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The Study Paper on: Problems in Underwater Wireless Sensor Network (UWSNs)

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Abstract*—In the present scenario terrestrial wireless sensor network (TWSNs) is a great area for the research and experimental work. There are many applications which are work on this concept because it take advantage of low-cost, small-sized, easily configurable and scalable TWSN nodes to monitor, detect, and track various environmental phenomena and events. Due to the miniaturization, development and low power consumption in sensor network facilitated TWSNs to broaden their research to underwater techniques. Underwater wireless sensor network (UWSNs) are used in many applications which are useful for civil and military purpose. But there are so many technological and practical challenges in UWSN that need to overcome. In this paper we present an overview of the applications based on UWSN and their challenges .We also an overview on DTN (Delay Tolerant Network) routing protocol for UWSN. In this we also present a study on assorted UWSN architectures that are used in various currently working UWSN systems.*

Keywords*— TWSNs, Wireless Sensor Network, Underwater Wireless Sensor Network, DTN,AUV,ROV,UUV.*

I. INTRODUCTION

In the present scenario Terrestrial wireless sensor networks (TWSNs) are one of the dynamic area of study and development. There are many properties of TWSN , such as low-price, low-power, a huge number of miniaturized nodes that collaboratively are capable of supervising, detecting, and tracking various actions and objects within a specified environment, makes them very attractive for a number of marketable, trade, and military applications. With the help of TWSNs we are capable of fast operation, huge area coverage, low preservation, no difficulty in operation, and valuable scalability. In TWSN we notices a rapid increment in their application and it have vast area of application.

Ecological screening, health screening, habitat screening, seismic recognition , acoustic recognition , industrial process screening, military inspection, terror threat recognition, protection of critical infrastructure, intrusion recognition , screening of large crowds, and guidance in case of unexpected events, are just some of the possible applications. Fig. 1 describe a TWSN clustered architecture.

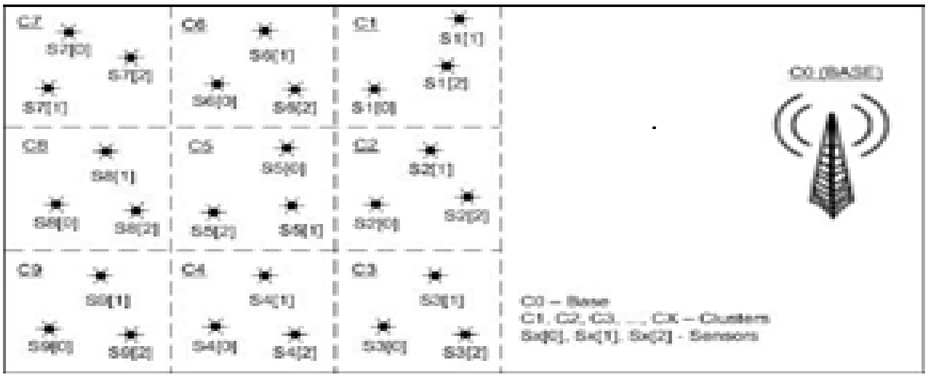

Fig:-1 Cluster architecture of TWSN

Underwater sensor nodes are very costly, therefore they are usually sparsely installed when monitoring of a huge area is required. In some cases, the networks used are so sparse that the nodes can only intermittently connect to others, which actually become Delay Tolerant Networks (DTNs). When such case arises, conventional routing protocols [10][13][14] cannot work and dedicated routing protocols for DTNs [5][6] must be used.

We usual come up to get used to currently available, and well verified terrestrial architectures, for underwater use. In this paper, we summarize the architectural mapping approach is very difficult to achieve. One of the important key reasons of architectural difference of TWSNs and UWSNs are extreme ecological differences in which these two networks operate. For example, We use RF communication in TWSNs. The reason of selecting the RF communication is that in

RF communication the transmission delay through air and the environmental noise is comparatively less. We do not prefer RF communication in underwater application because it has very limited RF wave's transmission, therefore in underwater application we prefer to use the audio communication. We relay more on audio communication because it is reliable and robust, but it have limited bandwidth in the rage of 5kb/s and 20kb/s , which is comparatively very slow over the air RF bandwidth which is in Gb/s.

To use WSN in underwater conditions we do many technical changes according to the ecological condition in which they are used , and these technical change is also affect in the architecture of networks that we required to use in underwater condition . We use hybrid approach (different type of nodes like static and mobile surface and seabed mount nodes) in UWSN structural design to make a robust networking solution, while in TWSN structural design is less diverse.

