International Journal of Engineering Research and Development
e-ISSN: 2278-067X, **p**-ISSN : 2278-800X, www.ijerd.com
Volume 4, Issue 10 (November 2012), PP. 01-07

Network Layer Analysis & Novel Recommendations Regarding Feasibility towards UWSN

Y.Appala Raju[1], U Devee Prasan[2]
[1] Final M.Tech, Dept of Computer Science and Engineering, Aditya Institute of Technology and Management – Tekkali, Srikakulam, A.P.
[2] Assoc Professor, Dept of Computer Science and Engineering, Aditya Institute of Technology and Management – Tekkali, Srikakulam, A.P.

Abstract:- Oceans becoming communication channels today. For the last few years raised more interest in monitoring oceanic environments, security, and military etc. Shipbuilding industries are showing more interested in technologies like sensor networks used in applications such as monitoring, mooring etc. So Underwater sensor networks (UWSNs) are providing more technologies for the applications like mooring and structural health monitoring etc. This paper presents more fundamental key aspects of UWSNs for the underwater sensor networks and underwater communications though devices for more applications.

Keywords:- Underwater Sensor Networks (UWSNs), Acoustic Communication, LMPC (Layered Multipath Power Control)

I. INTRODUCTION

The shipbuilding and offshore engineering industries are also increasingly interested in technologies like wireless sensor networks as an economically viable alternative to currently adopted and costly methods used in seismic monitoring, structural health monitoring, installation and mooring, etc. More Technologies are introduced for more new networking schemes. Sensor networks have revolutionized all the areas of technology i.e. science, industry and government. The revolution is due to the miniaturization and the advancement in technology i.e. availability of low powered processing, storage units and Micro Electrical and Mechanical Systems (MEMS) for constructing onboard sensing units. The ability to have small devices physically distributed near the objects being sensed brings new opportunities to observe and act on the world, for example with micro-habitat monitoring, structural monitoring[1] [2]. Structural applications a wireless seismic data acquisition system. Our goal is to build a wireless system that can collect tens of channels of vibration measurements in near real-time. Traditional data acquisition systems require several hundreds of feet of wiring from the sensors to a centralized data acquisition node. A wireless data acquisition system is much easier to deploy, not just because the placement of sensor is unconstrained by the availability of power and network connectivity, but also because a multi-hop wireless network offers significant placement flexibility in not requiring nodes to be within radio range of a base station.

Self-configuration:

A key requirement for a wireless seismic array is self-configuration the ability to form, without manual intervention, a communication structure across all nodes for transporting data to the base station.

Reliability:

Selection of a reliable parent is not a guarantee for lossless communication. Thus, on top of this communication structure, we have built a simple mechanism for ensuring reliable transmissions. Such mechanisms have been extensively studied in the computer network literature, and involve signaling between nodes to detect and repair message loss.

Compression:

Loss in packet transmission is just one of the challenges encountered while operating in a wireless environment. Another is limited data transfer bandwidth. In particular, the data transfer rate of the entire network is constrained by the radio receive bandwidth offered by a single radio. We use two simple techniques to deal with this challenge. First for an N channel seismic array, we constrain each node to transmit at 1/N of the nominal radio bandwidth. More importantly, however, we use data compression to reduce the transfer rate requirements.

While loss compression schemes can provide significant reduction in data rates, they are clearly not applicable given that we are designing a data acquisition system. Lossless compression schemes generally rely on detecting repeating patterns in the data. Our system uses a simple but effective silence suppression scheme for compressing vibration data. Essentially, it encodes a silence period as a "run-length. This approach can reduce the volume of data transferred in situations where the duty-cycle of vibrations is expected to be small. The approach is also desirable since it reduces network communication. [3]

II. UNDERWATER SENSOR NETWORK ARCHITECTURE

The underwater sensor network topology is still an open research issue for the research community. Some of the architectures supporting underwater sensor networks are static two-dimensional under water sensor networks and three dimensional under water sensor networks.

