OPTIMAL DEPLOYEMENT OF WIRELESS SENSOR NODES

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CERTIFICATE

We accept the work contained in this report as a confirmation to the required standard for the partial fulfilment of the degree of MS(EE).

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DEDICATION

This thesis is dedicated to two most important people (My parents), who have been a great source of love, motivation and encouragement for me, this thesis goes out to my loved ones who believed in me and I would like to convey my regards to my teachers who guided me at every step and extracted the best out of me.

DECLARATION OF AUTHORSHIP

I hereby declare that content of this thesis is my own work and that it is the result of work done during the period of registration. To the best of my knowledge, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Parts of this thesis appeared in the following publications, to each of which I have made substantial contributions:

- Publication…

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(Student Signature)

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ABSTRACT

The arena of underwater communication has developed a great deal in the last decade or so. Innovative ideas and techniques are being adopted, the use of WSNs is the topic of interest specifically. Wireless sensor nodes (WSNs) are deployed in an open or indoor region in order to collect information. As, obviously, that underwater communication and the WSNs are provoked by harsh environment so in this regard the deployment plays an important role. The type of deployment determines all the important parameters and results of the system or network. As WSNs are battery operated and in the mid of an ocean in deep sea it's not possible to replace the battery manually. Routing Protocols have been designed from time to time but an effective deployment can make the performance of network even more when incorporated with a routing protocol Therefore, the deployment schemes is proposed and is incorporated with "Greedy Algorithm to improve the Network Lifetime, packet delivery ratio and makes our network reliable. In past the researchers have intensely worked on different deployment schemes in order to solve energy consumption issue, since they have missed out on some of the important parameters which can be combined to deployment, which I find as my research gap. In this research an optimum deployment scheme based on Temperature, Salinity and pressure is presented. The desired area is divided into four layers on the basis of changing Temperature, Salinity and pressure with respect to depth. According to the proposed technique 15 percent nodes are deployed at the top,20 percent in layer two,25 percent in layer three and 40 percent in layer 4. The aim is to somehow extendthe lifetime of the network, and assure the packet delivery.

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ABBREVIATIONS

UWSNs	Underwater Wireless Sensor Networks
SNs	Wireless sensor networks
Sn	Sensor node
Iot	Internet of things
MN	Managing node
RS	Remote station
BER	Bit error rate
SNR	Signal to noise ratio
NLT	Network life time
EM	Electro magnetic
DSP	Digital signal processing
FPGA	Field-programmable gate array
PC	Personal computer
ISM band	Industrial, Scientific and Medical radio band
GHZ	Giga hertz
RF	Radio frequency
LED	Light emitting diode
Dh	High distance
Rs	Sensing range

FN	Fixed nodes
AUVs	Autonomous underwater vehicles
OUC	Optical underwater communication
MSN	Main sensor node
CH	Cluster head
AN	Anchor node
PREQ	Path request
Ph	Potential hydrogen
KHZ	Kilo hertz
PAR	Packet acceptance ratio
DBR	Depth base routing
EEDBR	Energy efficient depth base routing
EBECRP	Energy efficient and balanced energy consumption Cluster based routing protocol

Chapter1

Introduction

CHAPTER 1. INTRODUCTION

1.1. Thesis Background/Overview

Communication; can be demarcated as a process in which information: can be a signal or sound; or wave, is transferred from one place to another place via some medium. The Medium is air most of the times. Every Communication has to oblige the "Shannon Law of Communication": We have a sender, a receiver and in between we have a medium. Can be wired or wireless. In wired Optical fiber, Coaxial and Twisted pair etc. are the examples that comes to the mind upfront. In wireless air is used as a medium through which electromagnetic waves travel, Since EM waves are the only waves that propagates through the air.

When it comes down to Underwater communication just like any other typical communication; We have a sender, followed by a medium (Water in this case) and finally we have a receiver. About 71% of globe comprises of water and due to the increasing number of devices and applications the need of underwater communication is increases. In the decade or so, Underwater communication has been a hot favorite topic for researchers all over in the research community: Trying their supreme best to enhance the underwater communication, make it fast, reliable, flexible and secure.

As the technology is progressing. After exploring most of the parts (Probably) of land now they (Researchers) are moving towards sea and oceans in order to explore it. Due to this reason the applications of underwater communication are increasing in industry and academia is also taking interest in it. Underwater communication should be rapid, Trust worthy and accurate So that users can be facilitated to the best of possibility [1]. Some of the application in which underwater communication is used or water is used as a medium are Military Surveillance, Flood control, Measurement of characteristics of water, Animal monitoring, Disaster management, Underwater surveillance, Earth quick detection etc.[2]

In the last decade or so the topic of underwater communication has been the top priority of researchers; trying to identify and rectify the problems; optimize the system as much as possible; minimal the errors and to gain control of communication. They have been studying and trying to explore the cause from every possible angle that can ever exist or that can be thought of. But still as there is a saying "Nothing is Perfect", There always is a loop hole and a room of improvement. Scientists and researchers are still trying to explore the domain in order to make it more and more simple and understandable. [3]

There is a big difference when it comes to communication on land, as of that which is done underwater; Underwater communication is affected by many parameters which derails the quality of communication. To rectify those, worsen communications it's not practically possible for human to in person reach there or use any machine or dedicated robot to take care of things. It becomes difficult at times to get hold of things in the best way, that we desire for. Hence the communication is compromised: These parameters or can be referred as "Harsh Environment", Since they have harsh and terrible effect on the communication. They are Temperature, Pressure and Salinity. All the three mentioned factors vary with the change in depth having effect on the overall SNR.[4]

Apart from Pressure, Salinity and pressure: There still are a number of problems that we face in "Acoustic Underwater Communication". Acoustic means Sound. Acoustic waves have better performance than Optical and Electromagnetic, that's why they are often used in Underwater communication, having said that. Still there are some adversaries that need to cater. These are Propagation delay, Bit Error Rate (BER) and sometimes temporary cutoff of the link [5]and[6]

It has been shown in previous studies that the acoustic sound's speed, which is 1500 m/s. The speediness dependent upon Temperature, Salinity and pressure. The temperature at sea surface is high so the speed of acoustic wave is good as well as the quality of communication is good but when we go in depths the temperature decreases which sabotage the signal quality. With the increase in depth the salinity and pressure also vary which has some interesting effect on our desired SNR and quality that we are eager of. With increase in pressure as we go down the salinity increases slightly which can be neglected for some time but when we reach at very depths the amount of

salt in water increases. Thus, making the water denser which worsen the quality of transmission. Same goes for pressure. The topmost layer of ansea is referred as 'Surface layer', where the effect of the above defined parameters is almost negligible. But beyond this layer is "Thermocline" which has a length or depth of few hundred meters. Beyond this region it has been observed that the temperature, salinity and pressure play a vital role in our communication [7]and [8]

When the speed of sound is good this means we will have a good signal to noise ratio (SNR).So relating speed of sound and SNR we can say that with the increase in temperature we tend to have improved SNR means ease in communication and less effort required for Sensor nodes to communicate hence better energy consumption eventually effecting all the other parameters including Network life time (NLT),Packet delivery ratio, Bit error rate (BER) etc. Similarly, as we go into depths of ocean the Pressure (P) and Salinity (S) increases while the temperature (T) which worsen the SNR, hence derailing the performance of the whole system or network. Warm water is less dense through which we can have better transmission as compare to cold water that is denser. The above all parameter when incorporated with density (D) we can formulate an equation

$$SNR = \frac{\tau\varsigma\,\Delta T}{\Delta SP\rho} \text{(Equation 1.1)}$$

In the above equation τ and ς are coefficients of thermal expansion and saline contraction.

τ is approximately equal to 0.2 kg m^{-Three}°C-1.

ς is approximately equal to 1 kg m^{-Three}psu-1.