In this paper, we explore a vast field of UWSN applications. We focus on challenges faced by UWSN-based applications. We also show how those challenges drive UWSN architectural and design decisions. The remainder of the paper is organized as follows: Section II presents various UWSN applications. We explore the use of UWSNs in commercial, industrial, and military applications. Section III focuses on challenges facing UWSNs. Section IV is an overview of currently available UWSN architectures. Section V concludes our work.

II. APPLICATION OF UWSN

We see our approaches as applicable to a number of applications, including seismic monitoring, equipment monitoring and leak detection, and support for swarms underwater robots. We review their different characteristics below.

a) Seismic monitoring: A promising application for underwater sensor networks is seismic monitoring for oil extraction from underwater fields. Frequent seismic monitoring is of importance in oil extraction. Studies of variation in the reservoir over time are called "4-D seismic" and are useful for judging field performance and motivating intervention. Terrestrial oil fields can be frequently monitored, with fields typically being surveyed annually, or quarterly in some fields,
and even daily or "continuously" in some gas storage facilities and permanently instrumented fields. However, monitoring of underwater oil fields is much more challenging, partly because seismic sensors are not currently permanently deployed in underwater fields. Instead, seismic monitoring of underwater fields typically involves a ship with a towed array of hydrophones as sensors and an air cannon as the actuator. Because such a study involves both large capital and operational costs (due to the ship and the crew), it is performed rarely, typically every 2–3 years. As a result, reservoir management approaches suitable for terrestrial fields cannot be easily applied to underwater fields.

b) Equipment Monitoring and Control: Underwater equipment monitoring is a second example application. Long-term equipment monitoring may be done with pre-installed infrastructure. However, temporary monitoring would benefit from low-power, wireless communication. Temporary monitoring is most useful when equipment is first deployed, to confirm successful deployment during initial operation, or when problems are detected. We are not considering node deployment and retrieval at this time, but possibilities include remote-operated
or robotic vehicles or divers.

Short-term equipment monitoring shares many requirements of long-term seismic monitoring, including the need for wireless (acoustic) communication, automatic configuration into a multihop network, localization (and hence time synchronization), and energy efficient operation. The main difference is a shift from bursty but infrequent sensing in seismic networks, to steady, frequent sensing for equipment monitoring.

Once underwater equipment are connected with acoustic sensor networks, it becomes an easy task to remotely control and operate some equipment. Current remote operation relies on cables connecting to each piece of equipment. It has high cost in deployment and maintenance. In contrast, underwater acoustic networking is able to significantly reduce cost and provide much more flexibility

c) Flocks of Underwater Robots: A third and very different application is supporting groups of underwater autonomous robots. Applications include coordinating adaptive sensing of chemical leaks or biological phenomena (for example, oil leaks or phytoplankton concentrations), and also equipment monitoring applications as described above.

Communication for coordinated action is essential when operating groups of robots on land. Underwater robots today are typically either fully autonomous but largely unable to communicate and coordinate with each other during operations, or tethered, and therefore able to communicate, but limited in deployment depth and maneuverability.

We expect communications between underwater robots to be low-rate information for telemetry, coordination, and planning. Data rates in our proposed system are not sufficient to support full-motion video and tele-operation, but we do expect to be able to support on-line delivery of commands and the ability to send back still frame images.

There are number of applications which are based on UWSN technique and it is constantly spread their area of use. The reason of spreading the area is that our planet is the one which contain maximum amount of water as compare to the land (70% surface of Earth is covered by water and it still required to explore) .One another important reason is that progress in areas like underwater sensors, underwater communication, many other underwater sensor networks.

There are number of application of UWSN that can be categorized as monitoring application. With the help of UWSN we can able to do this monitoring job very easily and effectively. There are many places where we can use this technique like monitoring of water feature examination, contamination monitoring (biological, water, nuclear, compound), observing of marine currents, trailing of marine organism , measurements of pressure and temperature

A great number of UWSN applications can be classified as monitoring applications. Water quality analysis, pollution monitoring (chemical, biological and nuclear), monitoring of ocean currents, tracking of fishes or micro-organisms, pressure and temperature measurements, as well as conductivity and turbidity analysis, are all examples of environmental monitoring [2]. Monitoring underwater structures such as oil platforms, oil and gas pipes, buried communication high-speed cables and other equipment monitoring can all be achieved using underwater WSNs.

