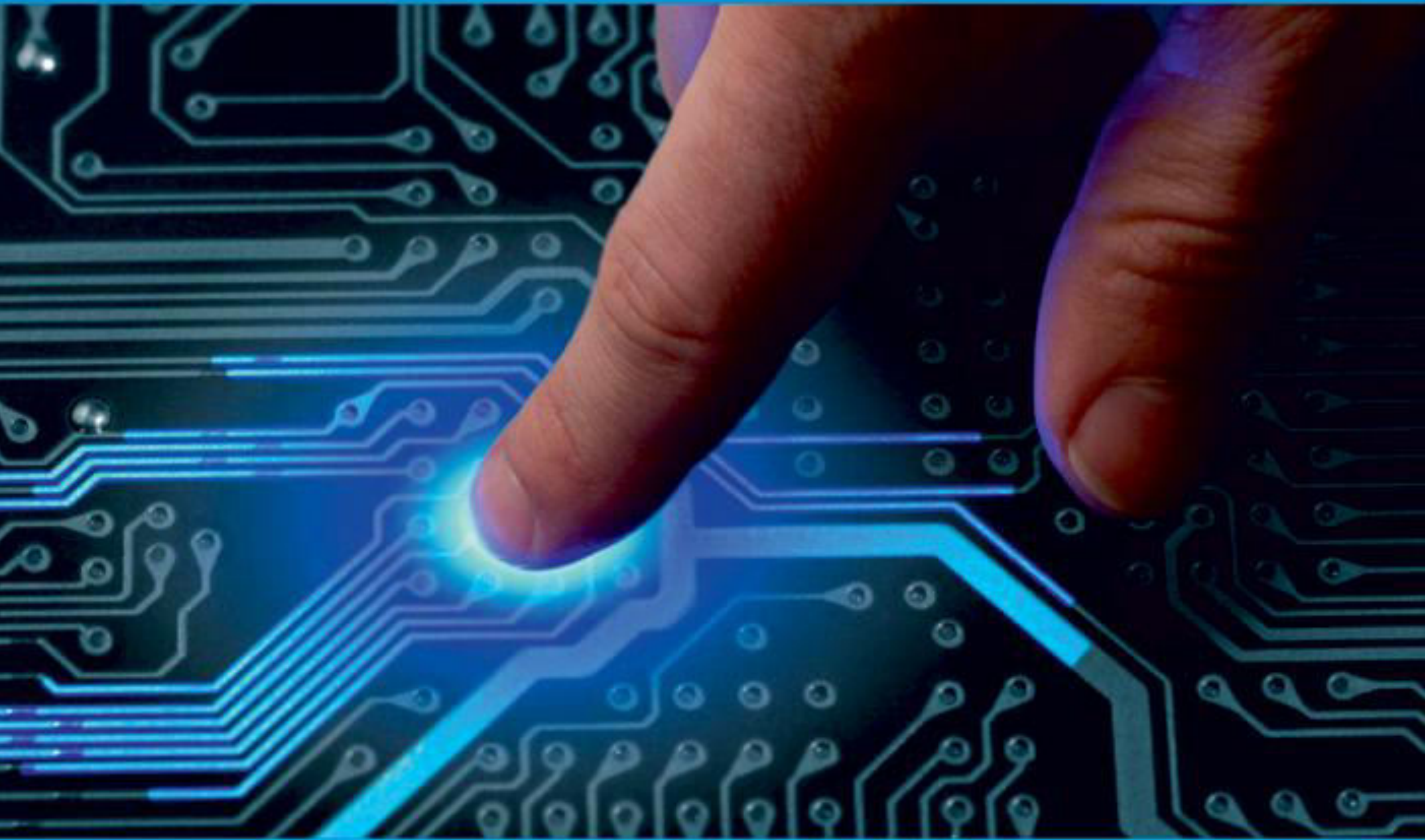
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 9, Issue 6, June 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.542

