International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

DA-Sync: A Doppler-Assisted Time-Synchronization Scheme for Mobile Underwater Sensor Networks

Yezarla Jaya Babu[1]& V.Krishna Pratap [2]
[1]PG Scholar,Dept of CSE, Chalapathi Institute of Technology,Guntur ,Andhra Pradesh,
Email: jayagcm@gmail.com
[2]Assistant Professor,Dept of CSE, Chalapathi Institute of Technology,Guntur,Andhra Pradesh,Email: pratapv9@gmail.com

ABSTRACT:

In recent years, underwater wireless sensor networks (UWSNs) have drawn considerable and increasing attentions from researchers. This paper examines the main approaches and challenges in the design and implementation of underwater wireless sensor networks. We summarize key applications and the main phenomena related to acoustic propagation, and discuss how they affect the design and operation of communication systems and networking protocols at various layers. We also provide an overview of communications hardware, testbeds and simulation tools available to the research community. Although there are many time synchronization protocols proposed for terrestrial wireless sensor networks, none of them could be directly applied to UWSNs. This is because most of these protocols do not consider long propagation delays and sensor node mobility, which are important characteristics in UWSNs. Further, UWSNs usually have very high requirements in network lifetime and synchronization accuracy. To satisfy these needs, innovative time synchronization solutions are demanded. In this paper, we propose a novel time synchronization scheme, called "Mobi-Sync", for mobile underwater acoustic sensor networks. Mobi-Sync novelly utilizes the spatial correlation of underwater mobile sensor nodes to estimate the long dynamic propagation delays. Simulation results show that Mobi-Sync outperforms existing schemes in both accuracy and energy efficiency.

Keywords: underwater acoustic communication; underwater sensor networks; acoustic modems; high latency; energy efficiency; protocol design.

INTRODUCTION:

Wireless information transmission through the ocean is one of the enabling technologies for the development of future ocean-observation systems and sensor networks. Applications of underwater sensing range from oil industry to aquaculture, and include instrument monitoring, pollution control, climate recording, prediction of natural disturbances, search and survey missions, and study of marine life. Underwater wireless sensing systems are envisioned for stand-alone applications and control of autonomous underwater vehicles (AUVs), and as an addition to cabled systems. For example, cabled ocean observatories are being built on submarine cables to deploy an extensive fibre-optic network of sensors (cameras, wave sensors and seismometers) covering miles of ocean floor [1]. These cables can support communication access points, very much as cellular base stations are connected to the telephone network, allowing users to move and communicate from places where cables cannot reach. Another example is cabled

submersibles, also known as remotely operated vehicles (ROVs). These vehicles, which may weigh more than 10 metri tonnes, are connected to the mother ship by a cable that can extend over several kilometres and deliver high power to the remote end, along with high-speed communication signals. A popular example of an ROV/AUV tandem is the Alvin/Jason pair of vehicles deployed by the Woods Hole Oceanographic Institution (WHOI) in 1985 to discover Titanic. Such vehicles were also instrumental in the discovery of hydro-thermal vents, sources of extremely hot water on the bottom of deep ocean, which revealed forms of life different from any others previously known. The first vents were found in the late 1970s, and new ones are still being discovered. The importance of such discoveries is comparable only to space missions, and so is the technology that supports them.

NETWORK ARCHITECTURE AND MOBILITY CORRELATION:

In Mobi-Sync, we consider a dense hierarchical network architecture , three types of nodes, surface buoys, super nodes and ordinary nodes, exist in the network.· Surface buoys: are equipped with GPS to obtain global time references and perform location estimates.· Super nodes: can communicate directly with the surface buoy and thus can maintain synchronization with surface buoys.· Ordinary nodes: can only communicate with its neighbors to get synchronized.