Two-dimensional underwater sensor networks

Reference architecture for two-dimensional underwater networks is shown in Fig. 1. A group of sensor nodes are anchored to the bottom of the ocean with deep ocean anchors. Underwater sensor nodes are interconnected to one or more underwater sinks by means of wireless acoustic links. Uw-sinks, as shown in Fig. 1, are network devices in charge of relaying data from the ocean bottom network to a surface station. To achieve this objective, uw-sinks are equipped with two acoustic transceivers, namely a vertical and a horizontal transceiver. The horizontal transceiver is used by the uw-sink to communicate with the sensor nodes in order to: (i) send commands and configuration data to the (ii) collect monitored. The vertical link is used by the uw-sinks to relay data to a surface station. In deep water applications, vertical transceivers must be long range transceivers as the ocean can be as deep as 10 km. The surface station is equipped with an acoustic transceiver that is able to handle multiple parallel communications with the deployed uw-sinks. It is also endowed with a long range RF and/or satellite transmitter to communicate with the onshore sink and/or to a surface sink. [7]

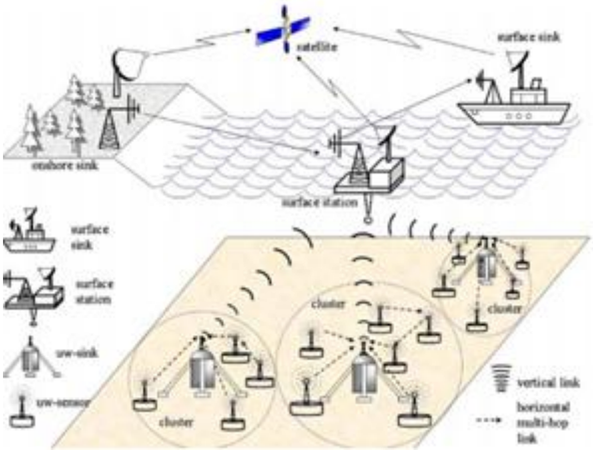

Fig-1: Architecture for 2D underwater sensor networks

Three-dimensional underwater sensor networks

Three dimensional underwater networks are used to detect and observe phenomena that cannot Fig.1. Architecture for 2D underwater sensor networks. In three-dimensional underwater networks, sensor nodes float at different depths in order to observe a given phenomenon. One possible solution would be to attach each uw-sensor node to a surface buoy, by means of wires whose length can be regulated so as to adjust the depth of each sensor node. However, although this solution allows easy and quick deployment of the sensor network, multiple floating buoys may obstruct ships navigating on the surface, or they can be easily detected and deactivated by enemies in military settings. Furthermore, floating buoys are vulnerable to weather and tampering or pilfering for these reasons, a different approach can be to anchor sensor devices to the bottom of the ocean. In this architecture, depicted in Fig. 2, each Sensor is anchored to the ocean bottom and equipped with a floating buoy that can be inflated by a pump. The buoy pushes the sensor towards the ocean surface. The depth of the sensor can then be regulated by adjusting the length of the wire that connects the sensor to the anchor, by means of an electronically controlled engine that resides on the sensor. A challenge to be addressed in such architecture is the effect of ocean currents on the described mechanism to regulate the depth of the sensors. [8]

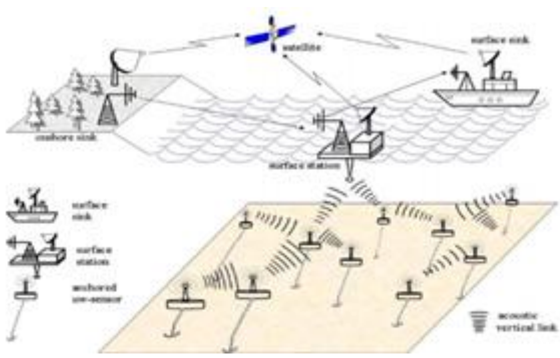

Fig-2: Architecture of 3D underwater sensor networks.

