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Interference Aware and Energy Efficient Multihop in Underwater Acoustic Networks

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Abstract – We study maximum multi-flow scheduling in an underwater acoustic sensor network. The network consists of underwater sensor nodes and surface gateways. The objective is to maximize the sum of the flows that can be finished within a fixed time duration. To address challenges posed by large sound propagation latency, we convert the original network to a time-expanded network, and develop a linear programming (LP) formulation for the maximum multi-flow scheduling. The solution to the LP formulation provides an upper bound of the maximal achievable flow. Through introducing a stronger constraint into the LP formulation, a feasible multi-flow transmission schedule is proposed, which guarantees a small approximation factor. Simulations are conducted to verify the theoretical results. Due to the battery resource constraint, it is a critical issue to save energy in wireless sensor networks, particularly in large sensor networks. One possible solution is to deploy multiple sink nodes simultaneously. In this paper, we propose a protocol called MRMS (Multipath Routing in large scale sensor networks with Multiple Sink nodes) which incorporates multiple sink nodes, a new path cost metric for improving path selection, dynamic cluster maintenance and path switching to improve energy efficiency. MRMS is shown to increase the lifetime of sensor nodes substantially compared to other algorithms based on a series of simulation experiments.

Index Terms – Linear programming formulation, Multipath routing in large scale sensor network, Underwater sensor node.

1. INTRODUCTION

Underwater acoustic sensor networks (UWSNs) have been commonly regarded as the enabling techniques for real-time and in situ data collection in a wide range of aquatic applications. The underwater nodes and gateways are acoustically connected under water, while the gateways can be also connected via high-rate radio links above water surface. A fundamental operation for UWSNs is to deliver large amount of data from underwater sensor nodes to surface gateways Relative to terrestrial radio networks, grand challenges are possessed by the large sound propagation latency in underwater acoustic networking. Recently, a series of works have been developed to take advantage of the long propagation delay of acoustic transmissions to boost the network throughput.

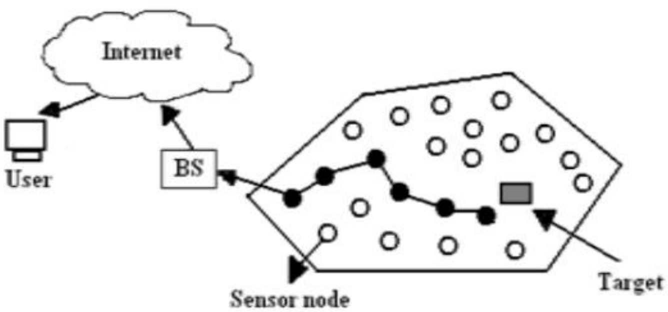
A wireless sensor network (WSN) consists of hundreds to thousands of low-power multifunctional sensor nodes, operating in an unattended environment, and having sensing, computation and communication capabilities. The basic components of a node are a sensor unit, an ADC (Analog to Digital Converter), a CPU (Central processing unit), a power unit and communication unit. Sensor nodes are micro-electro-mechanical systems (MEMS) that produce a measurable response to a change in some physical condition like temperature and pressure. Sensor nodes sense or measure physical data of the area to be monitored. The continual analog signal sensed by the sensors is digitized by an analog-to-digital converter and sent to controllers for further processing. Sensor nodes are of very small size, consume extremely low energy, are operated in high volumetric densities, and can be autonomous and adaptive to the environment. The spatial density of sensor nodes in the field may be as high as 20 nodes/m3.As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Several sources of power consumption in sensors are: (a) signal sampling and conversion of physical signals to electrical ones; (b) signal conditioning, and (c) analog-to-digital conversion.

Categories of SensorNode

- **Passive**, Omni Directional Sensors: passive sensor nodes sense the environment without manipulating it by active probing. In this case, the energy is needed only to amplify their analog signals. There is no notion of "direction" in measuring the environment.
- **Passive**, narrow-beam sensors: these sensors are passive and they are concerned about the direction when sensing the environment.
- **Active Sensors**: these sensors actively probe the environment.

Wireless sensor systems are accumulations of reduced size and moderately modest computational hubs that measure nearby natural conditions or different parameters and forward such data to the base station for proper preparing. The fundamental unit in a sensor system is a sensor hub.

Remote sensor systems can sense the earth, correspond with neighboring hubs and can likewise perform fundamental processing's on the information being gathered. Late advancements in sensor engineering and remote correspondence have helped in the arrangement of substantial scale remote sensor systems for a mixed bag of uses including natural checking of living space, information accumulation of temperature, weight, sound ,moistness, light, vibration and so on. For such kind of uses hundreds or a large number of minimal effort sensor hubs might be conveyed over the region to be checked. In information gathering sensor organize every sensor hub should occasionally report its sensed information to the sink.



The sensor hubs are for the most part fueled by little modest batteries. Subsequently vitality utilization ought to be overseen in a proficient approach to augment the post organization system lifetime. In the event that there is long separation between the sensor and sink, transmission is not vitality proficient since the transmission force is relative to the square or fourfold of the transmission separation. Multihop directing is performed than sensor to sink immediate transmission for long separation as more vitality could be spared. Be that as it may multihop directing reason abuse of the hubs near the sink and make them use up vitality rapidly. In a remote sensor system sensor hubs has constrained vitality .So to build the lifetime of remote sensor system vitality of sensor hubs must be preserved.

