CHAPTER-1

INTRODUCTION

1.1 *Overview of Wireless Sensor Network*

Wireless Sensor networks are most reliable technology in the present world for studying and round the clock analysis of any area which cannot be feasibly kept under surveillance of humans all the time. Being an amalgamation of MEMS (Micro Electronics Mechanical Systems) and wireless technology, Sensor networks are one of the widely accepted interface between the physical environment and the user of information.

Wireless Sensor Network is a network of spatially distributed autonomous sensors which monitor physical or environmental conditions and cooperatively pass their data through the network to a main location.

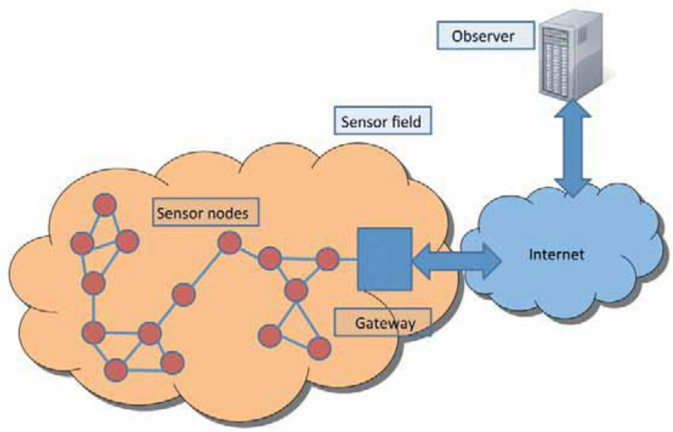

Fig 1.1 Wireless Sensor Network architecture

1.1.1 History of WSN

The need of sensor network arose to keep the battlefield and other conflicted areas under surveillance. Research on WSN started back in 1980s when DARPA (Defense Advanced Research Projects Agency) designed a program named 'Distributed Sensor Network' for the US military. DSNs were supposed to have an architecture of present WSN i.e. several spatially distributed low cost sensing nodes, teaming up with each other but operating autonomously, and subsequently routing information to the destination. But this could not be achieved with the technological know-how available at that time. Specifically, the sensors were large thus this limited the number of potential applications. Also, being an early technology, DSNs could not communicate easily in wireless domain.

With advancement in computing, MEMS technology and communication, WSN research took giant leaps which happened around 1998. The networking technology was mainly focused upon as they are of prime importance for dynamic ad-hoc environments and the system with lesser resources. Alongside, the size of the sensor has drastically decreased from being as big as a shoe box to small enough like a dust particle. Subsequently, the cost has reduced too.

DARPA, being the pioneer of revolutionizing the field of WSN , achieved this by launching an initiative program called SensIT, which allows a sensor network to get converted into an ad hoc network, have dynamic querying, reprogramming and multitasking. This has made WSN to be one of the most important technologies of 21st century.

1.1.2 Application areas of WSN

Sensor nodes of a network can monitor a wide variety of ambient conditions that include the following:

- Humidity
- Temperature
- Vehicular movement
- Lightning condition
- Pressure and mechanical stress
- Soil makeup
- Characteristics such as speed, direction, and size of an object.

WSN has its applications in various domains. The details are given in the flowchart.