Seismic monitoring is another very popular application, because most of the gas and oil reserves are underwater. The frequent 3-D and 4-D seismic monitoring is required for oil extraction [3]. In 3-D and 4-D seismic surveys, close coordination among sensors is required because those surveys rely on mapping the acquired data with the exact location of data-providing sensors.

In addition to monitoring applications, UWSNs are used for assisted navigation and control. Autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and underwater unmanned vehicles (UUVs) use UWSNs as location reference points. For example, sensors anchored at the ocean’s bottom at known locations can provide the location reference, as well as valuable water characteristics information, to passing AUVs, ROVs, and UUVs. Underwater sensors can also provide ships with valuable information about where to anchor or trespass shallow corridors. Communication with divers is another UWSN area of usage.

Unmanned underwater exploration, as well as object localization, also benefit from an UWSN infrastructure. AUVs, ROVs, UUVs were critical in the 1985 discovery of the Titanic by the Woods Hole Oceanographic Institution. A number of successful lost treasure discoveries were made with the help of UWSNs.

UWSNs are extensively used in military and homeland security applications [4]. Underwater sensors anchored to the ocean floor are used as a powerful surveillance tool. Underwater warfare, submarine navigation, submarine attacks, and submarine hunting can be initiated and controlled via UWSNs. Future UWSNs applications also envision using unmanned submarines and UUVs for active attack purposes. UWSNs are also used in securing critical infrastructure such as port facilities, ships and submarines anchored in ports. Further applications focus on enemy targeting and intrusion detection. Mine reconnaissance and de-mining activities are aided with UWSNs. Minefields are historically very difficult to detect early enough to avoid a disaster. AUVs, ROVs, and UUVs can be an effective mine discovery and deactivation tool.

Disaster prevention and disaster recovery are areas of active UWSN research. As Akyildiz et al. [2] points out, the UWSNs measuring seismic activity from remote locations can provide tsunami warnings to coastal areas. Various animal and coral activities properly picked up via UWSNs can serve as an early storm warning system. Hurricane disaster recovery can also be aided via detection by time-critical UWSNs. Disaster recoveries such as the ones caused by marine incidents, such as chemical pollutions and oil spills, can be aided by UWSNs.

UWSNs can also be used for corrosion detection in underwater oil and gas pipes, as well as corrosion detection of oil platform structures. Corrosion, a slow but steady process, is difficult to detect thousands of meters underwater. Corrosion detection sensors networked wirelessly into UWSNs can be a valuable tool for corrosion damage prevention.

Using UWSNs for exploring and harvesting natural undersea resources such as minerals, corals and coral reefs, fisheries, and rare metals, is becoming more attractive with the advancements in UWSNs. Imaging sensors applications can be used to visualize, classify, count, or simply observe various underwater species.Marine incident investigations can use UWSN as a powerful tool to unwind the sequence of events leading to the incidents. Incidents could also be prevented by creating early-warning UWSN systems.

III. UWSN CHALLENGES

UWSNs face a number of technological challenges. The fabrication, deployment, maintenance and recovery costs are very high compared to TWSNs. Typically a UWSN node costs around 10K, whereas a comparative terrestrial node costs only \$100. Fabricating a rugged pressure housing costs \$3k, whereas a simple underwater connector costs \$100 [1]. Oceanographic research ships cost between 5k and 25k per day

Power consumption and power harvesting are challenging in UWSNs. Since underwater sensors are residing deep in the water, power re-charging is logistically difficult. Therefore, UWSN node design must take power scarcity into consideration. This is especially true for AUVs, ROVs, and UUVs, which need additional propulsion power. As Partan et al. [1] note, the non-propulsion power (sensors, communication, electronics) is typically 30W, with propulsion power ranging from 15W to 110W. Power harvesting is problematic because the common power-rich energy sources, such as solar, are not available underwater. New power-efficient robust protocols such as one described by Xie et al. [5] must be developed for underwater applications.

The WSN localization issue is amplified underwater. Placing/anchoring a node at exact geo-locations, as well as preventing the node from occasional displacements over time, is a difficult task. Most of the TWSN localization techniques use time of arrival (ToA) or received signal strength indication (RSSI) to estimate the exact node position. However, since

UWSN nodes are sparsely deployed, localization accuracy using those techniques greatly suffers. In addition, some other localization techniques, such as techniques using GPS, do not work underwater. Chandrasekhar et al. [6] classify the localization schemes into range-based and range-free schemes (schemes that do not use range or bearing information). They also compare different localization schemes, and they outline the challenges facing each scheme.