Among the first underwater acoustic systems was the submarine communication system developed in the USA around the end of the Second World War. It used analogue modulation in the 8–11 kHz band (single-sideband amplitude modulation). Research has since advanced, pushing digital modulation–detection techniques into the forefront of modern acoustic communications. At present, several types of acoustic modems are available commercially, typically offering up to a few kilobits per second (kbps) over distances up to a few kilometres. Considerably higher bit rates have been demonstrated, but these results are still in the domain of experimental research (e.g. [8,9]). With the advances in acoustic modem technology, research has moved into the area of networks. The major challenges were identified over the past decade, pointing once again to the fundamental differences between acoustic and radio propagation. For example, acoustic signals propagate at 1500 m s−1, causing propagation delays as long as a few seconds over a few kilometres. With bit rates of the order of 1000 bps, propagation delays are not negligible with respect to typical packet durations—a situation very different from that found in radiobased networks. Moreover, acoustic modems are typically limited to half-duplex operation. These constraints imply that acoustic-conscious protocol design can provide better efficiencies than direct application of protocols developed for terrestrial networks (e.g. 802.11 or transmission control protocol (TCP)). In addition, for anchored sensor networks, energy efficiency will be as important as in terrestrial networks, since battery re-charging hundreds of metres below the sea surface is difficult and expensive.

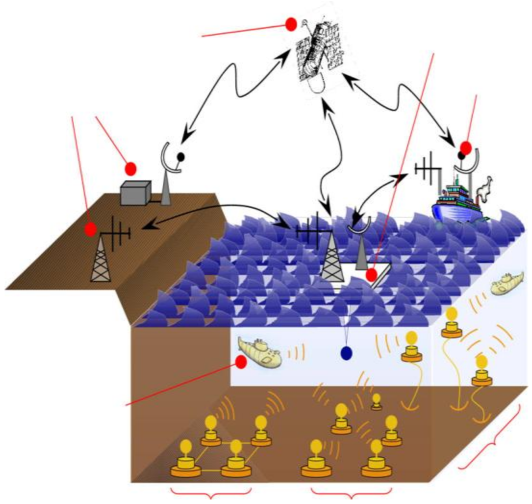
Underwater sensing applications:

The need to sense the underwater world drives the development of underwater sensor networks. Applications can have very different requirements: fixed or mobile, short or long-lived, best-effort or life-or-death; these requirements can result in different designs. We next describe different kinds of deployments, classes of applications and several specific examples, both current and speculative.

(a) Deployments

Mobility and density are two parameters that vary over different types of deployments of underwater sensor networks. Here, we focus on wireless underwater networks, although there is significant work in cabled underwater observatories, from the sound surveillance system military networks in the 1950s, to the recent Ocean Observatories Initiative [10].

Underwater networks are often static: individual nodes attached to docks, to anchored buoys or to the seafloor (as in the cabled or wireless seafloor sensors). Alternatively, semi-mobile underwater networks can be suspended from buoys that are deployed by a ship and used temporarily, but then left in place for hours or days [12]. (The moored sensors may be short-term deployments.) The topologies of these networks are static for long durations, allowing engineering of the network topology to promote connectivity. However, network connectivity still may change owing to small-scale movement (as a buoy precesses on its anchor) or to water dynamics (as currents, surface waves or other effects change). When battery powered, static deployments may be energy constrained. Underwater networks may also be mobile, with sensors attached to AUVs, low-power gliders or unpowered drifters. Mobility is useful to maximize sensor coverage with limited hardware, but it raises challenges for localization and maintaining a connected network. Energy for communications is plentiful in AUVs, but it is a concern for gliders or drifters



As with surface sensor networks, network density, coverage and number of nodes are interrelated parameters that characterize a deployment. Underwater deployments to date are generally less dense, have longer range and employ significantly fewer nodes than terrestrial sensor networks. For example, the Seaweb deployment in 2000 involved 17 nodes spread over a 16km2 area, with a median of five neighbours per node [13]. Finally, as with remote terrestrial networks, connectivity to the Internet is important and can be difficult.