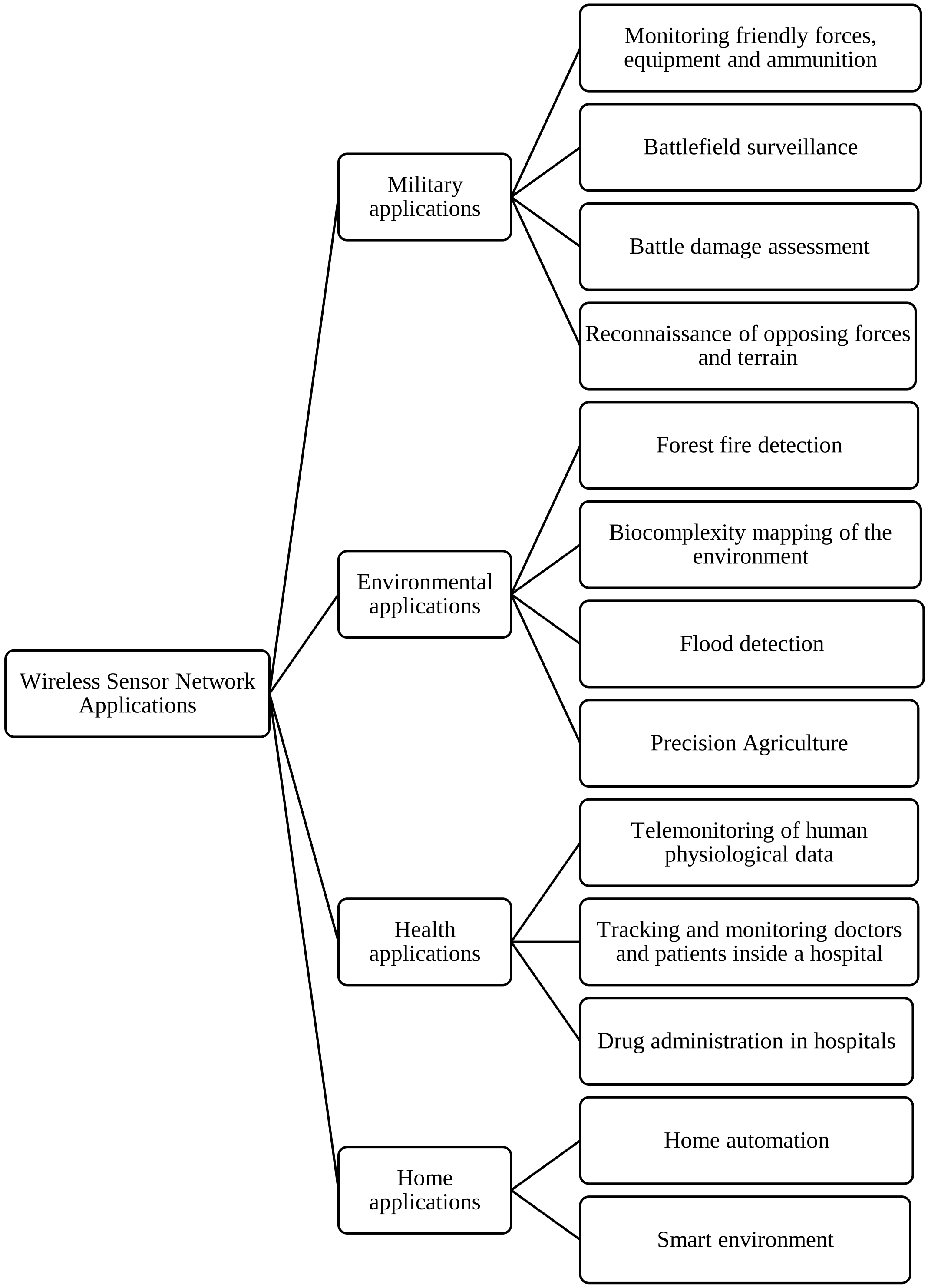

Fig 1.2 Flowchart of applications of Wireless Sensor Network

1.1.3 Architecture of Senor Node

The sensor nodes of a WSN generally comprise of the various components. The major blocks are Sensing Unit, Processing Unit, Power Unit and Transceiver.

1. Sensing Unit: It is responsible for interacting with the environment via sensors installed in it and sensing desirable parameters for example, pressure, temperature, humidity etc. The input of the sensor is an analog signal and it is then converted to a digital signal by an Analog to Digital Converter. This digital signal is further fed to following units for processing.

2. Processing Unit: This unit processes the digital data and converted it into the form which can used by other systems it is feeding to. It also has memory unit to store the required information regarding neighbouring nodes and data to be transmitted if to be kept for further use.