III. FACTORS THAT INFLUENCE THE COMMUNICATIONS IN UWSNs

Path Loss:

Attenuation is mainly provoked by absorption due to conversion of acoustic energy into heat, which increases with distance and frequency. It is also caused by scattering and reverberation, refraction, and dispersion. Water depth plays a key role in determining the attenuation. Geometric Spreading refers to the spreading of sound energy as a result of the expansion of the wave fronts. It increases with the propagation distance and is independent of frequency. There are two common kinds of geometric spreading: spherical.

Noise:

Man-made noises mainly caused by machinery noise and shipping Ambient Noise. It is related to hydrodynamics, seismic and biological phenomena.

Multi path:

Multi-path propagation may be responsible for severe degradation of the acoustic communication signal, since it generates Inter-Symbol Interference. It depends on the link configuration. Vertical channels are characterized by little time dispersion, whereas horizontal channels may have extremely long multi-path spreads, whose value depend on the water depth.

High delay and delay variance:

The propagation speed in the UW-A channel is five orders of magnitude lower than in the radio channel. This large propagation delay (0.67 *s/km*)can reduce the throughput of the system considerably. The very high delay variance is even more harmful for efficient protocol design, as it prevents from accurately estimating the round trip time, key measure for many common communication protocols.

Sonar:

Sonar is the name given to the acoustic equivalent of radar. Pulses of sound are used to probe the sea, and the echoes are then processed to extract information about the sea, its boundaries and submerged objects. An alternative use, known as *passive sonar*, attempts to do the same by listening to the sounds radiated by underwater objects.

Underwater communication:

The need for underwater acoustic telemetry exists in applications such as data harvesting for environmental monitoring, communication with and between manned and unmanned underwater vehicles, transmission of diver speech, etc. A related application is underwater remote control, in which acoustic telemetry is used to remotely actuate a switch or trigger an event. A prominent example of underwater remote control are acoustic releases, devices that are used to return sea floor deployed instrument packages or other payloads to the surface per remote command at the end of a deployment. Acoustic communications form an active field of research with significant challenges to overcome, especially in horizontal, shallow-water channels.

Underwater Navigation and Tracking:

Underwater navigation and tracking is a common requirement for exploration and work by divers, ROV, manned submersibles and submarines alike. Unlike most radio signals which are quickly absorbed, sound propagates far underwater and at a rate that can be precisely measured or estimated. It can thus be used to measure distances between a tracked target and one or multiple reference of baseline stations precisely, and triangulate the position of the target, sometimes with centimeter accuracy. Starting in the 1960s, this has given rise to underwater acoustic positioning systems which are now widely used.

Weather and climate observation:

Acoustic sensors can be used to monitor the sound made by wind and precipitation. Lightning strikes can also be detected. Acoustic thermometry of ocean climate (ATOC) uses low frequency sound to measure the global ocean temperature.

IV. APPLICATIONS AND CHALLENGES OF UWSNs

Ocean Sampling Networks:

Networks of sensors and AUVs, such as the Odyssey-class AUVs, can perform synoptic, cooperative adaptive sampling of the 3D coastal ocean environment.

Seismic monitoring:

A promising application for underwater sensor networks is seismic monitoring for oil extraction from underwater fields. Frequent seismic monitoring is of importance in oil extraction. Studies of variation in the reservoir over time are called “4-D seismic” and are useful for judging field performance and motivating intervention.

Flocks of Underwater Robots:

A third and very different application is supporting groups of underwater autonomous robots. Applications include coordinating adaptive sensing of chemical leaks or biological phenomena (for example, oil leaks or phytoplankton concentrations), and also equipment monitoring applications as described above. Communication for coordinated action is essential when operating groups of robots on land. Underwater robots today are typically either fully autonomous but largely unable to communicate and coordinate with each other during operations, or tethered, and therefore able to communicate, but limited in deployment depth and maneuverability.