9940 572 462 | 6381 907 438 | ijircce@gmail.com | www.ijircce.com

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

Underwater Wireless Communication using Acoustic & Optical waves

Vedant More[1], Deon Gracias[2], Naitik Arya[3], Harsh Wakode[4], Ayush Singh[5], Chintamani Chavan[6]

UG Students, Dept. of I.T., Thakur Polytechnic, Mumbai, India[1,2,3,4,5]

Lecturer, Dept. of I.T., Thakur Polytechnic, Mumbai, India[6]

ABSTRACT: The increasing exploitation of natural resources under water, particularly within the sea, has ignited the event of the many technological advances within the domains of environmental monitoring, oil and gas exploration, warfare, among others. altogether these domains, underwater wireless communications play a crucial role, where the technologies available believe radiofrequency, optical, and acoustic transmissions. Underwater wireless information transfer is of great interest to the military, industry, and therefore the scientific community, because it plays a crucial role in tactical surveillance, pollution monitoring, oil control and maintenance, offshore explorations, global climate change monitoring, and oceanography research. To facilitate of these activities, there's a rise within the number of unmanned vehicles or devices deployed underwater, which require high bandwidth and high capacity for information transfer underwater. Although tremendous progress has been made within the field of acoustic communication underwater, however, it's limited by bandwidth. This paper surveys key features inherent to those communication technologies, putting into perspective their technical aspects, current research challenges, and to-be-explored potential.

KEYWORDS: Underwater Wireless Communication, Multipath, Acoustic waves.

I. INTRODUCTION

The present work summarizes the recent advances in channel modelling and system analysis and design in underwater wireless communications (UWC). UWC has gained a substantial interest during the last years as an alternate means for broadband inexpensive submarine communications.

This technology supports, relatively, low data rates for medium distances and doesn't make sure the link security. Furthermore, the knowledge signal delay is sort of increased. it's a legacy technology, and albeit it works at long distances, it can only establish low speed transmissions.

In the previous couple of years, the interest towards optical wireless communication has increased for terrestrial, space and underwater links because it can provide high data rates with low power and mass requirement. Many researchers have administered work for terrestrial and space links [1]– [6], however underwater optical wireless links are relatively less explored because it is tougher than atmospheric links.

Underwater wireless communications present new and distinct challenges in comparison to wired and wireless communications through the atmosphere, requiring sophisticated communication devices to realize relatively low transmission rates, even over short distances. Indeed, the underwater environment possesses variety of distinguishing features that make it unique and rather different from terrestrial radio propagation where traditional communication systems are deployed. Under water, several phenomena may influence communications, like salt concentration, pressure, temperature, amount of sunshine , winds and their effects on waves, just to say a couple of .[7] [8]

There are three main technologies available for underwater wireless communication. One technology is radio-frequency (RF) transmission, which features high data output at short range and suffers from Doppler effect . Other technology is optical transmission, preferably in blue-green wavelength, which needs line-of-sight positioning. Another technology, which is that the most employed one, is acoustic communication. This latter technology is that the one that

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |
|| Volume 9, Issue 6, June 2021 ||
| DOI: 10.15680/IJIRCCE.2021.0906119 |

permits the longest range of communication, but achieves low throughput, is very impaired by Doppler effects, and is suffering from large delay spread that results in severe inter symbol interference [9]. altogether these technologies, it's important to think about both the implementation costs related to a target data throughput for a prescribed communication range, also because the relative transmission power which may cause environmental impacts like interference with marine life.The technology that's mostly used nowadays among divers, ships, etc. is especially supported sound wave transmission.

II. RELATED WORK

For decades, communicating between underwater and the air problem stands an unsolved. Underwater, submarines use acoustic signals (or SONAR) to communicate; within the air, airplanes use radio signals like cellular or Wi-Fi. But neither of those signals can work across both water and air.