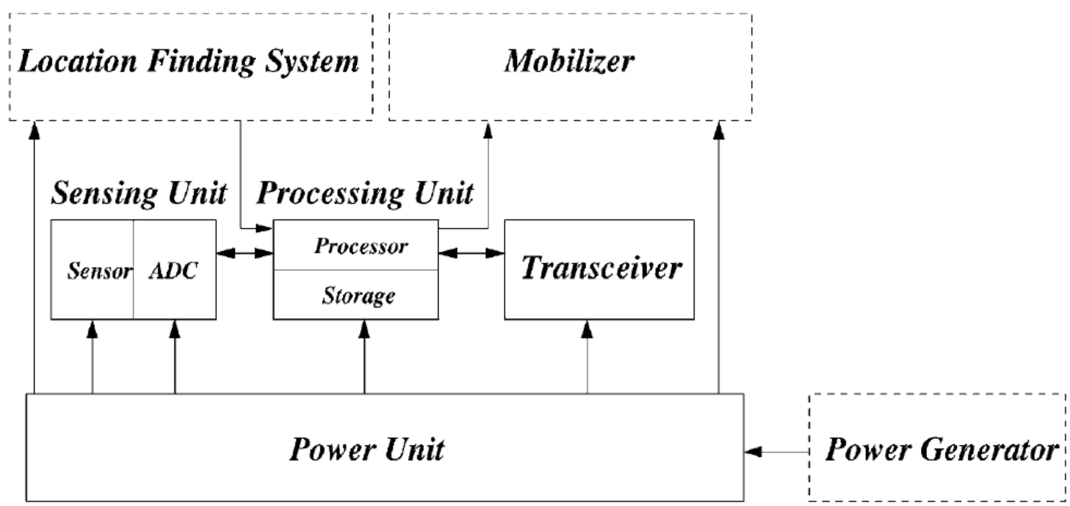

Fig 1.3 Architecture of a Sensor Node

3. Transceiver: This transmitting and receiving unit built according to the type of communication the links use, for example, RF, acoustic, optical or infrared. For transmission case, it consists of a modulator, pre-amplifier and an antenna or source. While for the receiver's case, it consists of a receiving antenna, a demodulator and a post-amplifier as per requirement.

4. Power Unit: The most important unit is the power supply unit which drives the whole system. The source is non-rechargeable in general to keep the cost of the sensing node low, but if required solar panel can be added to the node to generate power and recharge battery subsequently. These rechargeable nodes are generally bigger in size and limited in number in a network.

5. Location Finding Module: For the mobile nodes, the location finding module are also attached to the nodes, example the GPS location system. Depending on the terrain the node is employed in and the purpose for it is being used determines that how is it located.

6. Mobilizer: The sensing nodes may be as light as a small dust particle or may be as large as a shoebox. Depending upon the requirement, for example, for a node employed in a forest to capture activities of wild animals, mobility is ensured by adding wheels to it. This comprises of mobilizer unit of a sensing node.

1.1.4 Access Network Technologies and Topologies

Unlike wired systems, the wireless networks the channel needs to be properly divided to avoid conflicts between multiple users. The access network technologies are responsible of managing and coordinating the use of channels resources to ensure the interconnection and communication of multiple users on the common channel.

The access technologies used are different for different purposes:

- Bluetooth 4.0 is used in Medical WSN
- IEEE 802.15.4e (WPAN) technology is used in Industrial WSN

- WLAN IEEE.802.11 is used in IoT

  The architecture of a WSN consists of sensor nodes, a gateway module and the Internet. The deployment of a WSN is done as follows:

1. The nodes are placed/ deployed generally by an airplane for a network that is large and covers a remote area.
2. The sensor nodes broadcast their status to the surroundings and simultaneously receive status from other nodes to detect each other.
3. Thus, sensor network nodes are organized into a connected network according to a certain topology (linear, star, tree, mesh, etc.)
4. According to routing algorithm being used for the network, the communication takes place.
5. For large distance communication, multihopping is done.
6. The data is finally received by the gateway node from where it is stored onto the cloud.
7. The client may fetch the data by accessing the cloud.