1.2. Wireless Sensor Node

Wireless sensor nodes have sensors embedded in it, which are used to capture information from the surrounding; Process it and transmit it to the other wireless sensor node. The Sensor can be of any kind it can be a temperature sensor, pressure

sensor, Humidity sensor so far and so on. The sensor senses the data in analog domain; As all the things in nature are in analog domain for example Temperature, Noise, pressure etc. They all are analog; they are converted using an analog to digital converter so that micro-controller can process the data: As it works in digital domain. Sensors have very inadequate power of 0.5-2 ampere/hour and 1.2-3.7 volts. A wireless sensornode is basically a sensor just like we have temperature, Pressure, Motion, Fire and many other types of sensors. So basically, what is being implied is that the basic working is same as of any other common sensor that are available in the market. Wireless sensor nodes are "Sensors" or sometimes called "Nodes" (When are a part of a network). They have the capability to sense, Process and communicate with other nodes or sensors in a network. Sensor nodes devours energy in active state and idle state is usually equal therefore, in order to save energy, the sensor nodes can be turned off, when not in use... Wireless Sensor node is:Encompassedwith a Microcontroller, External Memory, Power sourceTransceiver, and Sensors. Each of them is explained bellow.

1.2.1. Micro-controller

The job of Micro-controller is to amassstatistics, arrange it and process it accordingly. Moreover, it has an additional role of controlling and see off all the other important roles of the wireless sensor node; ether the other parts of sensor node are working or not and the function is being performed in a correct manner or not. The most famous or one can say common controller is micro-controller. There can be other choices too. For example, one can use a general-purpose micro-processor that is used in PC and laptops, a digital signal processor (DSP) also serves the purpose or a FPGA can also be used; But almost all the times we use the Micro-controller, obviously has a reason or in fact reasons. Firstly, it is cheap (low cost), Flexible in terms of connectivity, Easy to configure and program plus the most important one is that they have low energy consumption. Since in underwater communication energy harvesting is not possible; best for our use. General purpose micro-processors have high energy ingesting; Digital Signal processors might be suitable for wireless communication but then again, not in case of Underwater communication because of its complexity. Underwater communication is already complex and one can’t afford to induce it

further. FPGA's can be programed again and again depending on the need or application (they are reprogrammable) but needs more time and energy which is not good.

1.2.2. Transceiver

Transceiver is a combination or device that has the properties of sender and receiver at the same time, means it can send data and also can receives. Sensor nodes uses the free or unlicensed band: Industrial, Scientific and Medical radio band or ISM band. It is a2.4 GHZ band which provideswithout cost radio coverage, Range and worldwide connectivity. The other mediums of transmission can be Radio Frequency (RF), Infrared and Optical (Laser or LED). Lasers consumes low energy but they have short range, in underwater. They also require line of sight which is not possible most of the times. Infrared are low power operated but has low capacity. Radio Frequency (RF) are the best suited when it comes to Underwater communication, there for they are mostly used in many applications.

1.2.3. External Memory

Mainly, we can have two type of memories in wireless sensor nodes: Firstly,memory that is built-in on the chip which is used to store the program or to program the chip, second type of memory that can be a flash etc. and is used for additional purpose: For example, to store some personal data or some applications related to the program by the user.

1.2.4. Power Source

Wireless sensor nodes are mainly battery operated, so as the name suggests "Power Source", it provides the electrical energy to the wireless sensor node so that it can run and perform different functions. Power sources can vary in size based on the application.

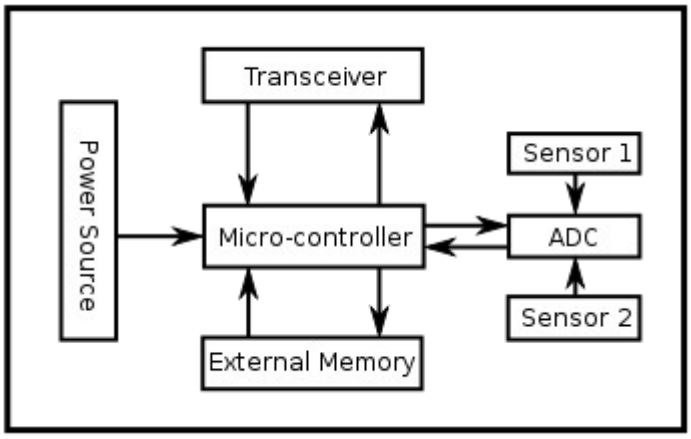


Figure 1-1 (Wireless sensor node Architecture)

1.3. Wireless Sensor Networks (WSN)

When a Collection of Sensor nodes are spread that sense, accumulate, communicate with each other and lastly forward the detected or collected information to a sink or a center. There can be one or multiple sink nodes. Each sensor node sense or detect information, forward it to another or nearby sensor node so on and so far, finally the data reaches to the sink or central node. Wireless sensor network (WSN) is referred as the connection or link between digital word and real word. It connects us and makes us able to collect data and execute that data in order to perform different tasks. It is also used in Internet of thing (IoT). It is the eyes and ears of Internet of things (IoT). When sensor nodes are placed in a region, they sense data, they communicate with each other and sends that sensed data to a station which is at some far-flung location, it is called remote station (Rs). Sometimes also called sink node (Sn).

It is a cost-effective process in Internet of things (IoT) that gives us accurate data from the field. When it comes to IoT wireless systems (IoTs), the main concept lies in, different embedded devices connect to achieve intelligent management and surveillance through distributed sensor networks. In figure 1-2a typical Wireless sensor Network (WSN) can be seen. It comprises of sensor field which means the area or surface or the region in which the Sensor Nodes (Sn) are deployed. The area can vary from large to medium and small. Similarly, each application has a different arrangement or deployment style, which changes from application to application and

the sum of nodes is also not constant. The second important component is Sensor nodes (Sn). They sense data and forward that data through neighboring sensor nodes and finally to the sink node (Sn). The Sink node is connected to a “Rs”, which is usually on land. It has no limitations when it comes to resources’ remote station manages all the data therefore, also called Manager node or Managing Node (MN). The communication between sensor nodes (Sn) is usually via Acoustic or RF.

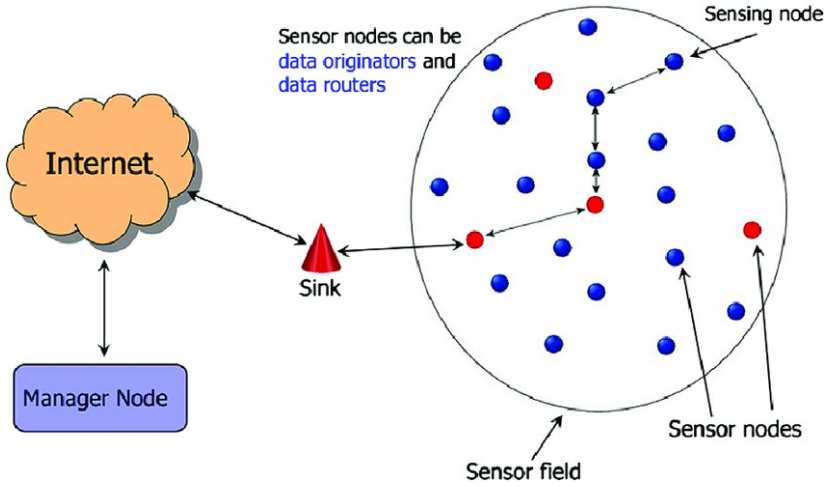


Figure 1-2 (Wireless Sensor Network)

1.3.1. Sensor field

The vicinity in which sensor nodes are deployed is called “Sensor field”. The region can vary from small regions to large regions. The sensor nodes sense the info, collect it, Communicate with each other. A node looks for its closest neighbor and forward the data packet to that node which further transmit it to the other closest node. In this manner the data packet propagates towards the Sink node.

1.3.2. Sink node

A node which gathers the data from all the nodes and transmit that data to a remote location or manager node via internet. Sometimes called a “Master node”

1.4. Applications and Challenges of Wireless Sensor Networks (WSN)

Wireless Sensor Networks (WSN) ishelpingInternet of things (IoT) in many ways, WSN is like a pedestal for IoTs on which it is standing right now and expanding its wings. WSNis like a link or a pipeline between real world and digital interface, since its applications are Increasing day by day, it's becoming one of the most talked about topic from the past several years.