MIT Media researchers developed a water-air communication system, TARF (Translational Acoustic-RF communication), the primary technology that permits communication between underwater and therefore the air. ATARF transmitter generates standard sound (or SONAR signals). Sound travels as pressure waves; when these waves strike the surface, they cause it to vibrate. To select up these vibrations, a TARF receiver within the air uses a really sensitive radar. The radar transmits a sign which reflects off the water surface and comes back. because the water surface vibrates, it causes small changes to the received radar signal, enabling a TARF receiver to sense the small vibrations caused by the underwater acoustic transmitter.

Because TARF uses acoustic signals underwater and radio signals in air, it's ready to achieve the simplest of both worlds. MIT researchers have tested the system in controlled and uncontrolled settings, including swimming pools with swimmers and circulation currents. The system incorporates new algorithms that enable it to affect present waves and may successfully and quickly communicate between underwater and therefore the air.

III. PROPAGATION PHENOMENA OF UNDERWATER SENSOR NETWORKS

Acoustic communication regarding the underwater environment may be a complex phenomenon because tons of environmental factors affect acoustic communication. These factors are variables like long propagation delays, environmental noise, path loss, Doppler spread, and multipath effect. Underwater environmental factors make acoustic channels highly variable.They also create bandwidth dependency upon both frequency and distance between two nodes. Generally, the ocean is split into two parts; these are shallow and deep oceans. Shallow and deep ocean characteristics are described within the below table. Shallow ocean highly affects the acoustic channel due to heat gradient, multipath effect, background noise, and enormous propagation delays, as compared to deep ocean. Underwater environment major propagation factors that affect acoustic communication are described in the table below.

Characteristics	**Shallow Ocean**	**Deep Ocean**
Depth	0 -100 m	100 - 10000 m
Temperature	High	Low
Multi-path Loss	Surface Reflection	Suffers from Surface and Bottom Reflection
Spreading Factor (K)	Cylindrical	Spherical

- Path Loss

When sound propagates from an underwater environment then majority of its strength converts into heat. Acoustic wave propagation energy loss is often categorized into three main categories which are described below.

o Geometric Spreading Loss. When a source generates acoustic signal, it propagates far away from the source within the sort of wave fronts. it's independent of frequency, however, depending upon distance covered by wave front. Geometric spreading is split into two types: first spherical spreading that depicts deep ocean communication; second cylindrical spreading that depicts shallow water communication [11,12]

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

o Attenuation. Attenuation is defined as "wave energy converted into another sort of energy", like heat, absorbed by the medium used. In acoustic communication, this phenomenon is compassionated as acoustic energy is converted into heat. The converted heat is absorbed by the underwater environment. Attenuation is directly proportional to frequency and distance [11,12].

o Scattering Loss. Deviation regarding the road of sight of a sign or change in angle is usually a property. Underwater channel also contains this property that affects acoustic channel data transmission during communication. Surface roughness increases thanks to increase within the wind speed. That raises the merchandise of scattering surfaces. Scattering surface not only affects delays but also affects power loss [11,12].

- Noise

Noise can be defined as a quality of communication system that degrades signal strength of any communication system over a period of time. just in case of underwater acoustic channel there exist different sorts of noises. Underwater noises are often divided into two major categories. These are ambient noise and noises by citizenry . Both sorts of noises are described intimately within the following sections.

o Noise by Human Beings: These noises are thanks to heavy machinery utilization, shipping activities, fishing activities, military activities, sonar activities, and aircraft activities and since of heavy data traffic sending and receiving activities cause different quite disturbance and interference during acoustic communication. Sometime noises thanks to human beings also disturb natural acoustic communication [13].Ambient Noise. Ambient noise may be a complex phenomenon regarding underwater communication. It also can be defined as a mixture of various sources that can't uniquely identify [14]. Ambient noise is additionally called ground noise that happens due to unidentified sources [15]. These noises are divided into four major categories which are referred to as wind, shipping, thermal, and therefore the turbulence [16]. Wind noise is because of breakage of wave or due to bubbles created by air. Noise is often simply predicted and forecast from weather forecasts due to dependence of noise upon wind speed. sizable amount of ships present at large distance from communication system in ocean produce high traffic noise in acoustic communication, if sound propagation is sweet enough. Ships consider main source of anthropogenic ambient noise [14]. Turbulence are often defined as surface disturbance thanks to waves or tides that generates low frequencies that results continuous noise in acoustic communication. Underlying noise is taken into account as thermal noise within the absence of all other sources of noise, including self-noise. Thermal noise is directly proportional to the frequency which is employed for acoustic communication [17].

