International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 9, September - 2022, Pages: 1-6

Acoustic Torpedo Decoy Prototype as part of Clustering in the Context of Underwater Wireless Sensor Network (UWSN)

Panagiotis Rizos[1] and Euangelos Rizos[2]

1Department of Informatics, School of Information Sciences and Technology, Athens University of Economics and Business, Athens, Greece

2Department of Informatics, School of Sciences & Applied Sciences, Open University of Cyprus, Nicosia, Cyprus.

Abstract— *Exposed to the threat of enemy attack in deep and littoral waters, submarines are a likely target for acoustic homing torpedoes fired from ASW helicopters, ships, or enemy submarines. Defending against these threats requires quick response, automated decoys. This paper aims to present a prototype expendable acoustic torpedo decoy named Thelxiope as part of clustering in the context of underwater wireless sensor network (UWSN). Thelxiope is a self-propelled, expendable torpedo decoy, capable of protecting submarines and surface ships from passive acoustic homing torpedoes. Designed to respond simultaneously to multiple passive acoustic homing torpedoes, Thelxiope is launched immediately following a torpedo alert, moving automatically to operating depth, generates and transmits customized deception signals. We present how it could work by operating as a cluster sensor node in a UWSN network, considering the latest trends in the field.*

Keywords— Underwater Wireless Sensor Network, Torpedo, Countermeasure, Decoy

1. INTRODUCTION

For a submarine lacking high maneuverability, there is no space for reaction when the torpedo is typically less than 200 meters away. Therefore, the parameter of the timely soft kill counter-measure release reaction, is very important compared to the last phase of attack where torpedo can only be neutralized by hard kill systems [1].

Thelxiope system belongs to category of soft kill disposable acoustic countermeasures for submarines and surface ships. Except that can be produced and used in the defense industry may also bring demand in the global defense market. It's about an acoustic decoy for passive acoustic torpedoes, capable of producing threat sounds and specific distortion frequency signals, and can be fired from submarines, surface ships or even from ASW helicopters.

In order to further this idea as well as the construction, it would be fruitful to integrate this decoy system as part of clustering in the context of underwater wireless sensor network (UWSN).

From the beginning of its construction, at prototype stage, Thelxiope decoy system was unable to communicate with other countermeasures. If a torpedo comes towards us, we can launch the Thelxiope decoy. This will move independently and will have two functions. The first function is to take the sounds from the enemy torpedo, to process them, and to reproduce similar sounds in order to confuse the hostile torpedo. The second function is to produce sounds similar to our ship in order to confuse the hostile torpedo.

There is a variety of decoys with different characteristics and functions in tactical scenarios but there is no one is part of a UWSN, to be able to keep him informed for sounds of enemy torpedo or submarine and to communicate with other decoys for distance calculation, position synchronization, energy efficiency, or even better to communicate with the command-and-control base station [2].

We present how it could work by operating as a sensor node in a UWSN network, considering the latest trends in the field. In this case we would consider the nodes to encounter challenges when transmitting packets, communicating delays, loss of power, noises, interference, low bandwidth. We will also consider sound as the best way for communication between sensor nodes, as opposed to optical and radio communication [3].

2. MATERIALS AND METHODS

2.1 Thelxiope decoy

The market dominated by underwater soft kill countermeasures decoys. They have almost the same technical characteristics and philosophy and are in a stable financial environment because they are consumable countermeasures [4].

Subscut, Scutter and Nae Beacon countermeasures are self-propelled, and generally all countermeasures have a lifetime of 10 minutes. Based on the above, initially the acoustic countermeasure decoy Thelxiope, was developed against passive initial and active torpedoes, which combines the variability of launch, using submarines, surface ships and helicopters. The acoustic decoy has the basic characteristics (Frequency Range, Motor) and structure (Dimensions 12cm X 1,2m) which are necessary for experimentation and further development. The acoustic decoy also demonstrates a cheap material-economical aspect of an industrial product.

Thelxiope decoy is a passive acoustic torpedo tuner, capable of producing threat sounds and signals of specific misleading frequencies. It can be launched by submarines, surface ships or by ASW helicopters, using a parachute. In case of a surface ship launch, it can be either thrown into the water or to incorporate into a special launcher. Also, has a programmable library with realistic sound threats, such as frigate and submarine propeller and various frequencies up to 18 KHz.