- Pollution Monitoring and other environmental monitoring (chemical, biological, etc.).
- Distributed Tactical Surveillance AUVs and fixed underwater sensors can collaboratively monitor areas for surveillance, reconnaissance, targeting and intrusion detection systems.

Under water sensor network consists of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize in an autonomous network which can adapt to the characteristics of the ocean environment. Underwater networks can be characterized by their spatial coverage and by the density of nodes. [4]

Major Challenges are:

- Battery power is limited and usually batteries cannot be recharged, also because solar energy cannot be exploited.
- The available bandwidth is severely limited.
- Channel characteristics, including long and variable propagation delays, multi-path and fading problems.
- High bit error rates.
- Underwater sensors are prone to failures because of fouling, corrosion, etc.[5][6]

Differences between underwater sensor networks and terrestrial networks[6] are Cost-Underwater sensors are more expensive, Deployment-deemed to be more sparse in USNs, Power-Higher power is needed in USNs due to higher distances and more complex signal processing at receivers. Memory-Underwater sensors need to have large memory compared to terrestrial sensors as the underwater channel is intermittent.

V. RESEARCH CHALLENGES IN UWSNs

A protocol stack for uw-sensors should combine power awareness and management, and promote cooperation among the sensor nodes. It should consist of physical layer, data link layer, network layer, transport layer, and application layer functionalities.

Physical layer:

The communication media that can be chosen for underwater sensor networks are radio frequency waves or optical wave or acoustic wave. The main objective of underwater acoustic communication is to overcome performance limitations observed in dispersive channel and also improve bandwidth efficiency. To achieve high bandwidth efficiency the suitable modulation schemes are as follows. [9] Frequency-shift keying is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is binary *FSK*. BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

Data link layer:

Frequency division multiple accesses (FDMA) are not suitable for UW-ASNs due to the narrow bandwidth in UW-A channels. Time division multiple access (TDMA) shows limited bandwidth efficiency because of the long time guards required in the UW-A channel. Although the high delay spread which characterizes the horizontal link in underwater channels makes it difficult to maintain synchronization among the stations, CDMA is a promising multiple access technique for underwater acoustic networks.

Network layer:

The network layer is in charge of determining the path between sources. There has been intensive study to find the route from source to the destination in different gateways of underwater sensor networks. Existing routing protocols are divided into three categories, namely proactive, reactive and geographical routing protocols [7].

In virtual circuit routing, the networks use virtual circuits to decide on the path at the beginning of the network operation. In packet-switch routing, every node that is part of the transmission makes its own routing decision, i.e., decides its next hop to relay the packet. Packet-switch routing can be further classified into proactive routing and reactive routing protocols. Most routing protocols for ground-based wireless networks are packet-switch based.

Proactive routing protocols attempt to minimize the message latency by maintaining up-to-date routing information at all times from each node to any other node. It broadcasts control packets that contain routing table information. Typical protocols include Destination Sequence Distance Vector and Temporally Ordered Routing Algorithm. However, proactive routing protocols provoke a large signaling overhead to establish routes for the first time and each time the network topology changes. It may not be a good fit in underwater environment due to the high probability of link failure and extremely limited bandwidth there. Virtual-circuit-switch routing protocols can be a better choice for underwater acoustic networks. The reasons are:

a) Underwater acoustic networks are typical asymmetric instead of symmetric. However, packet switched routing protocols are proposed for symmetric network architecture;
b) Virtual-circuit-switch routing protocols work robust against link failure, which is critical in underwater environment; and
c) Virtual-circuit-switch routing protocols have less

Signal overhead and low latency, which are needed for underwater acoustic channel environment. However, virtual-circuit-switch routing protocols usually lack of flexibility. How to adapt some degree of flexibility into virtual-circuit-switch routing protocols is a question that needs to be answered by UAN network layer research.