- Multipath

Sound propagation in shallow water is influenced by surface reflections while trouble propagation is suffering from bottom reflection that becomes explanation for large and variable communication delay in acoustic communication. a serious cause that creates the acoustic signal weak is named multipath effect that becomes explanation for inter symbol interference which also makes acoustic data transmission difficult and erroneous. Vertical acoustic channel is a smaller amount suffering from multipath effect as compared to horizontal acoustic channel [12, 13, 18].

To address the matter of long propagation delay and high lite error rate a routing protocol QERP was proposed to handle end-to-end delay but this protocol still must address the mobility issues [19]. Mostly in deep oceans due to variable sound speed, refraction of sound occurs that cases of multipath effect in acoustic channel. Number of propagation paths, propagation delays, and its strength are determined by acoustic channel impulse response that's influenced by channel reflection and geometry. Numerous paths exist in acoustic channel but only those paths are considered which have less energy loss and reflections. All other paths are discarded as a result only a finite number of paths remains for acoustic communication and data transfer [20].

- Doppler Spread

Because of channel flaws, wireless signals practice a range of degradations. for instance , electromagnetic signals are suffering from interference, reflections, and attenuation; acoustic signals regarding underwater also are suffering from an equivalent quite factors [21]. Underwater acoustic channel may be a complex channel thanks to time variation and space variation. The relative motion of transmitter and receiver that causes the mean frequency shift is named Doppler effect. Although the fluctuation of frequency within the region of this Doppler effect is named Doppler spread [22], two sorts of influences are observed on acoustic channel due to Doppler Effect: first is pulse width which will be compressed or stretched and second is frequency offset due to frequency offset compressing or expanding of signal time domain occurring [23].

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

IV. OPTICAL WAVES

For optical waves the water is seen as a dielectric for optical propagation. the reason for this phenomenon lies within the plasma frequency, whose value determines the range of frequencies that the medium behaves as a conductor or as a dielectric. The seawater switches from conductor to dielectric at frequencies around 250 GHz.

UWOC provides many technical benefits like e.g., high rates of knowledge transmission, secure links, but also economical ones, like low installation and operational costs. Moreover, since the optical band isn't included within the telecommunications regulations, it doesn't require payment of licensing fees and tariffs.

The main disadvantage of underwater optical communication is that the water may be a medium that highly absorbs optical signals; the second problem is optical scattering thanks to the particles present within the sea. Anyway, with reference to the visible spectrum, seawater features a lower absorption within the blue/green zone. Exploiting this physical feature, working with signals with wavelengths belonging to the blue/green region of the spectrum, high speed connections are often attained consistent with the sort of water. Lowest attenuation is centered at 460 nm in clear waters, but this wavelength shifts to higher values in dirty waters, for coastal waters reaching values upto 540 nm, e.g.

$c(\lambda)=a(\lambda)+b(\lambda)$

VALUES FOR BEAM ATTENUATION COEFFICIENT, ABSORPTION COEFFICIENT, SCATTERING COEFFICIENT, BACKSCATTERED COEFFICIENT FROM [24]

Water Type	c(λ)	a(λ)	b(λ)
Pure Seawater	0.056	0.053	0.003
Clear Ocean	0.150	0.069	0.080
Coastal Ocean	0.305	0.088	0.216
Turbid Harbor	2.170	0.295	1.875

A. Noise in Underwater Optical Communications

The main noise types impairing underwater optical transmissions are excess noise, quantum shot noise, optical excess noise, optical background noise, photo-detector dark current noise, and electronic noise.