The decoy can operate stationary or self-propelled, capable of moving at random speeds and can also be used for training in Navy exercises. It has a timer relay inside that can be adjusted for up to 30 minutes when launching. The engine assists in further removal at random speed and random positions. The 17Hz85KHz audio frequency generator is connected to amplifier and then to piezoelectric sensor. The wattmeter, which is connected to the rechargeable battery, displays voltage, current, power and consumption on LCD screen, giving information for battery status at the end of exercises or after long term storage.

The tests of Thelxiope decoy were performed in vertical and horizontal position in 2 meters deep sea water, with the aim of assessing both waterproofing, speed, sinking and hydroacoustic analysis of its produced signals. Hydroacoustic analysis was performed with a 3 meters cable mounted from decoy whilst SpectrumLaboratoy spectrograph was able to visualize the frequency and intensity results of signals reaching the hydrophone. The acoustic torpedo decoy prototype Thelxiope in Figure 1.

Fig 1. Thelxiope countermeasure

2.2 UWSN Architecture

Classification of a UWNS network can be done either by how the nodes communicate in RF, visual and acoustic architecture, or by the architecture of sensor nodes topology in Unstructured or Structured Wireless Sensor Network in two-, three- or four-dimensional architectures.

UWSNs are divided into Unstructured Wireless Sensor Network and Structured Wireless Sensor Network. In unstructured network, the nodes sensors are scattered in contrast to structured UWSN where the nodes are in a fixed position.

Based on their architecture they are divided to 1D Architecture, 2D Architecture, 3D Architecture and 4D UWSN Architecture. In 1D UWSN Architecture, each sensor is a unique system responsible for detecting, preparing, and transmitting data to the remote station. In 2D UWSN Architecture, sensor nodes are grouped into clusters with one taking over the role of header. The sensors collect and send the data to the header and then send it to the surface station. In 3D UWSN Architecture, the sensors are developed in the form of clusters that are anchored to different depths and heights. At 4D UWSN Architecture we have a combination of fixed 3D UWSN and mobile UWSN, i.e. ROVs and AUVs [5].

Underwater networks are different from terrestrial networks because they have high propagation delays, high error probability and node mobility. The propagation speed in water is five times less than the propagation speed of a radio signal in the air. The high probability of error is due to the limited bandwidth, noise, multipath noise, and Doppler deployment. The mobility of the nodes is probably due to the weather, shifting the nodes together.

Communication in underwater networks use acoustic waves (acoustic communication) because of the lower absorption than radio or optical communications. The low absorption of the acoustic wave allows the signal to travel long distances with little loss compared with radio waves and optical waves where attenuation causes effects to signal and accuracy [6].

2.3 TACTICAL SCENARIO

Firstly, we must say that in this paper refer to wireless torpedoes (self-control torpedo) which can be easily misled, in addition with wired torpedoes. Wired torpedoes are attached to the ship’s control center and can neutralize the decoys.

In this section we could give a plethora of tactical scenarios. As shown in Figure 2, when the warship senses the arrival of torpedo, it maneuvers to increase its speed to 2530 knots from the 1820 knots it had during sailing. Maneuvering of ship maximizes the distance from the torpedo while at the same time it can launch decoys.

In another case our ship is embarrassed or sailing at a low-speed of 1820 knots and decides to place decoys at strategic points to listen submarines or torpedoes from a distance. Then the ship stays or leaves the area completely [7]. In both cases of tactical scenarios, we have described, decoys have been dropped either for surveillance or for instant defense against torpedo attack or for instant attack.

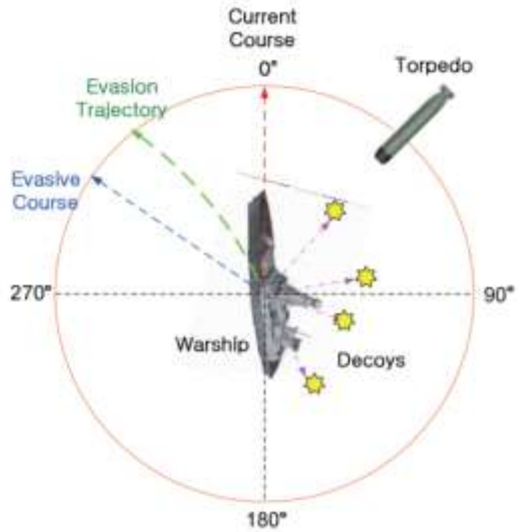

Fig. 1. Tactical scenario map. Source: [7]

Once the decoys fall into the sea can create an underwater sensor network. The architecture will belong to the 3D UWSN category, where decoys sensor nodes are developed in the form of clusters to different depths and heights but are not anchored. Every node communicates its other and one of them plays the role of header.