(b) Application domains

Applications of underwater networks fall into similar categories as for terrestrial sensor networks. Scientific applications observe the environment: from geological processes on the ocean floor, to water characteristics (temperature, salinity, oxygen levels, bacterial and other pollutant content, dissolved matter, etc.) to counting or imaging animal life (micro-organisms, fish or mammals). Industrial applications monitor and control commercial activities, such as underwater equipment related to oil or mineral extraction, underwater pipelines or commercial fisheries. Industrial applications often involve control and actuation components as well. Military and homeland security applications involve securing or monitoring port facilities or ships in foreign harbours, de-mining and communication with submarines and divers.

Motivations for underwater sensor networks are similar to those for terrestrial sensornets: wireless communications reduce deployment costs; interactive data indicate whether sensing is operational or prompts corrective actions during collection; and data analysis during collection allows attendant scientists to adjust sensing in response to interesting observations.

(c) Examples

There are many short-term or experimental deployments of underwater sensing or networking; here we only describe a few representative examples. Seaweb [13] is an early example of a large deployable network for potential military applications. Its main goal was to investigate technology suitable for communication with and detection of submarines. Deployments were in coastal ocean areas for multi-day periods. Massachusetts Institute of Technology (MIT) and Australia’s Commonwealth Scientific and Industrial Research Organisation explored scientific data collection with both fixed nodes and mobile autonomous robotic vehicles. Deployments have been relatively short (days), in very near shore areas of Australia and the South Pacific [3]. By comparison, the Ocean Observatories Initiative is exploring large-scale cabled underwater sensing [10]. In this static, scientific application, cables provide power and communications to support long-term observations, but require significant long-term investments.

Underwater communications and networking technology

In this section, we discuss a number of technology issues related to the design, analysis, implementation and testing of underwater sensor networks. We begin at the physical layer with the challenges of acoustic communication, then proceed to communications and networking layers, followed by a discussion on applications, hardware platforms, testbeds and simulation tools.

(a) Physical layer

Outside water, the electromagnetic spectrum dominates communication, since radio or optical methods provide long-distance communication (metres to hundreds of kilometres) with high bandwidths (kHz to tens of MHz), even at low power. In contrast, water absorbs and disperses almost all electromagnetic frequencies, making acoustic waves a preferred choice for underwater communication beyond tens of metres. Propagation of acoustic waves in the frequency range of interest for communication can be described in several stages. Fundamental attenuation describes the power loss that a tone at frequency f experiences as it travels from one location to another. The first (basic stage) takes into account this fundamental loss that occurs over a transmission distance d. The second stage takes into account the site-specific loss due to surface–bottom reflections and refraction that occurs as sound speed changes with depth, and provides a more detailed prediction of the acoustic field around a given transmitter. The third stage addresses the apparently random changes in the large-scale received power (averaged over some local interval of time) that are caused by slow variations in the propagation medium (e.g. tides). These phenomena are relevant for determining the transmission power needed to close a given link. A separate stage of modelling is required to address the small-scale, fast variations of the instantaneous signal power. Directional motion causes additional time variation in the form of Doppler effect. A typical AUV velocity is on the order of a few metres per second, while freely suspended platforms can drift with currents at similar speeds. Because the sound propagates slowly, the ratio of the relative transmitter/receiver velocity to the speed of sound can be as high as 0.1 per cent—an extreme value that implies the need for dedicated synchronization. This situation is in stark contrast with radio systems, where corresponding values are orders of magnitude smaller, and typically only the centre frequency shifting needs to be taken into account.The development of bandwidth-efficient communication methods that use amplitude or phase modulation (quadrature amplitude modulation, phase-shift keying) gained momentum in the 1990s, after coherent detection was shown to befeasible on acoustic channels [17].

