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Bayesian network based energy efficient ship motion monitoring

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Abstract

It is extremely important to safeguard our harbours from intruders and smugglers who aim to benefit from unlawful activities and cause harm. Theft, terror attacks in commercial boats and cargo ships docked on harbours needs to be prevented. Camera surveillance, radar, satellites images have not been very reliable so far as they fail to work in drastic weather conditions and can be manipulated as well. Underwater Wireless Sensor Network (UWSN) could be installed in both shallow and deep water of the harbour for detecting various types of harbour activities. Ship movements namely heave, sway, surge, yaw, pitch and roll, could be detected and classified using pressure, position and underwater sensors. Such information can help in tracking ship motions, movements, loading and unloading activities. Any unplanned unloading activity can thus be detected and necessary alarms can be raised for ship owners and harbour official's attention. However designing such a network needs one to ensure that the severe energy constraints of the UWSN are well addressed. Bayesian Network based approach is explored in this paper for scheduling the sleep and active cycle of network nodes. Our proposed technique of ship motion monitoring system reduces energy consumption of the network nodes and enhances the network lifetime by balancing network load intelligently. The tracking mechanism proposed here explores the fundamental behaviour of ships motions in waves with reference to translating coordinate system.

Keywords: Underwater Wireless Sensor Network (UWSN); Ship motion monitoring; Bayesian network

1. Introduction

Underwater Wireless Sensor Network (UWSN) is a network of sensors equipped with acoustic modems. Its applications in harbour and ocean floor surveillance are gaining a lot of attention these days. When close to three fourth of the earth is full of water, we need advanced and alternate techniques for open water monitoring. Satellite and radar are the currently used techniques. But in addition, if UWSN is employed, a more realistic monitoring could be achieved. However, UWSN has different working constraints unlike traditional wireless sensor network. Multi-hop which is an inherent nature of wireless sensor network cannot be fully exploited in UWSN. UWSN is network that communicates with the help of acoustic waves [1]. Huge delay in propagation is a typical property of acoustic wave propagation. Reducing energy

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consumption of nodes in transmission is the major concern of such a delay tolerant network, so that the network life time is prolonged. Yuanming [2] has proposed energy balanced routing algorithm for wireless sensor network that avoids routing loop and redundancy in path selection in order to save energy. But this approach cannot be applicable in the case of underwater wireless sensor network, due to dynamic topology due and water current. Li et al. [3] have proposed a compression algorithm for wireless sensor network deployed on sea surface for sea route monitoring. Their algorithm is based on computation of distortion based on L1-norm. Their results prove that data transmission and network survivability is improved. However, their system is not helpful in detecting intrusions and thefts. The concern of detecting ship intrusions has been dealt by Luo et al. [4]. Their technique helps in detecting ships trespassing harbour areas by classifying ship generated waves and ocean waves. Underwater wireless sensor networks have some inherent constraints due to the acoustic medium of data transmission. Kohli and Bhattacharya [5] have pointed out the implication of depth, temperature and salinity of ocean water in acoustic mode of data propagation. Li et al. [6] have proposed a delay tolerant MAC layer protocol inspired by coupon collector problem to address the issues of long propagation delay and swarm mobility of underwater sensors. Similarly there are other issues related to protocol and network design of underwater sensors. Coles et al. [7] argue that instead of deploying a huge number of static nodes for surveillance, a set of mobile nodes could be deployed guided by decentralized discrete Bayesian network implementing an optimized grazing strategy. Many researchers have aimed to reduce energy consumption of nodes (Huang et al. [8]; Latif et al. [9]; Yang et al. [10]; Shazzad et al. [11]). Techniques like depth based routing, sleep cycles; efficient MAC protocols with collision avoidance have been explored. Mandal [12] has attempted to study TDMA variants that could be suitable for underwater sensor network. But none of the authors talk about energy efficient ship motion detection.

The work here, significantly contributes towards building an autonomous ship motion detection system that is equipped with strategies for identifying different types of ship motions, namely heave, sway, surge, yaw, pitch and roll that vary due to different angles of force and gravity. Using underwater wireless sensor network the proposed technique predicts a possible unplanned unloading activity of the ship (theft) and raises alarm. It is also designed to raise an alarm when a ship docked in the harbour is manoeuvred away from the dock (robbery) without prior information. It ensures that the routing information collected by the sensor nodes is forwarded to the base station in an energy efficient manner while avoiding load imbalance and achieving an enhanced network lifetime.

2. Problem statement

Fig. 1 depicts the satellite impression of ship traffic along harbours on oceans as per the information available at www.maritime.com [13]. Red arrows indicate tanker ship positions while green arrows indicate the cargo ship positions as received via satellite. However, this information is not enough for detecting and evading intruders. It will certainly help identifying various ships and their movements. When assisted with radar technology, more accurate information of objects surrounding a ship on ocean can be known. However, it cannot help in intrusion detection. Chainas [14] attempts to find alternative ships for serving ports in situation when a desired ship fails to reach its course, probably due to malfunction. Ports are informed of the arrival and departure of ships, but monitoring such huge entities needs more than camera and human surveillance. Underwater Wireless Sensor Network can be installed in harbours for detecting various motions of ships. Currently there is no reliable technology to detect when a ship is being robbed and therefore cannot be prevented. Neither is there a mechanism to know when the cargo of a ship is being stolen. These crimes are reported only later by human surveillance or by the help of satellites images. By using sensors we can enable the harbour officials with (at the moment) information for efficient decision making in combating with such crimes.

Here, we have attempted to develop a system that detects various motions of ships to help ship owners and harbour officials to track ship activities in order to avoid theft and robbery. Robbery can be differentiated from theft as a situation where an intruder exercises coercion. Ship robbery can be very dangerous than ship theft. However, both these situations need to be curtailed. Here we consider taking away of the ship permanently from the harbour by an intruder as robbery. Our goal is prevent such situations with the help of underwater wireless sensor networks in a robust and scalable way.

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