1.1.5 Factors influencing Wireless Sensor Network design

There are numerous factors that need to be considered before designing a network. Some of them are as follows:

1. Fault tolerance: The network must be designed in such a way that it can sustain sensor network functionalities without any interruption due to node failures. Algorithms and Protocols must be designed to cater to the level of fault tolerance required by the sensor networks.
2. Scalability: The need to expand the network is not rare, therefore the schemes used must be competent enough to control the network and work with large number of nodes.
3. Sensor network topology: Due to mobile nature of the large number of nodes deployed, careful handling of topology maintenance is required.
4. Operating environment: The environmental conditions sensor nodes are expected to work in play an important role in defining the life of a network and its node.

5. Hardware constraints: The sensor nodes comprise of four basic components, a sensing unit, a processing unit, a transceiver unit and a power unit. All this combined must very small size, very light weight, lowest power consumption.
6. Transmission media: In WSN, communicating nodes are linked by a wireless medium. Depending on the terrain specification, environmental conditions we use the links like RF, infrared, acoustic or optical.
7. Power consumption: Sensor node has no means to recharge its battery in the general case, therefore very low power consumption is the most desired thing.
8. Production costs: The cost of a sensor node is a very challenging issue as the number of functionalities are large to be kept at a very low price.

1.1.6 Underwater WSN and its Areas of Applications

- ***Ocean biology*:** The health of the water bodies and of the marine life it sustains, is an accurate indicator of the level of pollution in the environment. To study this, we need a power efficient, self-sustained network to sense and analysis the required parameters.

- ***Disaster Management*:** Having the seabed under surveillance would help in disaster management as we could sense various disasters having their epicenter in the ocean or sea, at an early stage. From the information gathered, pre-warning can be generated for the nearby terrestrial areas.

- ***Surveillance Systems*:** The world has seen large number of border issues between countries sharing boundaries, be it on land or in waters. So Wireless Sensor network can be used to keep the disputed water areas under surveillance to check for any enemy intrusion.

- ***AUV/ROV operation*:** The unmanned robots are used underwater for various data collection purposes. Unlike on the land, the communication between different robots cannot be done through RF. Therefore, the Autonomous Underwater Vehicles can form a sophisticated network if communication takes place using appropriate link.

- ***Aid in search and rescue operations*:** In case of any accident that happens in oceans and other water bodies, deployed networks can be of help in the search and the rescue operations conducted. Critical data can be gathered from these, which is important in such scenarios.

1.2 Need of Work

With various applications of Underwater WSN ranging from oceanography to early warning systems for natural disasters (like tsunamis), ecosystem monitoring, oil drilling, and military surveillance, this further becomes an important area of research. Till today, the work has been done to study the underwater channel for acoustic transmission. Due to its very less bandwidth and high interference tendency, work to find a better alternative still continues. With advancements in optical technology, visible light communications started to be a major part of underwater communication owing to its higher bandwidth, real time audio and video data transmission capability and higher power efficiency. But the more sophisticated systems derived through research used both acoustic and optical links as limitations of both could be overcome by the other’s advantages. Since all time, for a designed sensor network for underwater environments have revolved around areas like appropriate channel modelling, accurate modulation for efficient communication, error detection and correction for data sent, optimization of routing algorithms used in multihop networks and sensor node localization schemes. Since for efficient communication, channel modelling is the pre-requisite. Therefore, we model underwater environment in discrete event simulator- Qualnet, since simulation of the network, in the environment it is going to be deployed in real time, helps reduce cost and study the behavior of the network in advance.

Since the underwater domain is unexplored in Qualnet 5.0, we attempt to construct physical layer protocols for underwater environment for a simple sensor network. Subsequently the results analyze the results of using AODV routing protocol.