WSN is used in real time applications, Also, in non-real time applications; Real time are those in which the delay is unacceptable and the data has to be sent or received at real time (without any delay); Non-real time applications are those where even if in case there is a delay. The results or performance of the system or network is not compromised. Some of the famous usage of WSN is in Smart cities, Smart homes, underwater surveillance, fire detection in forests, earth quick detection, Volcanic eruptions are detected with the help of WSN. WSN is also used to detect land Sliding in hilly regions, Enemy intrusion can be detected, Specially in Military applications, Water quality can be checked, composition of water (minerals),protection of dams, motion detection, WSN can be used to explore or detect oil and gas deep down the earth or in oceans, Enemy movement can be monitored, the water levels in dams can be constantly checked, Animal surveillance, Can be used in health department, to prevent pollution and keep a check on air and water pollution, Machine monitoring on land and in oceans and is used vastly in industrial applications.[9]Due to the inventions and research in the field of electronics; Most of the things are being converted into digital, One can say it's a digital era. This digitization is helping WSNto grow more and more as low cost and low energy consuming devices are being developed by engineers and scientist which will help the energy and power related issues in Wireless Sensor Networks.[10].When a proliferation of nodes combine together to perform any function i.e. sensing, transmission or reception of data they form a wireless sensor network (WSN).The WSN play avitalpart in monitoring wide regions and open areas which are slightly tough for humans to cover them effectively [11]and [12]

As in underwater communication we are not certain of the environment and the

performance of WSN is compromised, knowing that they are battery operated and can't be replaced. Also, there is no harvesting mechanism so the energy and network life time become very critical in order to have uninterrupted communication. When many sensor nodes unify together, they form Wireless sensor network (WSN). The challenge that is faced is that wireless sensor nodes are mainly battery operated, Harsh environment drains the battery quickly and if the battery is to be replaced manually, thus escalates the network's cost. The performance of wireless sensor networks (WSN)is highly effected due to the energy issue. Therefore,since it is a major issue and it needs to be taken care of.To lengthen the network lifetime, and resolve the energy constrains many researches and energy consumption algorithms have been so that the nodes do not die in between the communication. On the contrary the sink node has enough energy (It has high energy). The sink node can be static as well as it can be movable (depending upon the application). The main purpose of Sink node is, bring together information or fetch data from battery-operated Sensor nodes that are Scattered in the desired region and forward that data to some remote location that is usually on land. The data is processed at the remote station [13]

As Sensor nodes have limited sensing range (Rs), Some of the events can't be detected if sensor nodes are at high distances (Dh). Therefore, the sensor nodes have to be kept in the distance where the event is occurred or the place at which data has to be sensed. The distance "D" should be slightly less than Sensing range "Rs" (D<Rs).

WSNs are mainly used in dangerous conditions where human safety is of high importance. WSNs are also used in those areas where human can't reach e.g. volcanos, flood region and deep oceans.[14],[15] and [16]

1.5. Deployment of wireless sensor nodes

"Deployment" as the name suggests to place, scatter or position; It is the process in which wireless sensor nodes are thrown from a helicopter or a ship in the desired area in order to collect or sense information. As the sensor nodes are electronic devices, though cheap in price i.e. from 20-60, but still in order for their safe landing; otherwise the process has to be repeated again. Which will consume for time and

resources. Low price parachutes are used to insure, they land safely. Figure 3-1 illustrates the deployment.

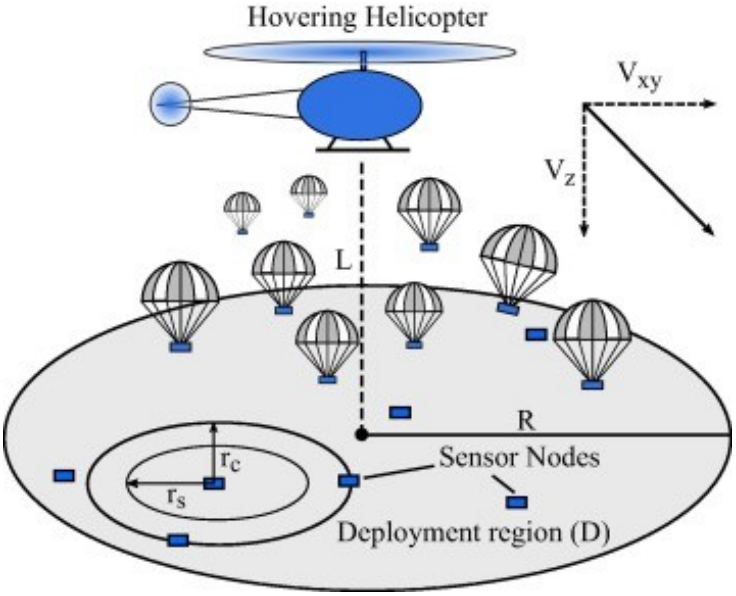


Figure 1-3 (Deployment of wireless sensor nodes)

1.5.1. Random Deployment

In Random Deployment we don't have pre-known idea about the place, environment or area. This type of deployment is mainly used for large areas where the conditions are harsh and it is not possible for a human to reach there, without risking life, also without damaging the equipment. This type of deployment is cheap and low cost as compared to deterministic deployment, since in this a person has not to go personally to deploy sensor nodes, neither an Autonomous Underwater Vehicle (AUV) or any Robot is Used, so energy and resources are saved. Sometimes can also be used for small area if the conditions are very hazardous for example Volcano eruption, enemy camps, floods etc.

1.5.2. Deterministic Deployment

It is the deployment in which we have Pre-knows idea of the area, we have knowledge about the dimensions or environment or both of them. It is expensive in a sensethat a robot or a person has to go and manually place the nodes on the desired locations. Not suitable for the applications where the danger to life is high or is risky. It is a hard and time-consuming process but accurate as we have knowledge about each and everything.

We can also have fixed nodes (FN) as well as moving nodes too in a WSN. Fixed nodes are placed at desired locations to facilitate the moving nodes or other nodes. It (Fixed Nodes) can save a lot of time, can reduce load on the other nodes, can reduce delays and saves energy, gives us enhance energy consumption. Hence prolonging the network life time. Works excellently in real time application where delay is critical.

1.5.3. Applications and Challenges of Deployment

The type of deployment that is being made determines all the characteristics of your network including network life time, Energy efficiency, BER, overall output and cost etc. Thereby it is of immense importance to choose a deployment method that can fulfil our desire cause. The deployment method plays a major role to cater challenges that we face in underwater communication [17],[18] and[19].As we are dealing with hostile environment and human can't reach there due to danger so the deployment of WSN should be in such a way that it is long-lasting, reliable and secure at the same time because they can't be replaced or maintained. Efforts have been and are still being put to the cause in demand that quality is boosted, boosting efficiency of entire network and to improve durability, when facing harsh conditions. Deployment can be of two types random and deterministic. In Random Deployment sensor nodes (SN) are dropped from a helicopter using low price parachutes to insure safe landing. This type of deployment is used where the scenario or conditions are unfavorable or the area is too large to cover then random deployment is used. Large area or open area can be Ocean, battlefield or disaster effected place. Random small-scale deployment can also be made in those area where human can't reach or too expose e.g. Enemy camps, spying etc. Whereas when it comes to deterministic deployment it is best

suited for small regions, we mostly know the conditions of that place and we strategically deploy the nodes in order to collect information. Random deployment is easy, cheap but sometimes less effective. Deterministic deployment is expensive and is a very hectic task to specifically deploy the nodes where we want them by using human effort or any automatic robot, increases the cost and time of

deployment [20].

1.6. Problem Description

Initially researchers were working on Optical Underwater communication (OUC) and it was one of the most interesting field back in the day. The reason was the high speed of light but very soon this dream of using light in underwater communication sought of faded, because light dispersed in water. As a result, long range communication became impossible.

Having done this, the research community attention asserted towards using Acoustic waves for underwater communication. The range was definitely improved but along with this; As underwater communication is affected heavily by the not so good environment of the sea; as a result, the communication was handicapped by several parameters. These parameters are: Delay was produced in communication, pressure had an effect, Temperature, Salinity, Depth, Doppler shift etc.