Today with the development of torpedo intelligence and signal processing, they could understand if it was a non-real target and if all decoys produce sounds simultaneously. In this case, enemy torpedo would pivot a bit on its course but in the end will find the real target [8]. In the above tactical scenarios, in the most underwater decoys network, only one decoy node at a time generates misleading sounds depending on the distance from the enemy torpedo, and then generates the sounds of the neighboring node as well. Also, in the first case our network could operate autonomously, while in the second case, decoys clusters could be created with one node as cluster header. The cluster header will be the one that will communicate with surface station and then with the ship by radio waves or by satellite communication with command-and-control base station.

2.4 ENCAPSULATION

The marriage of two above technologies, could be regarded as encapsulation. Thelxiope system encapsulates underwater network technology. For this reason, it is necessary to describe how this will be achieved based on their technology and tactical scenarios.

Underwater networks consist of wireless nodes called nodes. Nodes, regardless of their location at the seabed, collect, store and transmit data via embedded programs [9]. Because, as we mentioned in the chapter of UWSN architecture, the best solution for underwater communications is acoustic waves. For this purpose, Thelxiope acoustic decoy will be integrate a software acoustic modem system to communicate with other decoys in the cluster. In UWSNs, nodes sensors have a software acoustic modem system to communicate its other.

Because each node can send a series of data that it has collected during an update, the transmission rate plays an important role. In the case of decoys, they communicate via multihop links. After sampling a node, the data is sent to the neighboring node which processes it and then communicates with the original node or neighboring node and so on. This could be the case if the decoys were deployed at the seabed at the critical time of the first tactical scenario.

On the other hand, if decoys are deployed at the seabed for simple surveillance of the area of the second tactical scenario, after sampling a node, the data is sent to the transceiver of a surface node (surface base station) which then communicates via radio waves with a server on the surveillance ship or even farther to the maritime command and control base via satellite communication. The surface base station is equipped with a long-range wireless broadband card that uses a cellular or satellite connection to stream network data to our ship or maritime command and control base. Regarding the communication material in physical layer level in our system, each node decoy sensor consists of a microphone and piezoelectric sensor playing the role of receiver and transmitter respectively.

2.5 Routing Protocol

Because when launching a cluster of decoys, a random structure of positions is formed between the nodes, and because each node is prone to move by weather, we need a protocol for mobile nodes. Our system uses the DSRP routing protocol.

This model involves changes in position and velocity of sensor nodes to move to a new destination. At each destination, nodes stop momentarily and then move to new positions. The proposed routing strategy involves the movement style of nodes, the expected traffic along the chosen paths and the localization of nodes. The speed which nodes move, is kept between the maximum and minimum values. The conditions of no mobility, low mobility and high mobility of nodes are compared.

The advantages of this protocol are the highly efficient and addresses mobile nodes, while its two disadvantages are that it has high energy consumption and end to end delay. Another similar mobile node communication protocol, called DBR, gives high performance and addresses mobile nodes but has high energy consumption due to redundant packet transmission caused by flooding and early death of low depth nodes due to frequent selection as forwarder nodes [10].

2.6 Distributed Localization

Thelxiope decoy as part of an underwater sensor network cluster has a 12V battery and a 30-minute lifetime when activated. Therefore, this lifetime should be increased through energy savings.

One method for this is the clustering system, which offers greater scalability to the number of nodes, which saves energy and extends the life of the system. Another method is for each node to know its current location and synchronization time with respect to the other nodes so as not to delay data transfer. If it’s not done properly, this delay has the effect of additional processing power for each node and reduces its battery life. GPS (Global Positioning System) system cannot function properly to locate underwater nodes, because GPS high frequency radio waves weaken in the sea. For this reason, each node can determine its position or synchronize its time with GPS free. To do this on a network with node mobility, the key problem is the range and direction of measurement [11].

In the second tactical scenario for surveillance of an area, decoys node sensors create clusters, so each node communicates with a header that sends the data to the surface base station. Conversely, the surface base station can receive the high frequency radio waves of GPS, and then through the underwater acoustic transceiver to send the position signal for each node. A problem that may appear here is the delay of the position value of the surface base station at each node, due to the change of temperature and water pressure.

2.6 Threats

Submarine decoys like all underwater networks are vulnerable to threats and attacks. Although each node has an identifier and other privacy data such as a secret key, encryption algorithm, reliability value, it cannot be safe from attacks. Attacks are divided into active and passive attacks. Both of these categories can be found in tactical scenarios we mentioned.