- Excess noise is generated in the process of amplifying the signal at the receiver, which is necessary for overcoming the effects of thermal noise.
- Quantum shot noise occurs due to random variations of the number of photons in the optical receiver.
- Optical excess noise is caused by transmitter imperfections.
- Optical background noise occurs due to the environment.
- Optical clutter.
- Photo-detector dark current noise is caused by electrical current leakage from photodetector.

V. ACOUSTIC WAVES

Acoustic communication is an alternate technology to succeed in higher distances, currently being the dominant technology for wireless underwater communications. The speed of propagation of waveforms is based on the electromagnetic or mechanical properties of the medium. Electromagnetic waves can propagate through air at speeds on the brink of the speed of light in a vacuum, which is around 4 to five orders of magnitude larger than the speed of propagation of sound waves in fluids. This imposes tremendous constraints on the general transmission process using acoustic waves.

Acoustic waves aren't the sole means for wireless communication underwater, but they're the sole ones which will travel over longer distances. Radio waves which will propagate over longer distance through conductive sea water are the additional low frequency ones (30 Hz-300 Hz) which require large antennae and high transmitter powers, while

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

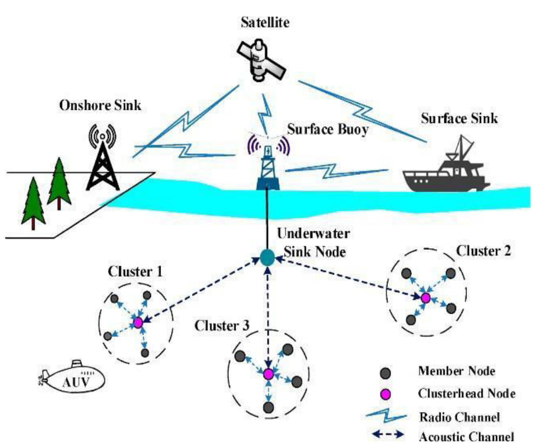
|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

higher-frequency signals will be generated only over very short distances (few meters at 10 kHz). Optical waves propagate best within the blue-green region, but additionally to attenuation, they're suffering from scattering, and are limited to distances on the order of 100 meters. Narrow laser beams are power-efficient but require high pointing precision, while simple light-emitting diodes aren't as power-efficient. Thus, acoustic waves remain the only best solution for communicating underwater, in applications where tethering isn't acceptable and anything, but a really short distance is to be covered. Sound propagates as a pressure wave, and it can easily travel over kilometers, or maybe many kilometers, but to hide a extended distance, a lower frequency has got to be used. generally, acoustic communications are limited to bandwidths that are low compared to those used for terrestrial radio communications. Acoustic modems that are in use today typically operate in bandwidths on the order of a couple of kHz, at a comparably low center frequency (e.g. 5 kHz centered at 10 kHz). While such frequencies will cover distances on the order of a kilometer, acoustic frequencies within the 100 kHz region are often used for shorter distances, while frequencies below a kHz are used for extended distances. Underwater acoustic communication over basin scales (several thousand kilometers) are often established during a single hop as 1 well; however, the attendant bandwidth are going to be only on the order of 10 Hz. Horizontal transmission is notoriously harder thanks to the multipath propagation, while vertical channels exhibit less distortion. Frequency-dependent attenuation, multipath propagation, and low speed of sound (about 1500 m/s) which ends up during a severe Doppler effect, make the underwater acoustic channel one among the foremost challenging communication media.