Due to these reasons Researchers proposed several methods to rectify these challenges as these challenges effect the SNR, BER, Network lifetime, Packet delivery ratio, through put and cost respectively. Different deployment schemes have been presented in the last several years to make a change in terms of energy usage, extending the operation and reliability of the system.

Energy is drained due to the transmission and reception of data packets between different nodesandsince, it is a well-known fact that the nodes are battery operated and it is not possible to harvest energy into the communication in order to make the communication going... The batteries can’t be changed manually or during communication. If the nodes die down it will paralyze the whole network, hence effecting the communication and flow of information. For this purpose, (to help the

sensor nodes), in the range or nearby area of wireless sensor nodes, mobile nodes are placed. In this way the Energy Consumption issue was taken care of, it enhances the overall performance of the network, although cost is an issue but overall it is good for the desired results that we yearn for. The major con of such deployment was it caused delays; this sort of deployment is suitable for those applications where delays can be tolerated [21]

In this type of deployment four movable sinks moves along the horizontal axis, the purpose is to facilitate the nodes that are deployed in the sea. The nodes that are nearer to the mobile sink send its data to the mobile sink. All the sinks check the nodes that are in its reach and gathers the data from them,this reduces the burden on the nodes and they perform better causing the network to sustain for longer durations and increases productivity. The number of sink nodes can be altered according to the need and application and hence cost can vary from network to network[22]

Three deployment schemes triangular, Square and hexagonal are analyzed and compared on the basis of coverage area. The simulations that were performed shows that when it comes to coverage area the triangular deployment is best, then Square and finally the hexagonal has the least coverage. The adversity that we face is that when coverage area is increased, A large area to be covered may need as many nodes as it can get, hence can increase the cost perspective of the network. Triangular deployment turns out to be costly as compare to hexagonal, if the cost perspective is kept in mind. Otherwise triangular is better [23]

Numerous deployment schemes and structuresexists, some researchers facilitated the sensor nodes by deploying Autonomous Underwater vehicles (AUVs), these vehicles support the nodes, resulting in solving or improving a great deal of energy and life time related issues. Improving the BER or SNR etc. in some combinations Mobile sink, Mobile nodes, fixed nodes has been used. Improving some parameters and compromising some others: As there is always a tradeoff. Since the performance of any network is deeply affected by the strategy that is adopted while doing the deployment or the method of deployment: Which includes Network life time, SNR, BER, Packet delivery ratio and cost. All of them can’t be improved at the same time

there is always a tradeoff between thing, depending upon the requirement. There are few parameters that has been missed out which if considered can make a difference.

1.7. Thesis Objectives

Pressure, Salinity and Temperature are the three parameters, though they have been discussed in general in few papers. It's a well-known fact that these parameters do affect the communication: Still there has not been a deployment scheme based on these parameters (Since they do matter). A deployment scheme based on these Three parameters have been proposed in this work. The routing protocol used is "Greedy Algorithm". Since not only the routing protocol is not enough it has to be backed by a feasible deployment. This is what the crux of this work is.

The purpose is to proof that a good deployment scheme can enhance the network performance than it had before. The mechanism and working of deployment are discussed in CHAPTER 3. The results are compared with the graphs of few famous deployment schemes to verify the validity of the hypothesis.

1.8. ThesisOrganization

CHAPTER 1 covers the introduction and background part Underwater Communication, Wireless Sensor Nodes their applications and the challenges are briefly discussed, further more Wireless Sensor Networks (WSNs), its applications and the hurdles that we have: Deployment: Its need, Applications, types and challenges have been covered in this chapter. The sequence goes as: CHAPTER 2, this chapter covers the supportive literature and background overview, Different deployment schemes have been discussed in detail. The methodology part has been covered in CHAPTER 3. Simulation results are plotted, verified and compared with other recent deployment schemes in CHAPTER 4. The last chapter that is "CHAPTER 5" it covers the conclusion and the future direction for the upcoming researchers.

Chapter2

Literature Review

CHAPTER 2. LITERATURE REVIEW

Before the formation of the problem statement and the solution that I came up with, a good number of papers was studied, probed carefully: in order to look for a research gap. All started off from the very scratch, broader picture was visualized at first, and kept on narrow downing until a solid problem was found. Here is the review of some of the prominent papers that I have studied.

2.1. Supporting Literature

In Underwater Wireless Sensor Networks (UWSNs), Battery or power consumption is the main issue. Since sensor nodes are battery operated, have limited energy. Also, there is no such mechanism of energy harvesting (Battery replacement). The battery can't be changed or replaced manually as the conditions are not suitable for humans or even machines sometimes face hurdles to do so. Which compromises the network lifetime (NTL), It is defined as 'For how long or for how much time the network or system is capable to deliver'.

It is very essential to facilitate the sensor nodes in such a way that they can operate for longer durations, increasing the overall network life time. A special Deployment scheme was suggested in which Autonomous Underwater Vehicles (AUVs) were deployed along with the sensor nodes. These AUVs acts as a bridge amid the sensor nodes, if the distance is large in between the nodes, these AUVs try to overcome it by coming in-between the two nodes. Hence the data or info hop over on the AUV and finally reaches to the other node.

Autonomous Underwater Vehicle (AUVs) are vehicles which can go underwater into deep oceans for collecting data, exploring oceans and help other systems to work efficiently.WSNs are widely used now a days for different applications all around the world. It is not feasible or physically possible to replace the batteries, Since, the sensor nodes need a battery to run. This results in the derailing of performance of

WSNs.In oceans the environment is harsh which has unfriendlyconsequences on the operation of the networki.e. Network life time, BER, throughputetc. so for this purpose a strategy was developed to deploy AUVs along with the WSNs for better performance. This reduces the burden on WSNs, the AUVs can act as a bridge between the two nodes that are intended to be communication, thus the energy consumption can be enhances as the AUVs have no energy limitations, are mostly fuel operated and sometimes battery operated. The negative aspect of this deployment is firstly it can increase the cost but suitable for those applications where cost is not an issue for example Military. Secondly it can result some delay in the network. Apart from this it has several advantages which includes the network life time of the entire system as energy is the main hurdle that we face when it comes to underwater communication, BER is improved and the system reliability is increased [24]

In this Energy consumption-based deployment the sensor nodes move about the static sensor node with slow pace, or one can say keeps a track of the sink node which is fixed. The reason for doing so is: In Underwater Wireless Sensor Networks (UWSNs), equal energy distribution or equal work load is often considered as a major hinder. In the wakening of all data to be transferred or transmitted, the nodes in the network starts to die one by one. It is vivid: The one that has a high work load will die down first, and the others will follow.

So, by this method all the sensor nodes take part in the process, improving the energy consumption among the nodes[25]

In this type of deployment, the AUVs are installed into the network along with the sensor nodes. In this arrangement the AUVs facilitates the Sensor nodes. When the density of network decreases it causes the void regions or huge gaps, these are the regions where, there are less nodes or no nodes at all. Due to which transmission delays are caused effecting the performance of the system so for this it was suggested to deploy certain number of fixed nodes in different deterministic points. Thisdeclines the energy consumption and the average end to end delay among the nodes throughout the communication[26]

A relay node is deployed right in between the source and destination at a same hoping distance to reduce energy consumption. The data or information hops on the

relay node and then it is engaged in the direction of its destination in a hop-to-hop manner, Hence the sensor nodes consume less energy in transmission or reception, the relay node helps in that. The energy saved increases the network life time as the prime or core issue that we have in Underwater domain is the energy and power issues. [27]

Manal et.al came up with a unique deployment strategy in which moving sink had the ability to redeploy itself. The sink is reorganized, if the energy consumption is not up to the point. The judgement is made by surface sink. It helped in reducing energy usage [28]

Sensor nodes randomly deployed around a cluster head (CH). A cluster head is basically a sensor node, not different at all. The basic concept is that the sensor nodes selects it as a head node (All the data is sent to it). Different parameters can be used to elect the cluster head (CH). AUVs are used, which goes to specific selected nodes (Cluster heads) and collects the information this reduces the overall energy consumption of the network and overall burden; simplifying of things. Increasing the operability of the network for longer durations[29]