(b) Medium access control and resource sharing

Multi-user systems need an effective means to share the communication resources among the participating nodes. In wireless networks, the frequency spectrum is inherently shared and interference needs to be properly managed. Several techniques have been developed to provide rules to allow different stations to effectively share the resource and separate the signals that coexist in a common medium. In designing resource-sharing schemes for underwater networks, one needs to keep in mind the peculiar characteristics of the acoustic channel. Most relevant in this context are long delays, frequency-dependent attenuation and the relatively long reach of acoustic signals. In addition, the bandwidth constraints of acoustic hardware (and the transducer in particular) must also be considered. Another quasi-deterministic technique for signal separation is code division multiple access (CDMA), in which signals that coexist in both time and frequency can be separated using specifically designed codes in combination with signal processing techniques. The price to pay in this case is a bandwidth expansion, especially acute with the narrow bandwidth of the acoustic channel (20 kHz or less for typical hardware). CDMA-based medium access protocols with power control have been proposed for underwater networks [22], and have the advantages of not requiring slot synchronization and being robust to multi-path fading. While these deterministic techniques can be used directly in multi-user systems, data communication nodes typically use contention-based protocols that prescribe the rules by which nodes decide when to transmit on a shared channel. In the simplest protocol, ALOHA, nodes just transmit whenever they need to (random access), and end-terminals recover from errors owing to overlapping signals (called collisions) with retransmission. More advanced schemes implement carrier-sense multiple access (CSMA), a listen-before-transmit approach, with or without collision avoidance (CA) mechanisms, with the goal of avoiding transmission on an already occupied channel. While CSMA/CA has been very successful in radio networks, the latencies encountered underwater (up to several seconds) make it very inefficient underwater (even worse than ALOHA). In fact, while ALOHA is rarely considered in radio systems owing to its poor throughput, it is a potential candidate for underwater networks when combined with simple CSMA features [23]. A number of hybrid schemes have also been studied, in which two or more of the earlier-mentioned techniques are combined [30].

(c) The network layer, routing and transport:

In large networks, it is unlikely that any pair of nodes can communicate directly, and multi-hop operation, by which intermediate nodes are used to forward messages towards the final destination, is typically used. In addition, multi-hop operation is beneficial in view of the distance-bandwidth dependence as discussed in §3a. In this case, routing protocols are used to determine a variable route that a packet should follow through a topology. While there are many papers on ad hoc routing for wireless radio networks, routing design for underwater networks is still being actively studied. Early work on underwater routing includes that by Pompili et al. [31], where distributed protocols are proposed for both delaysensitive and delay-insensitive applications and allow nodes to select the next hop with the objective of minimizing the energy consumption while taking into account the specific characteristics of acoustic propagation as well as the application requirements. A geographical approach is proposed in Zorzi et al. [32],where a theoretical analysis has shown that it is possible to identify an optimal advancement that the nodes should locally try to achieve in order to minimize the total path energy consumption. A similar scheme, where power control is also included in a cross-layer approach, was presented in Montana et al. [20]. Other approaches include pressure routing, where decisions are based on depth, which can be easily determined locally by means of a pressure gauge.

(d) Network services

Of the many network services that are possible, localization and time synchronization have seen significant research because of their applicability to many scenarios. Localization ad time synchronization are, in a sense, duals of each other: localization often estimates communication time-of-flight, assuming accurate clocks, and time synchronization estimates clock skew, modelling slowly varying communication delays. Under water, both pose the challenge of coping with long communications latency, and noisy, time-varying channels. Time synchronization in wired networks dates back to the network time protocol in the 1990s; wireless sensor networks prompted a resurgence of research a decade later, with an emphasis on message and energy conservationthrough one-to-many or many-to-many synchronization, and integration with hardware to reduce jitter. Underwater time synchronization has built upon these ideas, revised to address challenges in slow acoustic propagation. Timesynchronization for high latency networks showed that clock drift during message propagation dominates the error for acoustic channels longer than 500 m. More recently, D-Sync incorporated Doppler-shift estimation to account for the error due to node mobility, or due to water currents.