Sensor hubs after sensing the information will convey it to the sink through multihopping nodes close to the sink will expend more battery force than others. Because of this these hubs will fastly empty out their battery vitality and decrease the lifetime of the system. Sink movement is an effective strategy for upgrading the lifetime of the system. Vitality mindful sink migration system is utilized here.

A relocatable sink helps in drawing out the lifetime of the system by abstaining from staying at a certain area for quite a while which may diminish the lifetime of adjacent sensor hubs. The sink movement system has two sections. The principal part is to figure out if to trigger the sink movement by figuring out if a migration condition is met or not. The second part figures out which heading sink is heading in and the movement distance for migration condition sink intermittently gather the remaining battery vitality of every sensor hub in the remote sensor system.

At that point greatest limit way steering convention is utilized to discover the most extreme limit way regarding every sensor neighbor of the sink. For every most extreme limit way greatest limit quality is found. Sink migration happens when the greatest limit quality drops beneath an edge esteem. The sink migration component considers the remaining battery vitality of the sensor hub and afterward drives the sink to a position with a substantial amount of lingering vitality contrasted with others.

A sensor network is composed of a large number of wireless sensors, densely deployed, in the range of a phenomenon to observe, study and/or monitor. A sensor is an electronic device which generally gathers three main capabilities: the ability to measure and collect data relative to the environment surrounding it, the ability to process these collected data, and the ability to exchange it with other devices. The other devices can be sensor nodes or sinks. A sink is a particular node which collects the information resulting from the sensing nodes, process them and/or send them to a data concentration center. Generally, sensor nodes deliver their collected data to the nearest sink.

The main constraint in sensor networks is their limited energy supply. Therefore any program running on this device has to manage carefully the autonomy issue. Indeed, it has been shown that a wireless communication is one of the more expensive operations the sensor has to perform. Hence, all research efforts in this area have focused on energy-aware solutions so that the lifetime of the network is maximized. Most proposed routing approaches in sensor networks are centered on energy minimization by looking for multi-hop links. In fact, the largely explored multi-hop approach is based on the observation that the transmission power of a wireless communication is proportional to distance squared, or even higher (in the presence of obstacles). Hence, the multi- hop routing consumes less energy than direct communication.

Although proposed routing protocols are able to dynamically adapt according to nodes energy, the nodes nearby the sink serving as last-hop relays observe rapid depletion in their energy supply. Therefore, to improve the network lifetime by reducing the total transmission power, the sink is moved towards the last-hop relays which are the most involved in packet transmitting. Such an approach has also the advantage of reducing the average delay observed by data packets.

On the other hand, in a network where not only a single but multiple sinks are present, the correct placement of the sink nodes directly affects the lifetime of such a network. Some research works dealing with the optimal multi-sink positioning problem have been proposed. However, they have not taken into account the network evolution, they only try to place, in an optimal manner, the sinks.

2. RELATED WORK

2.1**Routing Protocols In Wsns.**

In this section, survey the state-of-the-art routing protocols for WSNs. In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all nodes are typically assigned equal roles or functionality.

In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network. A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, or coherent-based routing techniques depending on the protocol operation.

In addition to the above, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source finds a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. When sensor nodes are static, it is preferable to have table driven routing protocols rather than using reactive protocols. A significant amount of energy is used in route discovery and setup of reactive protocols. Another class of routing protocols is called the cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy use.

2.2 **Conceiving energy efficient protocols**

Conceiving energy-efficient protocols is a critical issue in energy-constrained wireless sensor networks. A life-optimal routing algorithm must take advantage of the total available energy resources in the network before its death. To achieve this, a load balanced routing scheme was proposed.

2.3 **Contention-Free Mac Protocol**

The objective of this paper is to provide a wide ranging analysis of the impact of different network design strategies for data gathering. To this aim, define several optimization problems in the energy-latency domain and tackle them with a multi-target approach. To design the optimization framework we considered quasi-ideal network condition by implementing a time scheduling that avoids collisions at the MAC layer and by assuming negligible transmission errors as well as ideal data correlation. The mathematical framework proposed here allows the WSN designer to foresee the impact of different design choices on optimal DA-trees as a function of different performance targets. The presented results will help researchers gain a deeper understanding of the fundamental characteristics of WSNs in the energy-latency domains.

3. PORPOSED MODELLING

3.1 SYSTEM ARCHITECTURE

In a WSN, sensor nodes deliver sensed data back to the sink via multi hopping. The sensor nodes near the sink will generally consume more battery power than others; consequently, these nodes will quickly drain out their battery energy and shorten the network lifetime of the WSN. Sink relocation is an efficient network lifetime extension method, which avoids consuming too much battery energy for a specific group of sensor nodes. Energy-Aware Sink Relocation (EASR) for mobile sinks in WSNs. The proposed mechanism uses information related to the residual battery energy of sensor nodes to adaptively adjust the transmission range of sensor nodes and the relocating scheme for the sink. The EASR method can extend the network lifetime of the WSN significantly.

