LPS: Laser Positioning System for Underwater Networks

1. INTRODUCTION

Underwater Sensor Networks (UWSN) have many potential applications, such as ocean exploration, pollution monitoring, public safety and military underwater surveillance [1]. In all of these applications, localization plays an important rule since detected events must be tagged with position information. Moreover, position may also be required for geographical routing.

GPS is not available in underwater because the signal does not propagate through water. Alternative schemes have been proposed, as discussed later. However, in underwater sensor networks battery power limitations are critical. Protocols must economize message exchange to save power. Existing positioning schemes take a toll on power because of frequent transmissions. Based on recent laser acoustic technology, we propose LPS, a Laser Positioning System for Underwater Networks. Recent experiments [2] have shown that a laser pulse can propagate underwater and at the end "burst" into an acoustic pulse at a predetermined distance from surface. Jones et al. [2] measured pulse durations on the order of 1 μs and sound pressure levels up to 170 dB. The laser source can be above water, i.e. on an airplane. We propose to use this laser/acoustic pulse as a localizating beacon. By hearing the beacon, and knowing the exact burst time and position, sensor nodes can get localize themselves via trilateration.

The benefits of LPS are:

- Simplicity: virtually a GPS equivalent for underwater.
- Covert operation: laser cannot be detected by eavesdroppers above water ; underwater "customers" are totally passive and preserve their privacy.
- Messages are encrypted, only members can retrieve the position and time values from the acoustic bursts.
- Easy to deploy, no need of support ship, buoy layout or underwater transponder installation.
- Energy efficient; does not requires sensor node transmissions.

In this short paper we describe the basic Laser Positioning System architecture.

2. RELATED WORK

Current state of the art oceanographic technology uses two types of systems to localize nodes: Long Base-Line (LBL) and Short Base-Line (SBL) systems [3]. In both, the sensors position themselves based on acoustic communications with a set of "localized" transponders. In LBL the transponders are deployed on the seafloor or under surface moorings around the area of operation [4]. In the SBL system, a ship follows the sensors and uses a short-range emitter to enable localization. Both techniques are expensive and require long planning for deployment.

In Underwater Sensor Networks, alternatives have been recently investigated. In DNR [5], the authors propose the use of mobile (sinking) beacons to increase the localization coverage in 3D space. Beacons dive and rise to act as underwater GPS. In turn, localized nodes also can act as beacons [6], enabling multi-hop localization. A similar approach consist of using autonomous underwater vehicles (AUVs) as beacons [6].

In [7], the authors propose to have surface buoys and two types of underwater nodes: anchor nodes and ordinary sensor nodes. At first, anchor nodes are localized by the help of surface buoys and then the ordinary sensors are localized by the anchor nodes. Anchors are uniformly spread among sensors to achieve better localization for large-scale 3D USN.

In the patent [8], the authors describe a localization scheme based on a laser acoustic burst where the burst is made to occur at pre-programmed position and time. Burst time and position are announced to all underwater assets before the mission begins. This however is impractical for underwater drifting sensor networks with unpredictable course.

3. SYSTEM ARCHITECTURE

Figure 1 illustrates the Laser Position System Architecture. Any device above water, say, an aircraft, can emit the laser. The underwater sensor nodes form a drifting swarm that moves with water currents. The aircraft flies over the underwater swarm area, i.e. at 1000 ft. It has 5 lasers: 4 point to the vertices of a square on the water, the 5th points to the center of the area. The aircraft fires four single pulse lasers first (say 1,2,3,4). The laser hits the water and generates an acoustic pulse at a fixed depth. Current results in

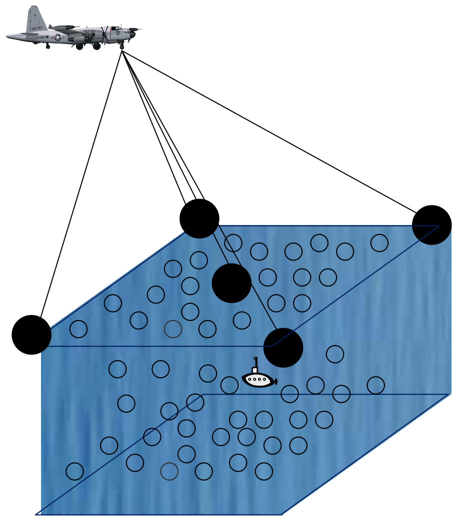

Figure 1: Laser Position System Architecture

laser acoustic report typical values of 10 meters depth [2]. The acoustic pulses are generated at such intervals (say one second) so that they can be distinctly received by all underwater assets within acoustic range. Then, the craft fires the 5th laser, that hits the water perpendicularly under the craft.

Using 4-MFSK modulation method, researchers have shown that it is possible to achieve a 160 bits/s data rate over a 320 meters underwater link [9]. The 5th laser burst thus is used to transmit a packet with the time and coordinates of the 4 previous laser impact points (clock, x, y). There is no need for z-coordinate since this is known to a sensor from its pressure gauge. This beacon is encrypted, in order not to give away coordinates to the enemy. It is authenticated to avoid malicious attacks. Only sensor nodes that are members of our swarm can retrieve the position and time values.

When the laser beam hits the water, it creates a powerful acoustic pulse that races towards the bottom of the sea. Each underwater sensor, upon receiving the packet, computes its distance to the impact spot. After hearing 3 acoustic, the sensor is passively localized (no need to send message) by using trilateration.

While laser acoustic explosion locations are precise, mobile under water beacons tracked via dead-reckoning accumulate errors. The mobile beacons XY coordinates are calibrated based on the point of impact with water when dropped from plane at certain speed. As the beacons move with water currents, (see, for example the Meandering Current Model [10]), the error due to mobility increases over time. Figure 2 shows the average error(in meters) for 400 nodes over time (in hours), when the main jet maximum speed is 0.3m/s.

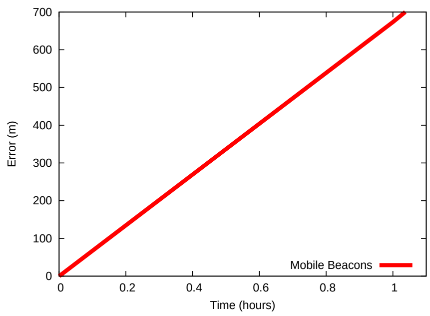

Figure 2: Mobile Beacon Error

4. FUTURE WORK AND CONCLUSION

Based on recent technology advancement on laser acoustic, we have described a Laser Position System(LPS) that enables covered operation, is easy to deploy and is sensor energy parsimonious. We are currently investigating the possibility to incorporate the coordinate data directly on the four positioning laser beams without requiring the 5th laser beam.

5. REFERENCES

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