(e) Sensing and application techniques

While full coverage of sensor technology used in underwater applications is outside the scope of this paper, we briefly summarize some challenges in this section. Some types of underwater sensors are easy and inexpensive, but many rapidly become difficult and expensive—from a few dollars to thousands or more. Inexpensive sensors include pressure sensing, which can give approximate depth, and photo-diodes and thermistors that measure ambient light and temperature. More specialized sensors include flourometers that estimate concentrations of chlorophyll, and devices to measure water CO2 concentrations or turbidity, and sonar to detect objects underwater. Such specialized sensors can be much more expensive than more basic sensors. Traditional biology and oceanography rely on samples that are taken in the environment and returned to the laboratory for analysis. As traditional underwater research has assumed personnel on site, the cost of sample return is relatively small compared with the cost of getting the scientist to the site. With lower cost sensor networks and AUVs, we expect the costs of sample-return relative to in situ sensing to force revisiting these assumptions.

(f) Hardware platforms

A number of hardware platforms for acoustic communication have been developed over the years, with both commercial, military and research success. These platforms are essential to support testing and field use. The Teledyne/Benthos modems are widely used commercial devices. They have been extensively used in SeaWeb [13], with vendor-supported modifications, but their firmware is not accessible to general users, limiting their use for new physical layer and MAC research. The Evologics S2C modems may provide some additional flexibility in that they support the transmission of short packets, which are completely customizable by the users and can be transmitted instantly without any medium access protocol rule (this feature is also supported by the WHOI micro-modem, discussed in §3g). By using such packets, there is some room for implementing and testing protocols, even though the level of reprogrammability of commercial devices remains rather limited in general. The data rates supported by these modems range from a few hundred bps to a few kbps in various bands of the tens of kHz frequency range, over distances up to a few tens of kilometres and with power consumptions of tens of watts.

Several modems (including Teledyne/Benthos, the SNUSE modem and others) support a low-power receive mode, which could in principle be used to implement wake-up modes for topology control. However, integration of this wake-up feature with higher layer protocols often depends on whether or not the firmware is accessible. While there is no universal development environment or operating system for underwater research, platforms are generally large enough that traditional embedded systems operating environments are feasible.

(h) Simulators and models

Unlike in radio frequency wireless sensor networks, where experimentation is comparatively accessible and affordable, underwater hardware is expensive (a complete, watertight node can easily cost more than US$1000) and costly to deploy (testing in a public pool can cost US$40 per hour due to the mandatory presence of a lifeguard, and deep sea deployments can easily cost tens of thousands of dollars per day); so alternatives are important. Also important is the need for rapid and controlled, reproducible testing over a wide range of conditions. Simulation and modelling is ideal to address both of these problems. Unfortunately, in many instances, the accuracy of networking simulators in modelling the physical layer and the propagation effects is poor, limiting the predictive value of such tools. Many researchers develop custom simulators to address their specific question, and others develop personal extensions to existing tools such as the network simulator (ns-2, a popular tool for networking studies [52]). However, distribution and generality of these tools is often minimal, constraining their use to their authors.

PERFORMANCE EVALUATION:

Simulation settings:

In our simulation, underwater sensor nodes are randomly distributed in a 50m£50m£50m region. Three anchor nodes cooperate with each other to supervise ordinary nodes within this area. Ordinary nodes can directly contact with all of the three super nodes by exchanging messages with them. In simulations, we randomly choose one ordinary node as sample node which aims to get synchronized with those super nodes. Without loss of generality, the inherent skew of this ordinary node is defined as 50ppm, and it maintains unchanged during time synchronization procedure. The clock offset of this ordinary node is initialized as 0:000080s. In addition, the pre-defined parameter tr1 is fixed as 2ms, and ti is 2ms. The propagation speed in the simulated environment keeps constant at 1500m=s. Regarding the mobility behavior of every node, we consider the kinematic model in [2].

CONCLUSIONS AND FUTURE WORK:

In this paper, we presented Mobi-Sync, a novel time synchronization scheme for mobile UWSNs. Mobi-Sync is the first time synchronization algorithm which does not suffer but benefit from sensor node mobility and it is also the first one which resorts to geometry knowledge to do time synchronization. Our simulation result shows that this new approach can achieve very high accuracy with relative low message overhead. In the future, we plan to explore other underwater mobility patterns and examine the applicability of our algorithm. We also want to investigate other approach to estimate node moving velocity and further examine how the accuracy of Mobi-Sync will be affected.