Transport layer:

In this section existing reliable data transport solutions for Wireless sensor Networks, along with their shortcomings in the underwater environment, and fundamental challenges for the development of an efficient reliable transport layer protocol for underwater sensor networks are discussed. In sensor networks reliable event detection at the sink [5] should be based on collective information provided by source nodes and not just on individual reports from each single source. Therefore, new ways should be defined to provide reliable could feasible lead to wastage of scarce resources. The features must have for the underwater environment to fulfill the design principles are although correct handling of shadow zones requires assistance from the routing layer, a transport protocol should also handle the shadow zones. A transport protocol should be explicitly designed to minimize the energy consumption. Packets should be continuously forwarded to accelerate the packet delivery process. A transport protocol should adapt to local conditions immediately, to decrease the response time in case of congestion. Thus, rather than sinks, intermediate nodes should be capable of determining and reacting to local congestion.

Application layer:

The research of application layer protocols for UANs is a brand new topic. The purpose of application layer is to provide a network management protocol that makes hardware and software detail of the lower layers transparent to management applications. Some examples of application layer protocols for ground-based wireless networks are Telnet, File Transport Protocol, and Simple Mail Transfer Protocol. Not much effort has been made to address the specific needs of the underwater acoustic environment. Instead of designing a complete new set of protocols, we can modify existing protocols of ground-based wireless networks to meet the UAN needs. Thus, it is a necessity to understand the application areas and the communication issues for UANs, and to apply its uniqueness into the existing application protocols.

VI. FUTURE ENCHANCEMENT ON LAYERED MULTIPATH POWER CONTROL

The provisioning of energy-efficient, reliable and low-delay communication in Underwater Sensor Networks (USNs) is a challenging research issue due to the use of acoustic channels. However, the existing mechanisms for enhancement of energy utilization and Quality-of-Service in USNs have not considered noise attenuation in deep water which can deteriorate energy efficiency and Quality of service seriously. To fill this gap, this paper presents a novel scheme, namely Layered Multi-path Power Control, to reduce the energy consumption as well as enhance reliable and robust communications in USNs. To this end, we first formalize an optimization problem to manage transmission power and control data rate across the whole network. The objective is to minimize energy consumption and simultaneously ensure other performance in terms of required packet error rate and maximum power. We then solve the key problems including establishment of the Energy-Efficient Tree and energy distribution in the tree and further provide a feasible solution for the optimization problem. Finally, the extensive simulation experiments are conducted to evaluate the network performance under different design alternatives. The simulation results show that the developed scheme outperforms the existing mechanism significantly [12]. LMPC adopts a tree-based transmission power control scheme. As aforementioned, the goal of this scheme is to minimize the total energy consumption and maintain the PER at an acceptable level. In this section, we first formalize an optimization problem to manage transmission power and control data rate across the whole network. Then two key problems including establishment of Energy- Efficient Tree and control of energy distribution in the tree are addressed for LMPC.

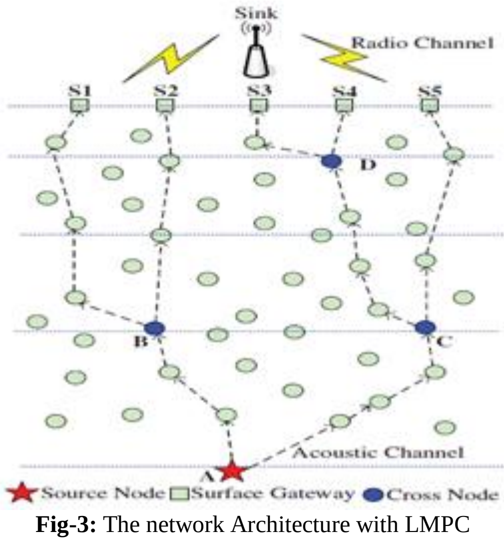

Fig-3: The network Architecture with LMPC

Problem Formulation

For clarity of the problem formulation, the important variables and notations are listed in Tab. 1. The tree-based network involves multiple paths, each of which consists of nodes and links. As illustrated in Fig.3 above there are 8 paths in the tree. The far left-hand path from the source node, A, to the sink consists of 9 nodes including the source and destination nodes and adopts node B and the surface gateway, S1, as the intermediate nodes.