It is a renowned deployment schemes that is used for security purposes and also in military (Navy), In such deployment the sensor nodes are placed in a circular manner around the candidate region and if there is intrusion then it can be sensed and further action can be taken [30]Some of the events for which we have certain knowledge or some kind of knowledge (e.g. Enemy camps) need target-oriented deployment and WSNs are deployed only at those points where they are supposed to be deployed. The condition is that there should be pre-Known knowledge [31]

In [32] a scheme of homogeneous deployment of WSNs is proposed in which the totalapplicantarea is ghettoized into hexagonal sub-structures and in the center of each sub-area (Also known as block),sensor nodes are placed. It's a Random deployment scheme in a sense that no previousfamiliarity about the candidatesection is offered. This type of deployment increases coverage area and outstrips the other current algorithms in perspective of coverage area. In our daily life most of the practical applications requires 2-D deployment the reason is that it is easy to setup and easy to handle.3-D deployment is hard to setup and hard to predict so it is important to have an eye on it as well and try to explore it. Node deployment is a most importantaspect

upon which the network's performance depends. Three 3-D based deployment schemes (The haphazard deployment, cube deployment and the regular triangular deployment) are debated and then compared on the basis of following parameters localization ratio, localization error, average number of neighbor nodes and the network connectivity. The simulations proved that the trilateral deployment is way in advance than the other two in terms of reducing localization error and enhancing the localization ratio and maintaining the average number of neighboring nodes and reasonable network connectivity at the same time. Triangular deployment increases the quantity of nodes in the network hence rises the costaspect.

Chapter3

Methodology

CHAPTER 3. METHODOLOGY

In this chapter the proposed technique and its details are discussed. In this chapter the working technique, conjectures and postulates, and how this technique can be helpful to cater the stated problem.

DBR is a depth base protocol, in this the nodes are nominated on the base of their depth. The numbers from a node to Sink node is forwarded in multi-hop way. The sending packet header includes its depth information in it and broadcast that packet to its neighbors. Upon reception the receiver relates its depth to the depth that the sender has. If the number is greater than that in packet. The packet is discarded. If the depth of receiving node is greater than sender node depth, the receiver is nominated as succeedingforwarder. Nodes with less depth has low holding time therefore, the decision has to be taken quickly. Note that, the nodes which has less depth are usually involve in data forwarding process. hence, their energy is drained quickly which can cause in formation of holes in the network. Since they demise quickly. The nodes with low depth consume quickly as compare to the nodes which have high depth[33]

For efficient energy consumption an advance form of DBR that is, EEDBR was presented. Similar to DBR the data from start to end point is sent in multi-hop fashion but this time the header has the Residual energy (RE) and depth. The receiver that has high residual energy and less depth are elected as subsequentforwarding node. The nodes that are near to sink have more load and usually die out earlier as compare to the those which are away, creating loop holes in the network [34]

The proposed system is called EBECRP.It has Two sinks that are sink1 and sink2. One covers the dense region and the other covers the less dense region. Also, the setup has cluster heads (CH), S type nodes and N type nodes. The hello packet header has node id, coordinates of other nodes and both the sinks. The hello packet is only used whenever the sink changes its position so for updating the system the hello packet is broadcasted. Upon reception of the hello packet, it tries to connect to the

nearest sink. If the sink has changed its position it discards the packet and updates itself and also convey the information about the change to the neighbors.The region to which sink is near, in that region the nodes will directly forward the packet to the sink otherwise it is through clustering in order to save energy.

In clustering each node producesanarbitrary value individually, and associate that value to other nodes. The one with maximum value is chosen as cluster head. While the others remain N type nodes.

The coordinates of sink and the nodes are shared throughout the network in order that it is known by every node.The CH accepts data from the N type nodes. The data is then transmitted from CH to the sink. This helps in load balancing on other nodes. The S type nodes unswervingly send data to the sink [35]

Underwater communication comprises of sensor nodes and asink. The sensor nodes bring togetherinformation and directs that data to the sink via following some routing protocol. There are different parameters under sea, which are mostly not in our control but we can apply different techniques to overcome those effecting causes and strive to make our communication better. These parameters include Doppler shift, ionization,challenges regardinglimited bandwidth, propagation delay etc. Some of them have been explored, while many are still to be explored. As said before these parameters are not in our control but we can surely harness our resources to overcome the challenges. AUVs can be used to facilitate the nodes in order to solve the power constrains, different deployment techniques can be of great use (2D and 3D both). Packet size and the channel used is also one of the aspects that can have substantial contribution to the performance of the system. Underwater communication is one of the hot topics that needs to be explored in future. [36]

3.1. Proposed System

We have an area of 800x800x800 m3 in which 100 nodes are deployed. These nodes gather data and transport that data to a Sink node (Sn).On the basis of change in deepness of water, the desired area is segregated into four layers. The water in this case is 800 meters deep.Please note that as per the x - y - z coordinates, the starting

point is zero.Thus, the bottom of the water is considered 0 meters whereas the surface of the water is treated at 800 meters. For this reason, as per the distribution, 40 percent nodes are distributed between 0 to 200 meters from the bottom. The next 25 percent are between 200 to 400 meters. The other 20 percent is between 400 to 600 meters and the last 15 percent nodes are at the top which is 600 to 800 meters.

This kind of distributed is on the basis of varying condition that includes the Temperature (T), Salinity (S) and pressure (P). As with the increase or decrease of depth these parameters vary which have an impact on communication, as a result can manipulate the whole system performance.

During the distribution, a clearance of 20 meters is kept so that nodes do not enter the other layer which means that for the 400 to 600-meter area, the node coordinates are set from 410 to 590 meters thus providing 10-meter clearance. Aside from the z – coordinates, the x- y coordinates are entirely random such that the coordinate assigned to one node is not repeated again.

After the nodes are distributed, some set values as per the temperature, salinity and Ph level w.r.t the depth is initiated. The following variables are initiated for this purpose which include,

1. Salinity: Changing w.r.t depth
2. Temperature: Changing w.r.t depth
3. Ph level: Changing w.r.t depth
4. Frequency: set to 4000 Hz or 4 KHz.
5. Signal to Noise Ratio (SNR): set to 50

but can be changed. 50 SNR means that each node will maintain this SNR by altering the transmission power which in turn depends upon the distance. Greater the distance, greater the power to transmit data. For this reason, the data loss remains constant. The packet loss rate will increase / Decrease w.r.t to SNR but constant for a specified value of SNR.

6) Node power -; Each node has been given an equal power of 3 Watts. Whereas the

power decreases with each cycle. As shown bellow.