VI. ARCHITECTURE & APPLICATION OF UNDERWATER WIRELESS COMMUNICATION

Underwater network's physical layer make use of acoustic technology for communication. Limited bandwidth, capacity, and variable delays are common constraints of acoustic technology. Therefore, new digital communication techniques and efficient protocols are required, for underwater acoustic networks. Designing the topology requires significant devotion from designer, because underwater network performance is usually depending upon topology design. Network reliability should increase with efficient topology and network reliability should also decrease with less efficient topology. Energy consumption of efficient topology is very less as compared to incorrect and fewer efficient topology design of underwater network. Design of topology for underwater sensor network is an wide area for research. Underwater sensor networks architecture is shown within the figure below.



Applications of UWSN are mentioned below.

- Fish Farm
- River Monitoring
- Ocean Monitoring
- Environmental Monitoring
- Water Quality
- Surveillance
- Target Tracking
- Exploration
- Ocean Sampling

In this sort of network, the sensors are deployed underwater within the sort of clusters and are anchored at different depths. thanks to the deployment of the sensors at variable heights, the communication between the sensors goes beyond the 2 dimensions. There are three communication scenarios during this architecture: (i) inter cluster communication of nodes at different depths, (ii) intra cluster (sensor-anchor node) communication, and (iii) anchor-buoyant node communication. altogether three sorts of communication scenarios, acoustic, optical, and RF links are often used.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

VII. CONCLUSION AND FUTURE WORK

As future work, the researchers offers better solutions on node mobility with high monitoring area (with high neighborhood range) scenarios to research the effect on network connectivity, coverage, energy consumption and network lifetime. to extend efficiencies of the UWSNs and improve its performance, the studies should direct the main target of the potential research towards implementing cooperative control among a couple of underwater vehicles.

REFERENCES

1. M. A. Khalighi and M. Uysal, ‘‘Survey on free space optical communication: A communication theory perspective,’’ IEEE Commun.Surveys Tuts., vol. 16, no. 4, pp. 2231–2258, Nov. 2014.
2. Z. Ghassemlooy and W. O. Popoola, Terrestrial Free-SpaceOptical Communications. Rijeka, Croatia: InTech, 2010, ch. 17,pp. 356–392.
3. X. Zhu and J. M. Kahn, ‘‘Free-space optical communication through atmospheric turbulence channels,’’ IEEE Trans. Commun., vol. 50, no. 8,pp. 1293–1300, Aug. 2002.
4. S. Bloom, E. Korevaar, J. Schuster, and H. Willebrand, ‘‘Understanding The performance of free-space optics,’’ J. Opt. Netw., vol. 2, no. 6,pp. 178–200, 2003.
5. K. E. Wilson, ‘‘An overview of the GOLD experiment between the ETS-6 satellite and the table mountain facility,’’ Jet Propulsion Lab., CaliforniaInst. Technol., Commun. Syst. Res. Sec., Pasadena, CA, USA, TDA Prog.Rep. 42-124, 1996, pp. 8–19.
6. G. Baister, K. Kudielka, T. Dreischer, and M. Tüchler, ‘‘Results from theDOLCE (deep space optical link communications experiment) project,’’Proc. SPIE, vol. 7199, p. 71990B, Feb. 2009.)
7. X. Lurton, An Introduction to Underwater Acoustics: Principles and Applications, 2nd ed. Springer, 2010.
8. M. Lanzagorta, Underwater Communication, ser. Synthesis Lectures on Communications. Morgan & Claypool Publishers, 2012, vol. 5.
9. T. Melodia, H. Kulhandjian et al., Advances in Underwater Acoustic Networking, 1st ed. Wiley, 2012, ch. 23.
10. C. Gabriel, M. Khalighi et al., “Monte-Carlo-Based Channel Characterization for Underwater Optical Communication Systems,” J. Opt. Commun. Netw., vol. 5, no. 1, pp. 1–12, January 2013. doi: 10.1364/JOCN.5.000001
11. L. Liu, S. Zhou, and J. H. Cui, “Prospects and problems of wireless communication for underwater sensor networks,” Wireless Communications and Mobile Computing, vol. 8, no. 8, pp. 977–994, 2008.
12. I. F. Akyildiz, D. Pompili, and T. Melodia, “Underwater acoustic sensor networks: research challenges,” Ad Hoc Networks, vol. 3, no. 3, pp. 257–279, 2005.
13. I. F. Akyildiz, D. Pompili, and T. Melodia, “Underwater acoustic sensor networks: research challenges,” Ad Hoc Networks, vol. 3, no. 3, pp. 257–279, 2005.
14. D. H. Cato, “Ocean ambient noise: Its measurement and its significance to marine animals,” in Proceedings of the Conference on Underwater Noise Measurement, Impact and Mitigation, pp. 1–9, Institute of Acoustics, Southampton, UK, 2008.
15. L. Liu, S. Zhou, and J. H. Cui, “Prospects and problems of wireless communication for underwater sensor networks,” Wireless Communications and Mobile Computing, vol. 8, no. 8, pp. 977–994, 2008.
16. N.-S. N. Ismail, L. A. Hussein, and S. H. S. Ariffin, “Analyzing the performance of acoustic channel in underwater wireless sensor network(UWSN),” in Proceedings of the Asia Modelling Symposium 2010: 4th International Conference on Mathematical Modelling and Computer Simulation, AMS2010, pp. 550–555, Malaysia, May 2010.
17. E. J. Harland, SAS. Jones, and T. Clarke, “SEA 6 Technical report: Underwater ambient noise,” A report by QinetiQ as part of the UK Department of Trade and Industrys offshore energy Strategic Environmental Assessment programme, 2005.
18. I. F. Akyildiz, D. Pompili, and T. Melodia, “State-of-the-art in protocol research for underwater acoustic sensor networks,” in Proceedings of the 1st ACM International Workshop on Underwater Networks, pp. 7–16, ACM, September 2006.
19. N. Li, J.-F. Martínez, J. M. M. Chaus, and M. Eckert, “A survey on underwater acoustic sensor network routing protocols,” Sensors, vol. 16, no. 3, p. 414, 2016.
20. M. Stojanovic, “Underwater acoustic communications: design considerations on the physical layer,” in Proceedings of the 5th Annual Conference on Wireless on Demand Network Systems and Services (WONS '08), pp. 1– 10, January 2008.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906119 |