Table-1: List of Variables and Notations

Notations	Meanings
N	The set of all nodes in the tree-based multi-path
P	The set of paths in the target network
P_j	The j^{th} path in the tree, p= { P_j ,j ε N}.
N_{ij}	The i^{th} node in the j^{th}path,N={ N_{ij}, $1 \le i \le C(P_j)$}
Po_{ij}	Transmission power of node N_{ij}
Pr_j	The aggregated packet error rate of path P_j
Pr_{ij}	The packet error rate of node N_{ij}
Pr_{reg}	The required packet error rate
RATE(Pr)	The maximum data rate under the given Pr
Po_{max}	The maximum power of each node
Pl	The length of the data packet
D	The depth of water

Establishment of Energy-Efficient Tree

To establish the energy-efficient tree, we first analyze the structure of the binary tree. A binary tree consists of three parts including two sub trees and a root path. Each of the sub trees also involves two sub trees and a root path at the next layer. Thus, the energy-efficient binary tree can be defined as follows:

$T=G(B_1,\Phi,B_2)$
$B_j=G(B_{i(2j+1)},P_j, B_{i(2j+2)})$
If not ($B_{i(2j+1)}= \Phi$ and $B_{i(2j+2)}= \Phi$)
$B_j=P_j$ if $B_{i(2j+1)}= \Phi$ and $B_{i(2j+2)}= \Phi$

where Bj is the jth sub binary tree, and G(Br,Pa, Bl) is a tree establishment function, which can establish a tree with the right branch, Br, root path, Pa and left branch, Bl. [15]
As illustrated in Architecture, a cross node in the tree is the node where two sub trees and a root path intersect. In LMPC, the key problem of the EET establishment is to discover the cross nodes the noise level, Pod(f), decreases as the distance, di, increases. That is to say, the noise signal becomes weaker and weaker as the Water depth increases. Hence, in order to build the energy efficient tree for LMPC, the communication plane is divided into multiple layers equally. The entire cross nodes are located at or near the border between two continuous layers. When a node receives a packet, this node first checks whether its location is near the border of the layer within a threshold value. If yes, this node multicasts the packet along two routing paths of the sub trees using Multicast Ad-Hoc On-demand Distance Vector protocol. Thus the multicast node is the cross node. Otherwise, this node relays and forwards the packet to the next hop.

Energy Distribution

Energy distribution in the tree is also a key problem in LMPC because it affects the overall performance directly. To address this problem, we first calculate the BER and PER of node Nij. The unique relationship between bandwidth and transmission distance of the underwater acoustic channel is derived from the dependency on frequency exhibited by both the attenuation and the noise power profiles. The SNR of the received signal depends on the transmission power and noise power, which can be expressed as

$$\mu_{ij} = \frac{Po_{ij}/F(d_{ij},f)}{Pod_u(f)} = \frac{Po_{ij}}{a(f)^{dij}.\sum_{u=1}^{n}\frac{Po_u(f)}{a(f)d_u}}$$

Where μij is the average received signal SNR of node Nij and dij is the distance from N(i−1)j to Nij.
The optimization problem that minimizes energy consumption and also guarantees the other performance metrics in USNs has been proven. This finding motivates us to develop a heuristic algorithm to investigate the explicit feasible solution to this NP-complete optimization problem.