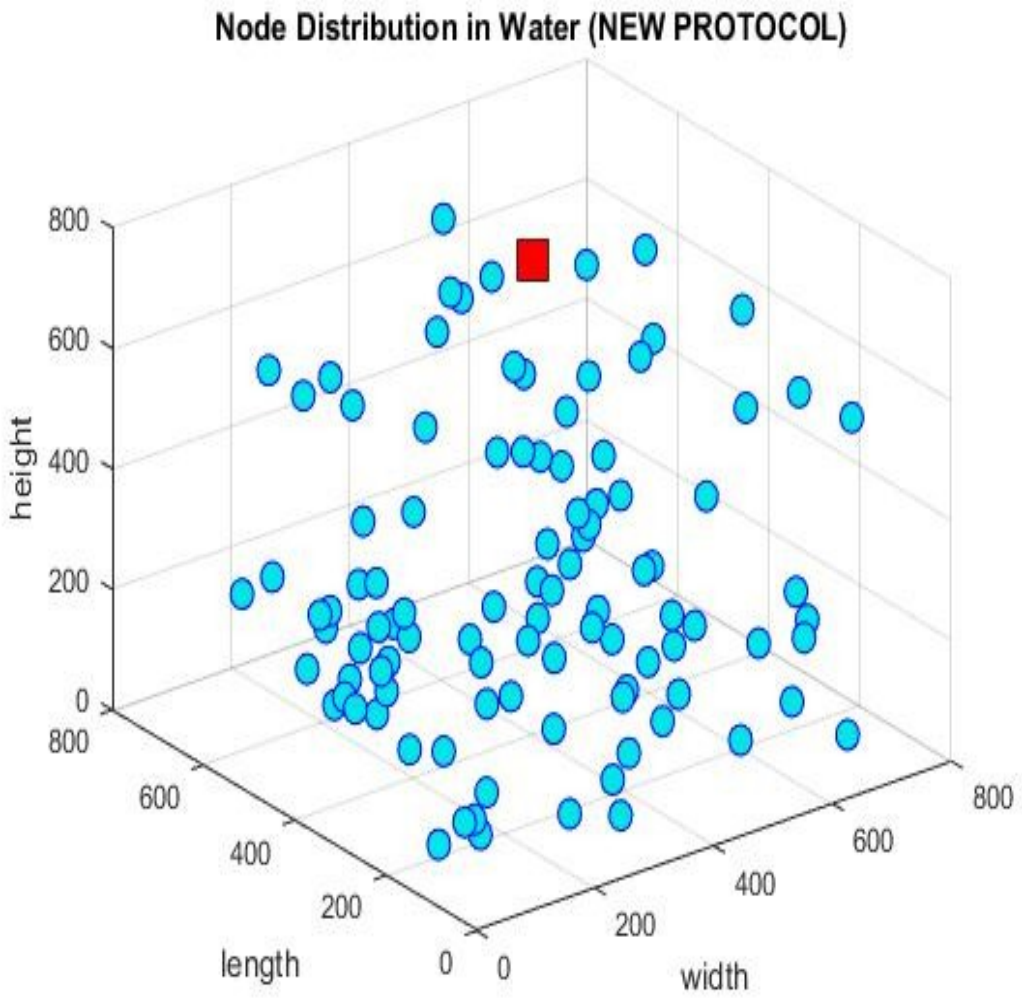


Figure 3-2(New proposed deployment)

3.2. Mechanism

The figure (3-2) shows the main graph which depicts the node distribution. It can be seen that as explained previously. 40 out of 100 nodes have been located at the bottom. 25 at the upper layer between 200 to 400 meters and so on.

As per Algorithm every node calculates the distance of its neighbor in the next layer (Temperature, Salinity and Pressure vary from layer to layer). And establishes a link with the nearest. This is how the data is routed from node to node and finally reaches to the Anchor Node (AN) or Sink Node (SN).Anchor node at the top which accepts

data from all the 100 nodes and the nodes adopt the greedy algorithm for forwarding the data to the sink node.

Assume a system, that has a sink node and many sensor nodes that are spread out in an area. The sensor nodes amassdata and the goal is to hop the data onto the sink node with the help of sensor nodes. In the proposed system “Greedy Algorithm” is used for routing the packet towards the sink. In case of the data has to be sent upwards the following steps occur.

- As soon as a source node requires a route towards the sink, A path request message (PREQ) is advertised to all the neighboring nodes.
- Upon receiving the path requests the receiver node. The receiver node calculates its distance from the other nodes, and the sink. If it has less distance to the sink node than other nodes packet is forwarded to the sink, else give it to another node.
- Until the packet is reached the sink the above steps repeat.
- When the sink receives a (PREQ) from a sink node, the forwarding table has record of all the multiple paths of each node.
- Upon generation of multiple routes, for enhance life time and better energy usage the shortest path is selected. Other paths are kept reserved.

The Euclidean distance between any two nodes for example q and r is calculated by

$$d(q,r)=\sqrt{(x_1-x_2)^2+(y_1-y_2)^2}$$ (Equation 3.2.1)

Two types of deploymentare made.

- Random deployment
- Proposed deployment on the base of temperature, Salinity and pressure.

3.2.1. Random deployment

100 nodes are haphazardlysettled over anarea of 800x800x800m.The nodes uses greedy approach, as soon as a node accepts a packet it computes the distance of it neighbor and packet is forwarded towards the nearest node. The receiver node checks its distance from other nodes and also the sink. If its distance from sink is less than other nodes it sends packet directly to the sink. If not, it asks for help from other nodes. The aforementioned parameters play its role in the performance of the system. The deployment is shown in figure 3-2

3.2.2. New Proposeddeployment

100 nodes are deployed over a region of 800x800x800m.The area is divided into four layers on the bases of change in temperature, Salinity and pressure w.r.t depth.15 percent nodes are deployed in the first layer,20 percent in the second,25 percent in the third and finally 40 percent in the last layer, Since the conditions are not so favorable for communication at high depths.

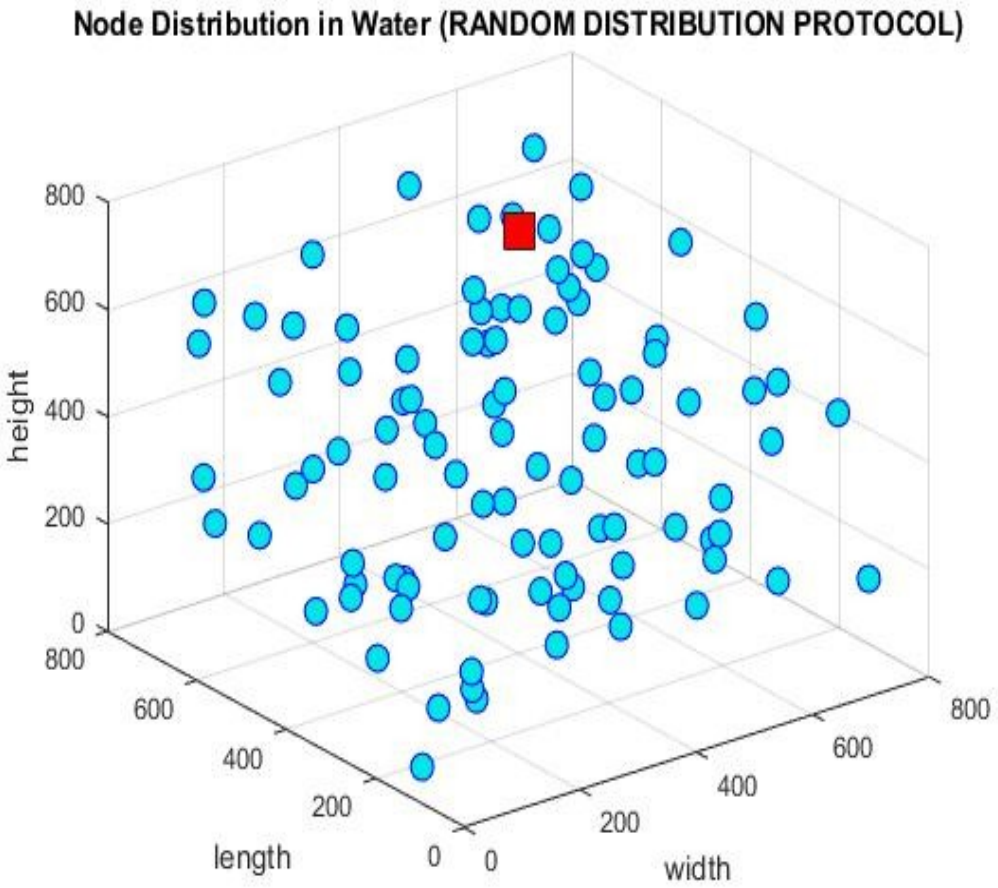

Node Distribution in Water (RANDOM DISTRIBUTION PROTOCOL)
height
800
600
400
200
0
800
600
400
200
0
length
0
200
400
600
800
width

Figure 3-2 (Random deployment protocol)

Chapter4

Evaluation

CHAPTER 4. EVALUATION

This chapter comprises of results. The results are compared to some other deployment scheme in order to confirm the superiority of our proposed scheme. Basically, what we have done is we have taken same routing protocol in both the deployments.What we have altered is "According to the hypothesis it is stated that When we deploy sensor nodes, we apply a routing algorithm upon for transmission of a packet from a sensor node to the sink.

What my work bring to the table is that only the deployment and routing schemes are not enough, the nodes ought to be deployed in a proper technique, thus the performance can be enhanced further. Temperature, Salinity and Pressure are the factors on which the deployment is made. Prior to this there was no deployment scheme which targeted the above-mentioned parameters.

Table 1 (System Parameters)

Table 1 embodies the system parameters.

