cut down cost of making huge hardware testbeds. There are three kinds of simulation techniques - Monte Carlo Simulation, Discrete-Event Simulation and Trace-Driven Simulation. This paper compares various simulation tools available which allow the programmer to mimic the underwater scenario and simulate the desired wireless networks. The simulators have been compared based on availability in market, scalability, user friendly interfacing, GUI availability, number of available protocols etc.

Guobao Xu et al. 2014, provided a comprehensive review of the state-of-the-art technologies in the field of marine environment monitoring using wireless sensor networks. It described application areas, a common architecture of WSN-based oceanographic monitoring systems, a general architecture of an oceanographic sensor node, sensing parameters and sensors, and wireless communication technologies.

2.5 *Summary of Related Work*

Table 2.1 summarizes the important literature read and studied related to the work.

Table 2.1 Summary of Literature read

S.No.	Name of Paper	Publisher	Description
1.	Design of optical-acoustic hybrid underwater wireless sensor network (Jingjing Wanga et al. 2017)	Journal of Network and Computer Applications-Elsevier	Proposed an optimal hybrid network of optical and acoustic integrated underwater wireless sensor network. They devised a four-tier model (based on SNR) to determine that which type of communication link should be setup between the nodes.
2.	Underwater Optical Wireless Communication (Hemani Kaushal and Georges Kaddoum 2016)	IEEE Access	Studied the channel characterization, modulation schemes, coding technique etc. Presented a hybrid approach that is acoustic and opto-communication system.
3.	Routing Protocols for Underwater Wireless Sensor Networks (G. Han et al. 2015)	IEEE Communications Magazine	Provided the comparison between various routing protocols used for Underwater WSN.
4.	Security and Privacy in Localization for Underwater Sensor Networks (Hong Li et al. 2015)	IEEE Communications Magazine	Discussed the security and privacy issues in localization of underwater sensor networks and then it discussed few secure and privacy preserving localization schemes and studied their suitability for UWSN.
5.	Evaluation of Underwater Optical-Acoustic Hybrid Network (Seongwon Han et al. May 2014)	China Communications	It proposed the concept of a hybrid system where a node is equipped with both acoustic and optical modems which outperforms the case in which only the acoustic modem is used from both throughput and energy consumption perspectives.
6.	A Survey of Channel Models for Underwater Optical Wireless Communication	IEEE- International Workshop on Optical Wireless	A survey of channel modeling schemes has been presented for underwater optical wireless communications, with

	(Laura Johnson et al. 2013)	Communications (IWOW)	reference to variable water composition, variable refractive index and the presence of additional light sources.
7.	Design and Performance Analysis of Underwater Acoustic Networks (Andrej Stefanov and Milica Stojanovic et al. 2011)	IEEE Journal on Selected areas in Communications	Analyzed the performance of underwater acoustic ad-hoc networks in the presence of interference. They also showed that a desired level of connectivity can be achieved through a judicious selection of the operating frequency, power and bandwidth.
8.	A Survey of Routing Techniques in Underwater Wireless Sensor Network (Muhammad Ayaz et al. 2011)	Journal of Network and Computer Applications- Elsevier	Presented an overview of state of the art of routing protocols in UWSN. They concluded that each of the protocols has some definite strengths and weaknesses, and suitability for specific situations.
9.	Simulation of Underwater Acoustic Networks with Field Measurements (Yang Guan et al 2010)	IEEE Oceans conference	Presented a simulation of an underwater acoustic network using the exact same parameters and architecture that was used in an experiment named 'KAM08', conducted in Hawaii 2008. Simulator used was Qualnet.
10.	Localization in Underwater Sensor Networks − Survey and Challenges (V. Chandrasekhar et al 2006)	WUWNET	Range schemes including infrastructure-based localization scheme, distributed positioning scheme and schemes with mobile nodes/beacons are discussed and compared for Underwater WSN.
11.	Underwater Optical Communications Systems Part 2: Basic Design Considerations (John W. Giles and Isaac N. Bankman)	IEEE 2005	Discussed the basic design issues for underwater optical communications systems. Also consider the effects of environmental noise and the optical transmitter and receiver.

The work referred cover most of the domains underwater wireless communication. Both optical and acoustic communication between sensor nodes has been focused upon. Along with this the channel modelling has been done for the marine environment according to its behavior for the types of communication links. Node localization has also been studied for efficient link setup. Lastly, the work on Qualnet as the simulator has been thoroughly read for better understanding about the software.