VII. CONCLUSION

This paper reviews the recent research development of Underwater Acoustic Networks. It analyzes the uniqueness of underwater acoustic channel first. Several practical issues of UANs are then raised, ranging from network topology, power efficiency, physical layer, network layer to application layer. This paper presents a novel scheme, namely Layered Multi-path Power Control, to reduce the energy consumption as well as enhance reliable and robust communications in USNs. To this end, we first formalize an optimization problem to manage transmission power and control data rate across the whole network for the future research.

REFERENCES

[1]. A. Cerpa, J. Elson, D. Estrin, L. Girod, M. Hamilton, and J. Zhao, *Habitat monitoring: Application driver for wireless communications technology*, In Proceedings of the ACM SIGCOMM Workshop on Data communications in Latin America and the Caribbean, Apr. 2001.

[2]. D. Whang, N. Xu, S. Rangwala, K. Chintalapudi, R. Govindan, and J. Wallace, *Development of an embedded sensing system for structural health monitoring*, In Proceedings of the International Workshop on Smart Materials and Structures Technology, Jan. 2004.

[3]. I. F. Akyildiz, D. Pompili, and T. Melodia, *Underwater acoustic sensor networks: Research challenges, Ad Hoc Networks*, pp. 257–279, 2005.

[4]. Zaihan Jiang, *Underwater Acoustic Networks – Issues and Solutions*, International journal of intelligent control and systems, VOL. 13, NO. 3, SEPTEMBER 2008, 152-161.

[5]. C. Baru, R. Moore, A. Rajasekar, M. Wan, The SDSC storage resource broker, in: Proceedings of the 1998 Conference of the Centre for Advanced Studies on Collaborative Research, 1998

[6]. P. Bose, P. Morin, I. Stojmenovic, J. Urrutia, Routing with guaranteed delivery in ad hoc wireless networks, ACM Wireless Networks 7 (6) (2001) 609–616.

[7]. K. Fall. Delay-tolerant network architecture for challenged internets, in: Proceedings of ACM SIGCOMM03, August 2003.

[8]. K. Akkaya, M. Younis, A survey on routing protocols for wireless sensor networks, Ad Hoc Networks 3 (3) (2005) 325–349, in this issue.

[9]. E. Fiorelli, N. Leonard, P. Bhatta, D. Paley, R. Bachmayer, D. Fratantoni, Multi-AUV control and adaptive sampling in Monterey Bay, in: Proceedings of IEEE Autonomous Underwater Vehicles 2004: Workshop on Multiple AUV Operations (AUV04), June 2004.

[10]. L. Freitag, M. Stojanovic, S. Singh, M. Johnson, Analysis of channel effects on direct-sequence and frequency-hopped spread-spectrum acoustic communication, IEEE Journal of Oceanic Engineering 26 (4) (2001) 586–593.

[11]. Y. Kim and S. Li, "Modeling multipath fading channel dynamics for packet data performance analysis," *Wireless Networks*, vol. 6, no. 6, pp. 481–492, 2000.

[12]. S. Bernard, Digital Communications Fundamentals and Applications. Prentice-Hall, Englewood Cliffs, NJ, 1988.

[13]. C. Yang "An energy-efficient routing protocol in underwater sensor networks," *3rd International Conference on Sensing Technology*, pp. 114–118, 2008.

Biografies:

Y.Appala Raju was Doing M.Tech in Aditya Institute of Technology and Management (JNTUK), Tekkali, Andhra Pradesh, India; His Research interest includes Wireless sensor networks, Network Security.

Mr. Devee Prasan.U is B.Tech (CSE), M.Tech (CSE) from JNTU Kakinada, Andhra Pradesh, India. He is working as Associate professor in Computer Science & Engineering department in Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh, India. He has 11 years of experience in teaching Computer Science and Engineering related subjects. He is a research scholar and his area of interest and research include Computer Networks, Wireless sensor networks, Wireless LANs & Ad-Hoc Networks. He has published several Research papers in national and international journals/conferences. He has guided more than 80 students of Bachelor degree, 18 Students of Master degree in Computer Science and Engineering in their major projects. He is a member of ISTE and CSI.