Parameters	*Values*
Network Size	800mx800mx800m
No of nodes	100
Power of node	Three Watts
Frequency	4 KHZ
SNR	50
Hello Packet Size	8 bits
Temperature,	Vary with depth

Salinity, Pressure

4.1 Network Life Time

The proportionof dead nodes to alive nodes gives us the network life time. In simple words the greater the no of alive nodes,the longer will the network withstand and communicate successfully. When the transmission starts the nodes faces harsh conditions which causes the nodes to drain energy. For a network in order to work efficiently the no of alive nodes should be greater than the no of dead nodes.

Figure 4-1depicts the no of dead nodes in random distributed nodes and proposed distribution. Both the distribution follows the same routing protocol, that is “Greedy Protocol”. It is evident that the proposed deployment based on temperature, salinity and pressure outperforms the random distribution scheme. This is because of the reason that the randomly deployed nodes are unable to resist the challenging environment as compare to, when we deploy nodes on the basis of temperature, salinity and pressure. The proposed distribution is specially designed to face the harsh conditions. Therefore, the no of dead nodes is quite less as compare to the random distribution.

Figure 4-2 shows the number of alive nodes and dead nodes in both the distributions. Remember that both faces the same adversities and both uses the same protocol. The better results are due to the specialized deployment which prolongs the live of nodes.

The proposed deployment scheme out performs the random deployment, by a far-off margin. Which means that not only the deployment and routing protocol is important but efficient deployment is important for making the network more reliable, efficient and long lasting.

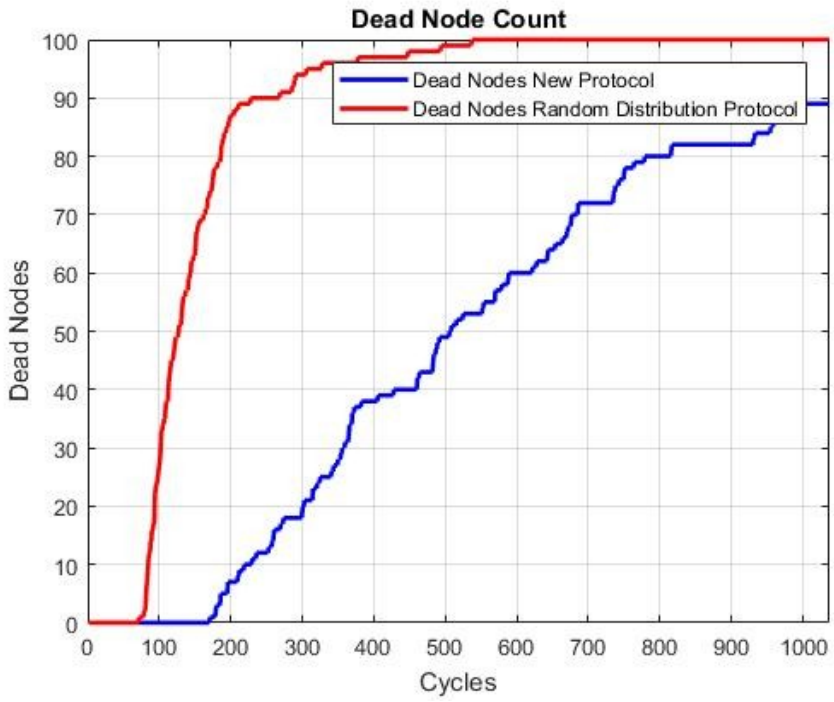


Figure 4-3(No of dead nodes)

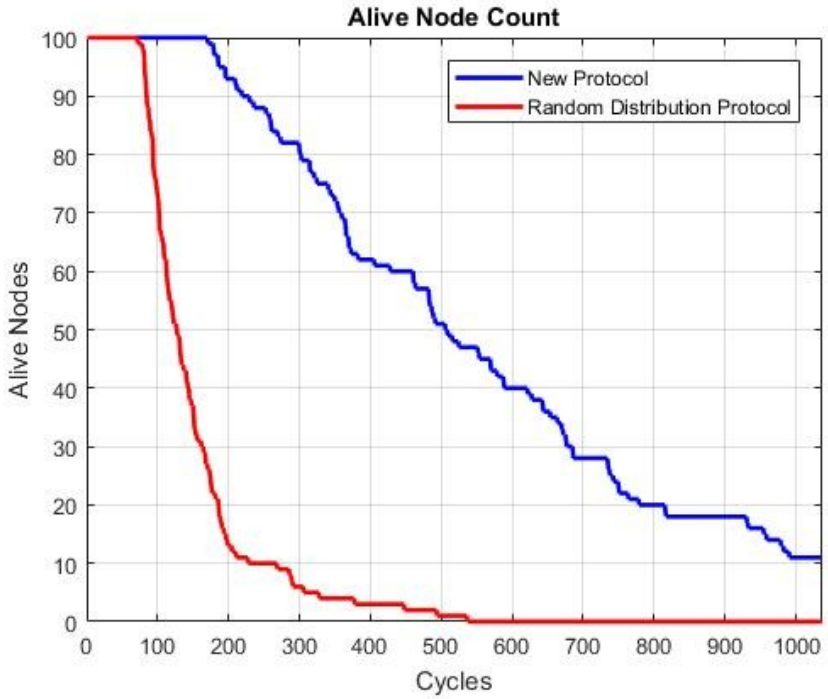


Figure 4-2(No of alive nodes)

4.2 Throughput

The total number of packets that are successfully received at the sink without any interruption is stated as “Throughput”. Figure 4-3 displays the over-all percent of packets that are effectively received at sink by both the deployment methods. It is cleared from the figure that, when nodes are deployed in proper way so that it can keep it up in front of all the harsh condition that they come across in deep sea. It shows better results as compared to randomly deployed nodes. By the new proposed deployment, the anchor node receives almost 97 percent of packets successfully. Whereas the random deployment gives us about 95 percent.

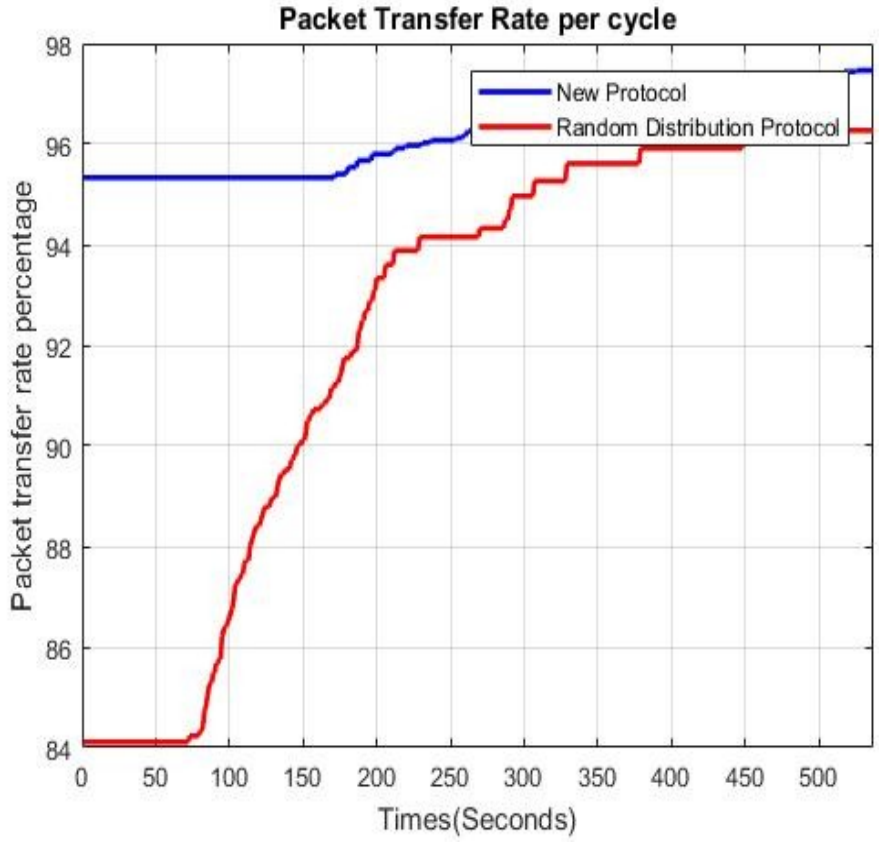


Figure 4-3(Packet transfer rate)