Time-synchronization is an issue, even in RF-based TWSNs. Elson et al. [7] proposed a synchronization solution that generally performs well in TWSNs, because the RF propagation delay is negligible. Unlike TWSNs, most UWSNs use acoustics for communication. Underwater sound propagation speed is 1500 m/s compared to 3x108 m/s for RF terrestrial signal. The five-orders-of-magnitude difference in propagation delay makes TWSN's time-synchronization techniques impractical. Also, clock drifting between nodes can create synchronization issues. Heidemann et al. [3] calculate that a drift rate of 50ppm can create a clock difference as big as 130s after 30 days. Syed and Heidemann [8] suggest the use of a clock synchronization-reducing protocol called Network Time Protocol (NTP). TWSN's preferred Time Division Multiple Access (TDMA) channel access method, which relies on precise clock-synchronization among nodes, is replaced with Code Division Multiple Access (CDMA) in UWSN. Unlike TDMA, CDMA can tolerate occasional loss of synchronization and various clock drifts and jitters.

UWSN lifetime is an area of extensive research. UWSNs suffer from a sensor's fouling and corrosion [9]. Electronics components, such as the battery, tend to degrade faster under extremely low temperatures such as the one found in deep underwater. As a consequence, the USWN lifetime is much shorter than the lifetime of a comparable TWSN. A shorter lifetime increases the replacement and maintenance costs. An example is an oil exploration survey that is run intermittently every 1 to 3 years and then only for a short survey time. The temporal nature of UWSN narrows the field of potential underwater applications that can greatly benefit from UWSN technology.

Communication among UWSNs is probably the biggest challenge facing UWSNs. Akyildiz et al. [9] point out that path loss (attenuation and geometric spreading), noise (man-made and ambient), multi-path, high propagation delays, and Doppler spread, can significantly disrupt or degrade the underwater communication channel. Another problem is that standard acoustic transducers cannot simultaneously transmit and receive [1]. Underwater network communications are therefore always half-duplex. In addition, transmit power is about 100 times more than receive power, making the communication channel asymmetric. Asymmetry, on the other hand, forces significant UWSN architectural changes and the shift from the traditional data sense-and-send approach to a rather more complex store-and-forward approach. High propagation delays, and low data rates also pose a challenge for carrier-sense based transmission schemes.

Underwater data collection, storage, and retrieval are a challenge. Long and varying propagation delays greatly affect the underwater, often multi-hop, data transfers. UWSN nodes often require more memory for data caching in order to offset the intermittent nature of underwater channels, as well as to efficiently implement the data store-and-forward-based architectures. Hardware (including storage and memory), and software extreme reliability requirements, create additional technological challenges. The control of vast numbers of sensors, especially the mobile ones, also contributes to the overall problem of data transfer efficiency.

Repair and replacement of defective nodes, as well as failure detection in underwater systems, is challenging and costly. Individual nodes might fail, either due to hardware malfunction or simply by reaching their end of life. To identify, recover, and replace the failing node causes the network's full coverage interruption because the expensive underwater nodes rarely have a backup covering the exact same area. In addition, the hardware rarely experiences a total breakdown. A more common case is an intermittent hardware malfunction that becomes more frequent over time, until a total breakdown is experienced. The intermittent, non-fatal hardware problems are more difficult to diagnose and repair.

The reliability and robustness of the underwater communication link is greatly affected by the environment. Variations in pressure, salinity, ocean currents, marine life, motion-induced Doppler effects, and man-made noise can create significant variations in link reliability. High bit error rates create a challenge in designing low-power error correction coding schemes.

Spatial data correlation among UWSN nodes is almost nonexistent. UWSN nodes are sparsely deployed because a large population within a small area can cause conflicts with throughput and navigation [3]. On the other hand, spatially correlated data can be very helpful in increasing the reliability of the event-to-sink data path. For example, Ozgur and Akyildiz [10] propose an event-to-sink reliable transport (ESRT) protocol that heavily relies on spatial correlation to achieve reliability with the least amount of energy.

Real-time data sampling and transfer imposes several challenges. Slow intermittent channels, long and variable propagation delays, asymmetric transmission, and high bit error rates (BERs) force any underwater network to be more store-and-forward oriented with unbounded network latency and variable throughput.

The capacity of underwater communication channels is limited. Kong et al. [11] report that the underwater range x rate product can barely exceed 40 km-kbps. Consequently, a rate of 5kbps can be achieved only on communication links 8 km long and shorter. Partan et al. report that the maximum data rate in shallow water is 5 kbits/s at the range of 2 km, but it can drop to as low as 80 bits/s.