3.2 MODULES:

Underwater Network SIM

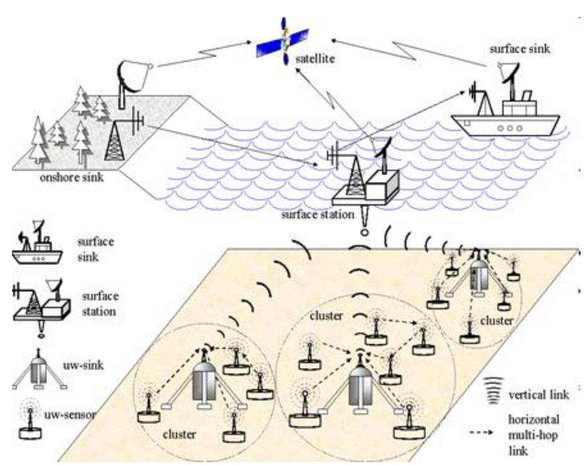
Acoustic Node Deployment

LP Formulation

Acoustic Communication As Design

Performance Evaluation

3.2.1 Underwater Network Sim



In this module we create a UNS, It consists of a number of underwater sensor nodes, underwater sink, surface station, Autonomous Underwater Vehicles (AUVs) that are deployed to perform collaborative monitoring and resource exploration tasks over a given area.

3.2.2 Under water network SIM design

The NAUTILUS project aims at providing a robust networking infrastructure for underwater telerobotics. Many commercial modems to date provide sufficiently high data rates to reliability support point-to-point transmissions. The missing ingredient is their interconnection into a self organized autonomous network. The overall objective of NAUTILUS is to investigate such a solution, both theoretically and practically.

3.2.3 Acoustic Node Deployment

In this module group of sensor nodes arean chored to the bottom of the ocean. Underwater sensor nodes are interconnected to one or more underwater sinks (uw-sink). UW-sink is used to receive data from the ocean bottom network and send to a surface station. uw-sinks are equipped with two acoustic transceivers A vertical and a horizontal transceiver. acoustic communication channel, such as high and variable propagation delay and the three dimensional volume of the environment make it necessary to design and develop new localization algorithms.

In this paper, a localization algorithm called three-dimensional underwater localization (3DUL) is introduced. 3DUL achieves network wide robust 3D localization by using a distributed and iterative algorithm. Most importantly, 3DUL exploits only three surface buoys for localization initially.

The sensor nodes leverage the low speed of sound to accurately determine the inter-node distances. Performance evaluations show that 3DUL algorithm provides high accuracy in underwater localization, which does not degrade with network size.

3.2.4 LP Formulation

In this module, a feasible multi-flow schedule will be developed based on the LP formulation with a stronger constraint. We now present an algorithm to schedule the flow obtained in the stronger LP. In the time-expanded graph, we sort all the virtual edges with non-zero flows in two steps.

The simplex algorithm, developed by George Dantzig in 1947, solves LP problems by constructing a feasible solution at a vertex of the polytope and then walking along a path on the edges of the polytope to vertices with non-decreasing values of the objective function until an optimum is reached for sure.

Like the simplex algorithm of Dantzig, the criss-cross algorithm is a basis-exchange algorithm that pivots between bases. However, the criss-cross algorithm need not maintain feasibility, but can pivot rather from a feasible basis to an infeasible basis. The criss-cross algorithm does not have polynomial time-complexity for linear programming.

3.2.5 Acoustic Communication Design

We are developing a multi-hop acoustic network targeting communication distances of 50-500 meters. Using a simple FSK signaling scheme we anticipate sending 5kb/s over a range of 500m using a 30mW transmitter output. The primary limitation is set by spreading loss and the background noise of the ocean.

4. RESULTS AND DISCUSSIONS

The proposed scheduling algorithm has also been validated via randomly generated network topologies with arbitrary signal propagation delays. The total amount of flow that can be scheduled without imposing the node fairness constraint is 3.916 with a breakdown of [fv1, fv2, fv3, fv4] =[1.5, 0, 2.083, 0.333]. The total amount of flow that can be scheduled with the node fairness constraint is 3.471 with a breakdown of fv1 = fv2 = fv3 = fv4 = 0.868.

5. CONCLUSION

Multi-flow scheduling is challenging in UWSNs due to the large sound propagation latency. This work focused on transmission scheduling from multiple underwater sensor nodes to any of the surface gateways. It was shown that the maximal value of the LP is at least the maximum achievable flow. A multi flow scheduling algorithm was also developed based on the solution to the LP formulation with a stronger constraint, which achieves a provable performance guarantee. Both theoretical results and the proposed scheduling algorithm were validated via simulations. which includes topology discovery, cluster maintenance and path switching. Since MRMS uses multiple sink nodes, cluster maintenance and path switching which can distribute the energy consumption in sensor networks more evenly, it enjoys significant improvement in key metrics compared to other approaches.

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