References:

[1] Tunnicliffe, V., Barnes, C. & Dewey, R. 2008 Major advances in cabled ocean observatories (VENUS and NEPTUNE Canada) in coastal and deep sea settings. In IEEE/OES US/EUBaltic Int. Symp., Tallinn, Estonia, May 2008, pp. 1–7. IEEE.

[2] Farr, N., Bowen, A., Ware, J., Pontbriand, C. & Tivey, M. 2010 An integrated, underwater optical/acoustic communications system. In IEEE Oceans Conf., Sydney, Australia, May 2010, pp. 1–6. IEEE.

[3] Vasilescu, I., Kotay, K., Rus, D., Dunbabin, M. & Corke, P. 2005 Data collection, storage, and retrieval with an underwater sensor network. In Proc. 3rd ACM SenSys Conf., San Diego, CA, November 2005, pp. 154–165. ACM.

[4] Cella, U. M., Johnstone, R. & Shuley, N. 2009 Electromagnetic wave wireless communication in shallow water coastal environment: theoretical analysis and experimental results. In Proc. 4th ACM Int. Workshop on Underwater Networks (WUWNet), Berkeley, CA, November 2009, pp. 9:1–9:8. ACM.

[5] Friedman, J., Torres, D., Schmid, T., Dong, J. & Srivastava, M. B. 2010 A biomimetic quasistatic electric field physical channel for underwater ocean networks. In Proc. 5th ACM Int. Workshop on Underwater Networks (WUWNet), Woods Hole, MA, September 2010. ACM.

[6] Urick, R. 1983 Principles of underwater sound. New York, NY: McGraw-Hill.

[7] 7)Stojanovic, M. 2007 On the relationship between capacity and distance in an underwater acoustic communication channel. ACM Mobile Comput. Commun. Rev. 11, 34–43. (doi:10.1145/ 1347364.1347373)

[8] Carrascosa, P. C. & Stojanovic, M. 2010 Adaptive channel estimation and data detection for underwater acoustic MIMO OFDM systems. IEEE J. Oceanic Eng. 35, 635–646. (doi:10.1109/ JOE.2010.2052326)

[9] Roy, S., Duman, T. & McDonald, V. 2009 Error rate improvement in underwater MIMO communications using sparse partial response equalization. IEEE J. Oceanic Eng. 34, 181–201. (doi:10.1109/JOE.2009.2014658)

[10] Fairley, P. 2005 Neptune rising. IEEE Spectr. 42, 38–45. (doi:10.1109/MSPEC.2005.1526903)

[11] Akyildiz, I., Pompili, D. & Melodia, T. 2005 Underwater acoustic sensor networks: research challenges. Ad Hoc Netw. 3, 257–279. (doi:10.1016/j.adhoc.2005.01.004)

[12] Shusta, J. 2010 Acoustic network architecture. In Proc. 5th ACM Int. Workshop on Underwater Networks (WUWNet), Woods Hole, MA, September 2010. ACM.

[13] Proakis, J., Sozer, E., Rice, J. & Stojanovic, M. 2001 Shallow water acoustic networks. In IEEE Commun. Mag. 39, 114–119. (doi:10.1109/35.965368).

[14] Heidemann, J., Ye, W., Wills, J., Syed, A. & Li, Y. 2006 Research challenges and applications for underwater sensor networking. In Proc. IEEE Wireless Communications and Networking Conf., Las Vegas, NV, April 2006, pp. 228–235. IEEE.

[15] Green, D. 2010 Acoustic modems, navigation aids, and networks for undersea operations. In IEEE Oceans Conf., Sydney, Australia, May 2010, pp. 1–6. IEEE.

[16] Singh, S.,Webster, S., Freitag, L., Whitcomb, L., Ball, K., Bailey, J. & Taylor, C. 2009 Acoustic communication performance of the WHOI micro-modem in sea trials of the Nereus vehicle to 11 000m depth. In IEEE Oceans Conf., Biloxi, MS, March 2009, pp. 1–6.