UWSNs security is a challenge that is often neglected by network architects. The security is difficult to achieve because it requires additional hardware and software layers that often translate into additional product cost. UWSN node's power budget is also very dependent on the transmission packet lengths; encrypted messages are longer and require more power to transmit. Data privacy, authentication and keying require additional computation capabilities [12]. Architectures integrating floating buoys are also vulnerable to weather conditions, tampering, and pilfering [2].

IV. UWSN ARCHITECTURES

UWSN architectures can be classified in various ways. One classification discriminates between static, semi-mobile, and mobile architectures [4]. Another popular UWSN classification method is to divide UWSNs into two-dimensional (cover ocean floor) and three-dimensional (includes depth as a dimension) [2]. UWSN can also be single-hop, multi-hop, or hybrid (single-hop individual sensors, multi-hop clusters). Architectures can be grouped into short-term, time-critical applications, and long-term, non-time-critical applications [13]. RF, optical, and acoustic wave based architectures are another way to look at the available UWSNs. Pompili et al. [14] classifies them into delay-sensitive and delay-insensitive applications.

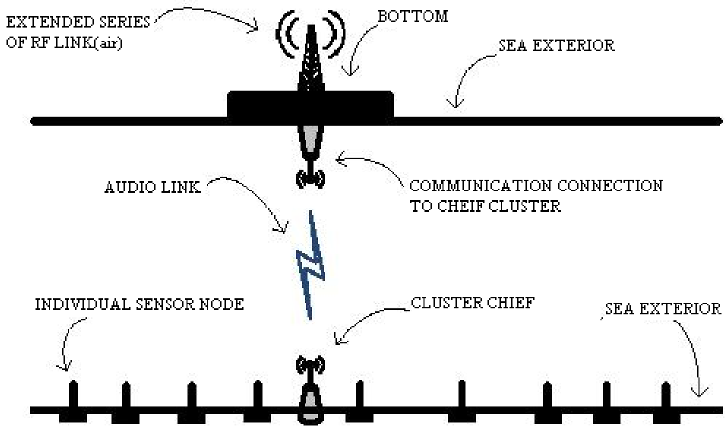

Fig. 2 shows the most common UWSN architecture.

The individual nodes are anchored at the ocean floor. They are usually smaller in size, battery operated, and they mostly transmit data via acoustic modems. The cluster heads are also anchored to the ocean floor. In addition to having acoustic modems, cluster heads are equipped with long-range vertical-direction modems, allowing them to communicate with a base station located at the ocean surface. The long-range modems can be acoustical, optical, or even RF for shallow waters. Acoustic modems are most widely used. Cluster heads communicate via horizontal acoustic modes with all other individual nodes within the cluster. The data transfer from node to cluster head can be single-hop (each node communicated to the cluster head directly) or multi-hop. The multi-hop approach is generally more power-efficient, because the signals have to travel shorter distances between two nodes. The network maintenance and configuration tasks are more complex in the multi-hop case.

Unlike TWSNs, the hardware of the cluster head node is different from all other nodes, because it has additional functionalities such as a direct communication link with the ocean surface. Therefore, a popular TWSN’s cluster head switching feature (which increases the overall network lifetime by efficiently distributing the power consumption among nodes) cannot be utilized in UWSNs. Also, the cluster head is potentially the most security-vulnerable component in UWSNs military applications, because it is a single point of failure node.

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Fig. 3 shows an alternative 3D UWSN architecture. 3D architecture can use the same nodes as those used in 2D UWSN architecture, although the nodes are anchored at different heights from the ocean floor. The buoyancy-controlled node positioning is achieved via a controllable tether anchored at the ocean floor. 3D architecture can have all nodes directly communicate to the surface base or can have only cluster heads communicate directly to the base. In the former case, all nodes are of the same type, but communication might be more energy intensive than that of the cluster head approach. The cluster head approach requires only the cluster head to carry a long-range communication modem. On the other hand, the clustered approach is vulnerable to single point of failure. Military applications are extremely sensitive to single point of failure hardware components.

While 3D architecture provides more complete images of a surveyed area, the challenge is to position all nodes in a structure that can ensure uninterrupted communication and full area coverage at all times. This is difficult to achieve because ocean currents, animals, passing ships and submarines might destroy some of the placed nodes, which can ultimately cause communication breakdowns.