Active attacks are carried out by internal or external attackers and attempt to destroy or alter the data transmitted to the underwater network of decoys sensor nodes. This results in the network being stopped. In the case of attacks coming from external nodes targeting the nodes belonging to the submarine network of decoys node sensors is an external attack. If the attacks come from an internal node, they are called internal attacks.

Internal attacks can be done by nodes that are actually our legal nodes before being exposed, while passive attacks can be malicious by nodes that perceive, intercept or interfere with the data transmitted between network nodes.

In the case of second tactical scenario we mentioned, there could be an active and passive attack by the enemy as we supervise the area. Of course, this can only be done if the passive or active attack gets an ID, breaks a secret key or an encryption algorithm of our underwater decoys network. But because, as we mentioned in the encapsulation and routing protocol, decoys nodes are very aware from enemy objects and communicate each other inside the cluster, such an attack could not be carried out [12].

3. CONCLUSION

In this paper, we have presented Thelxiope decoy and how this could incorporate with underwater wireless sensor network technology by taking the role of a node sensor, delivering energy saving performance through a cluster of sensor nodes. We have outlined the basic features of the decoy and underwater wireless sensor networks and concluded how these two technologies could be combined, based in two tactical scenarios. We also discussed the routing protocol of our system could have, based on the mobility of sensor nodes at the seabed as well as the types of threats that could be made to sensor nodes in our system. The ultimate objective of this paper is to encourage research efforts and lay the foundations for the development of an energy efficient and safe underwater decoys sensor network cluster.

4. REFERENCE

[1] North Atlantic Treaty Organization (NATO). (2002). *MultiNational Submarine and AntiSubmarine Exercise Manual* (Vol. MXP1 D). Navy & Air.

[2] Knut, R. A. (2000). The relationship between a submarine’s maximum speed and its evasive capability., Thesis, Naval Postgraduate School, Monterey, California.

[3] Nor, N.I., Liban, A. H., Sharifah H.S. (2010). Analyzing the Performance of Acoustic Channel in Underwater Wireless Sensor Network (UWSN). IEEE, DOI 10.1109/AMS.2010.111.

[4] K. Zhan et al. (2011). Simulations of the AntiTorpedo Tactic of the Conventional Submarine Using Decoys and Jammers. Applied Mechanics and Materials, (Vol. 65), pp.165168.

[5] V.K. Chandna, V.S. Rathore and S. Maheshwari. (2018). Security Challenges and Application for Underwater Wireless Sensor Network. *Kalpa Publications in Engineering*, Vol.2, pp.1521.

[6] Bhanu, K. K. (2011). MultiMetric Adaptive Routing Algorithm for Underwater Wireless Sensor Netwroks. *MsC Thesis*, Texas A&M University.

[7] Pak, J. M., Woo, D. G., Ku, B., Hong, W., Ko, H., Lim, M. T. (2009). Target Search Method for a Torpedo to the Evading Ship Using Fuzzy Inference. *IEEE*, ICCASSICE 2009 ICROSSICE International Joint Conference 2009, Proceedings pp.52795284.

[8] Collins, J., Mc Gaughey, D. R., Therriault, J., Pecknold, S. (2007). Estimating torpedo range using multipath signals and fast orthogonal search techniques. *Canadian Acoustics*,35(4), 1114.

[9] Heidemann, J., Li, Y., Syed, A., Wills, J., Ye, W. (2005). Underwater sensor networking: Research challenges and potential applications. *Proceedings of the Technical Report*, ISITR 2005603, USC/Information Sciences Institute.

[10] Khan, A., Ali, I., Ghani, A., Khan, N., Alsaqer, M., Rahman, A., Mahmood, H. (2018). Routing protocols for underwater wireless sensor networks: Taxonomy, research challenges, routing strategies and future directions. *Sensors*, 18(5), 1619.

[11] Tian, C., Liu, W., Jin, J., Wang, Y., Mo, Y. (2007, July). Localization and synchronization for 3D underwater acoustic sensor networks. *In International Conference on Ubiquitous Intelligence and Computing*, pp. 622631, Springer, Berlin, Heidelberg.

[12] Yang, G., Dai, L., Wei, Z. (2018). Challenges, threats, security issues and new trends of underwater wireless sensor networks. *Sensors*,18(11), 3907.

Panagiotis Rizos,
Department of Informatics
School of Information Sciences and Technology
Athens University of Economics and Business
Athens, Greece

Euangelos Rizos
Department of Informatics
School of Sciences & Applied Sciences
Open University of Cyprus
Nicosia, Cyprus.