1.3 Objective of the Thesis

Wireless Sensor Networks are deployed for various purposes in the underwater environment. It has varied applications in domains like environmental monitoring, military purposes etc. In this thesis we attempt to work on discrete event simulator- Qualnet 5.0. As every communicating network uses an OSI model to make the nodes communicate, each layer protocol needs to be carefully chosen. Since the communication medium here is, water, therefore to transfer information through it a corresponding physical layer protocol needs to be developed. In this work we have considered both the acoustic and the optical link of communication due to their characteristics which make them suitable for underwater environment.

Therefore, we develop two physical layer protocols namely 'UWOP' and 'UWAP' for optical and acoustic links respectively. These protocols are developed to interface with the custom underwater communication medium developed separately for both the modes. We then study their performance using the metrics like average jitter, average end to end delay etc. From the analysis we compare the performance of the acoustic and the optical link for various data ranges and transmitted power.

1.4 Methodology

The following flowchart explains the steps of the phases of the work for achieving the above stated objectives.

Step 1. For the type of communication link that is to be developed, communication medium needs to be modelled as per the codes given in Section 4.4.

Step 2. After modelling the medium, corresponding physical layer protocol is developed as given in Section 4.5 and 4.6.

Step 3. Modify the GUI according to new protocols developed to get the user input.

Step 4. Place nodes and create a network scenario to test the protocols with.

Step 5. Analyze the performance characteristics for the network working on UWAP and UWOP respectively and routing the information according to AODV.

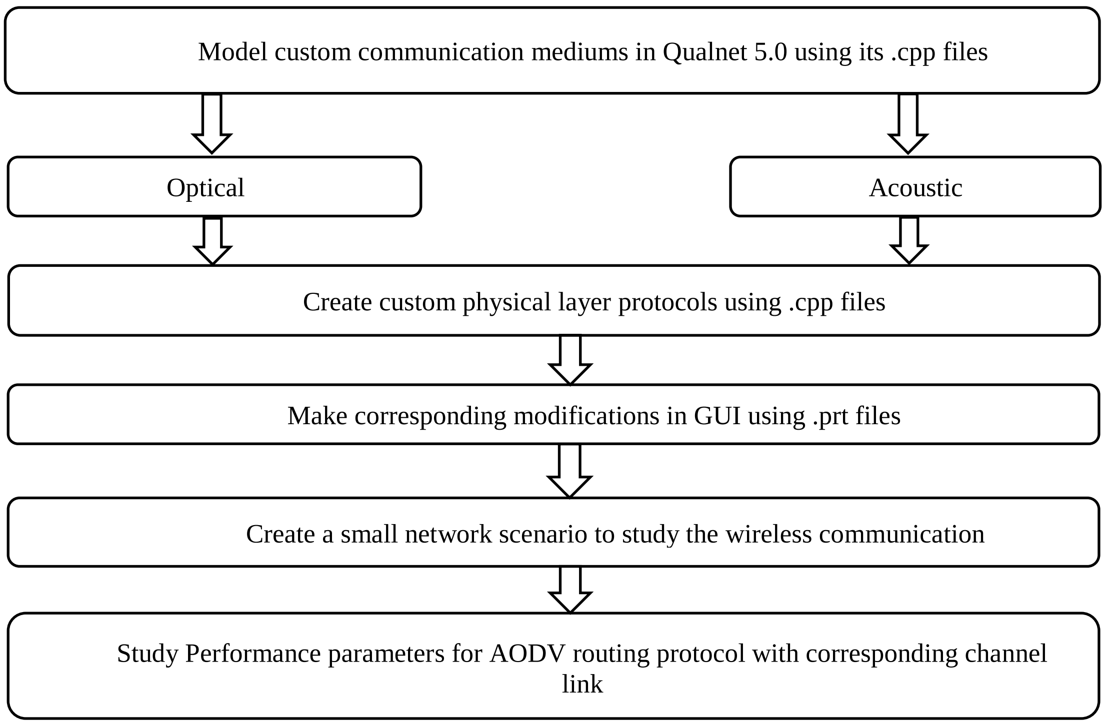

Fig 1.4 Flowchart of Algorithm

1.5 Organization of Thesis

This thesis contains six chapters. A summary of each chapter and its contributions are presented as follows.