4.3 Packet Drop

The number of packets that are dropped or discarded during communication is called packet drop. This means these are the packets which are not received by the sink and are dropped in the mid-way due to harsh environment and losses. When the nodes are randomly deployed, they are not able to compete the harsh behavior of the water, hence they tend to have more packet lost as compare to, when nodes are deployed in a proper way. In deep waters the temperature in low, Salinity is high and pressure is also high. Therefore, we obtain worst SNR.So, to cater this problem in the proposed scheme we have deployed 40 percent of nodes in the bottom layer. So that the nodes can efficiently communicate. At upper layers the number of nodes is in reducing order since the environment in shallow water is reasonably good for communication. We can clearly see the packet drop in both the deployments un figure 4-4

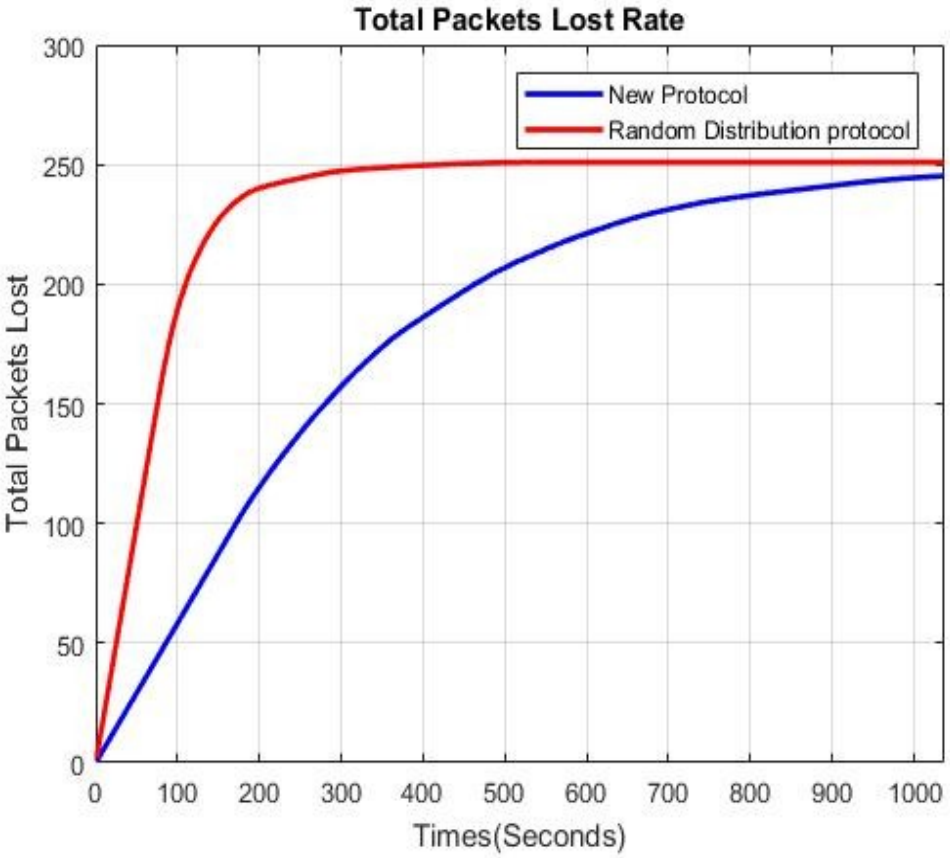
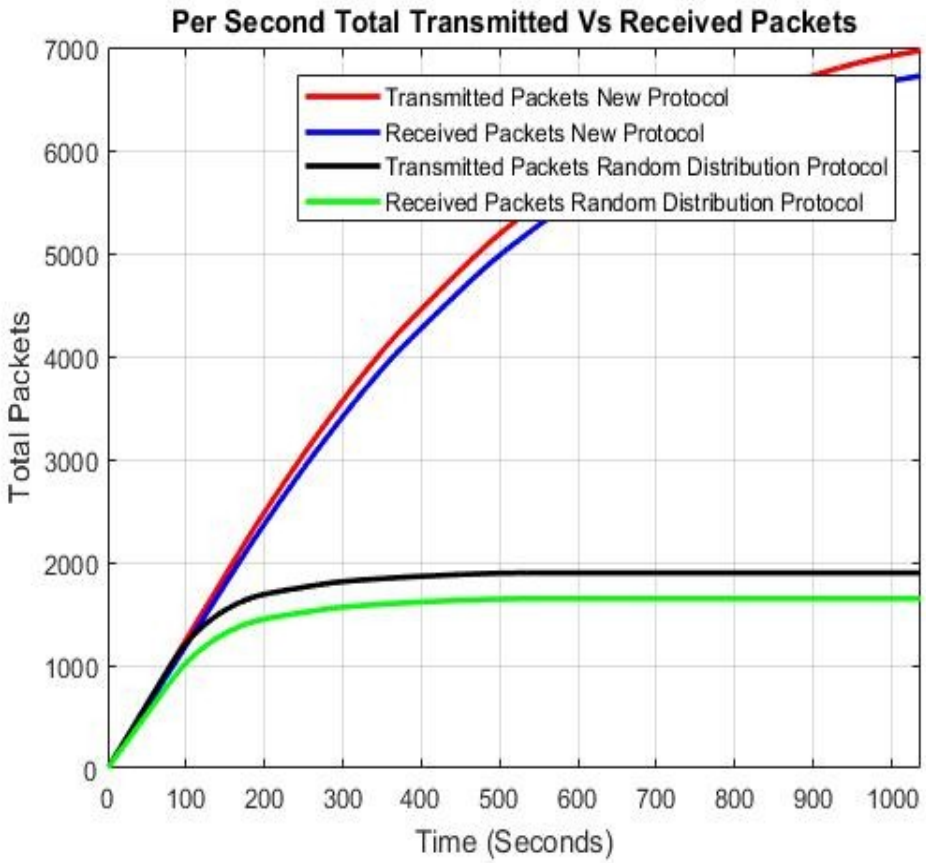


Figure 4-4(Packets dropped/Lost)

4.4 Packet acceptance ratio (PAR)

It is the ratio of packet transmitted and packets that are actually received by the sink, or in

simple words the proportion between transmitted packets and receivedpackets. Figure 4-5 shows that the proposed deployment scheme gives us better results as compared to the random deployment scheme. The proposed deployment when uses the same routing protocol that the random too is using. It occurs that the proposed technique gives us better Packet acceptance ratio (PAR).



Optimal

Figure 4-5(Packet Acceptance ratio)

Chapter5

Conclusionsand Future Work

5 CONCLUSIONS AND FUTURE WORK

5.4 Conclusion

Adeployment scheme founded on Temperature, Salinity, andPressure is presented in this thesis. In order to facilitate the routing protocol used. Firstly, we used random distribution, the nodes were deployed and data packet is sent from sensor nodes towards the sink using “Greedy protocol”. Each node calculates its distances from the other node and forwards the data packet to the nearest neighbor. The receiver node sends the packet to the other and so on…The packet Eventually reaches its destination.

Yet again, nodes were deployed but this time not random, a specific pattern is followed this time. The nodes are distributed in increasing order from top to bottom. The reason of doing so is because the unfavorable conditions increases as the dept increases. Thisimpose adverse implications on the performance ofnodes, that’s why the nodes are deployed in so manner.

The proposed deployment outstrips the random distribution. Although, the routing protocol used in both the cases is same. Whichbrings us to the conclusion, ‘The deployment, and routing protocol is not sufficient sometimes, for better network performance the deployment should be made systematically and in a proper way. Also, the importance of my work increases even more because there was no deployment based on these parameters, prior to this. Which in its self is a big success.

By just changing the deployment method the Network Life Time, Throughput, Packet drop and Packet acceptance ratio (PAR) has improved than it was previously.

5.5 Future work

This Deployment that is based on aforementioned parameters can be implemented on other routing protocol like DBR, EEDBR, EBECRP, and LEACH etc. to check the difference. The crux is 'By deploying nodes properly the performance can be enhanced.

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