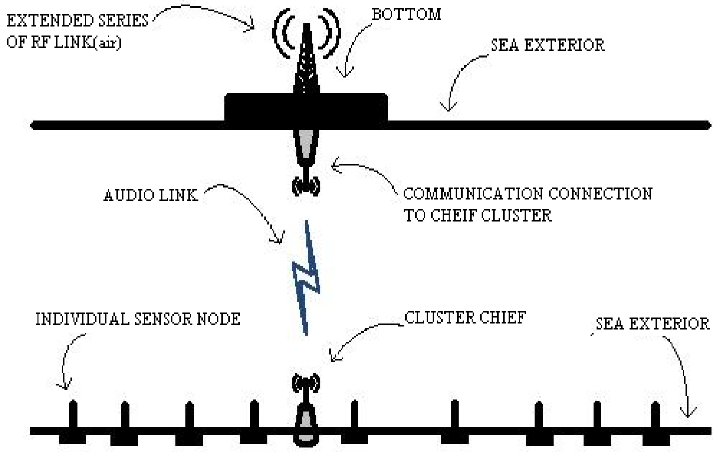

Fig. 3 shows an alternative 3D UWSN architecture.

The next architecture uses AUVs, ROVs, and UUVs as network nodes. Fig. 4 shows an example of the architecture. The feature that stands out in this architecture is the mobility of nodes. The mobility of nodes allows for easier network reconfiguration and adjustment, but that mobility causes an increase in network control complexity. In addition, mobile networks tend to consume more power, because they consume extra power due to propulsion. The power issue is somewhat offset by the use of low-speed gliders and drifters. Mobile network elements, however, tend to be less reliable, and their lifetime is shorter.

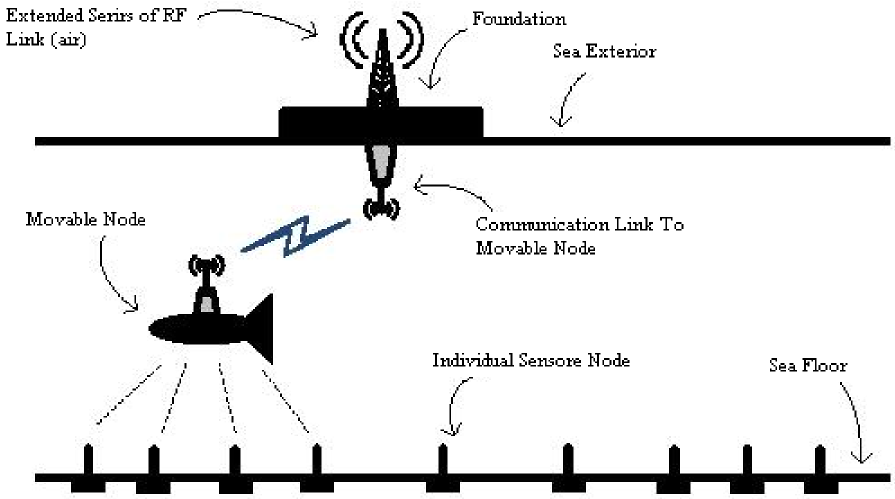

Fig. 4 shows an example of the architecture.

Both static and mobile UWSN architectures have their advantages and disadvantages. In order to emphasize the advantages of both architectures, a new, hybrid architecture is needed. Vasilescu et al. [15] propose a new, hybrid UWSN architecture that includes a mix of static and mobile nodes networked together so that data can be transferred efficiently from the ocean floor sensors to the ocean surface. The solution uses a combination of acoustic and optical communication. The low speed acoustic communication would mostly be used for data broadcasts, network health and welfare diagnostics, and overall network maintenance. The optical communication would be used for high data rate point-to-point communication. The point-to-point optical data communication is achieved via mobile nodes (AUVs, ROVs, and UUVs) traversing over the static field of nodes anchored to the ocean floor.

V. CONCLUSIONS

In this paper we introduce UWSNs as a means of monitoring, exploring, and tracking marine life. We present an overview of commercial, industrial and military UWSN applications. In this paper we also introduce a number of challenges facing the development and deployment of such applications, making the case that one-to-one mapping between TWSNs and UWSNs is not practical. At the end we describe a number of novel, practical UWSN architectures.

We plan to continue our UWSN study, focusing more on the underwater network stack. We expect to spend a fair amount of time on physical layer, because many of the challenges outlined in this paper are directly related to the UWSN's physical layer.

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