Chapter 1 presents the overview of Wireless Sensor Network. It gives a brief introduction about various application areas of WSN and the history of sensor networks. Further the details about the architecture of sensor nodes are also discussed. Also, different network technologies, topologies and other factors influencing Wireless Sensor Network design.

Finally, in the introductory section we briefly introduce Underwater WSN and its application. This chapter also contains the need and the contribution of this thesis.

Chapter 2 contains the survey of all the literature that has been studied for this work. The relevant literature are divided into section as follows:

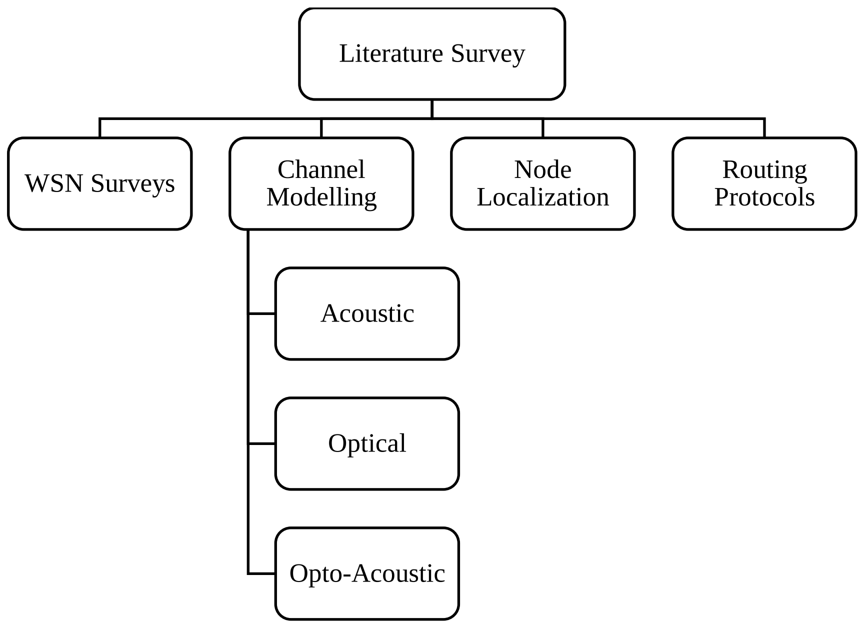

Fig 1.5 Literature Survey Organization

Chapter 3 presents details about Underwater Wireless Sensor Network. Different communication modes like RF, Acoustic and Optical are discussed. After learning about the possible communicating links channel modelling is studied in detail. Since, for efficient transfer of information the proper channel needs to be created using equations, we thereby study the pathloss models and environmental noise impacts for acoustic and optical signals. Further specific modulation techniques like PPM, OOK, QAM and PSK are discussed. After the data is digitally modulated to be sent across the channel, the receiver node needs to be located so that the least power is consumed, and we have a targeted communication. Furthermore, the routing protocols are also discussed and correspondingly AODV is chosen for the work. Lastly Hybrid Opto-Acoustic Underwater Wireless Sensor Networks are introduced.

Chapter 4 presents the work done on the Qualnet 5.0 simulator. Here we have created an\ wireless sensor network in underwater domain after learning about the advantages of a hybrid opto-acoustic network and the discrete event simulator- Qualnet. Alongside to make the network work in the desired environment, we have designed communication medium and corresponding physical layer protocol for both acoustic and optical links. Subsequently all the codes written are given step by step in this chapter.

Chapter 5 gives the results that are based on the analysis of the performance metrics like end to end delay and average jitter etc. Depending on the data rate, propagation distance and we study the network characteristics further and conclude results.

Chapter 6 presents the conclusions and the results of the work. Finally, the future scope is also discussed.