21. K. A. Perrine, K. F. Nieman, T. L. Henderson, K. H. Lent, T. J. Brudner, and B. L. Evans, "Doppler estimation and correction for shallow underwater acoustic communications," in Proceedings of the 44th Asilomar Conference on Signals, Systems and Computers, Asilomar 2010, pp. 746–750, USA, November 2010.
22. X.-P. Gu, Y. Yang, and R.-L. Hu, "Analyzing the performance of channel in Underwater Wireless Sensor Networks(UWSN)," in Proceedings of the 2011 International Conference on Advanced in Control Engineering and Information Science, CEIS 2011, pp. 95–99, China, August 2011.
23. X. Zhang, X. Han, J. Yin, and X. Sheng, "Study on Doppler effects estimate in underwater acoustic communication," in Proceedings of the ICA 2013 Montreal, pp. 070062–070062, Montreal, Canada, 2013.
24. C. Gabriel, M. Khalighi et al., "Monte-Carlo-Based Channel Characterization for Underwater Optical Communication Systems," J. Opt. Commun. Netw., vol. 5, no. 1, pp. 1–12, January 2013. doi: 10.1364/JOCN.5.000001.

BIOGRAPHY

Vedant Vikas More is a student in the Information Technology Department, Thakur Polytechnic, Mumbai, India. He enjoys creating software programs and applications.He has participated in multiple Technical Paper Presentations.
Deon Berton Gracias is a student in the Information Technology Department, Thakur Polytechnic, Mumbai, India. He has also attended Hackathons & other programming related competitions.

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 7.542

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

9940 572 462 6381 907 438 ijircce@gmail.com

Scan to save the contact details