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Under Water Vehicles in Wireless Sensor Networks for Underwater Pipeline Monitoring

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Abstract: Water Pipeline Monitoring Systems have emerged as a reliable solution to maintain the integrity of the water distribution infrastructure. Various emerging technologies such as the Internet of Things, Physical Cyber Systems, and machine to-machine networks are efficiently deployed to build a Structural Health Monitoring of pipeline and invoke the deployment of the Industrial Wireless Sensor Networks (IWSN) technology. Efficient energy consumption is imperatively required to maintain the continuity of the network and to allow an adequate interconnection between sensor nodes deployed in the harsh environment. In this context, to maximize the Lifetime of the WSN underwater Distribution system domain is a primordial objective to ensure its permanently working and to enable a promising solution for hydraulic damage detection according to diverse performance metrics In this context, the data aggregation techniques are well-designed and various smart algorithms are developed to reduce the quantity of transmitted data and to minimize the energy consumption. In this project, we combine between data aggregation and clustering algorithm in order to improve the WSN Lifetime. Data aggregation applied in order to eliminate redundant data either from different sensor nodes at the same time or from the same sensor node at various time steps. NS2 simulator tool has been used to evaluate existing and proposed system performance. Then, efficient data aggregation allowing the redundancy elimination at the cluster and sensor node level improves more the results and reduces the energy consumption.

I. Introduction

Acoustic wireless sensor nodes can be installed with underwater pipeline infrastructures. Each node has a limited transmission capability in which each node can communicate with few neighboring nodes. Multi-hop communication is used to transfer the sensed information among the underwater pipeline.

Wireless networks can solve some of the reliability problems of current wired networks technologies in pipeline systems. For example, wireless sensor networks can still function even when some nodes are disabled. Faults in sensor nodes can be easily tolerated by using other available nodes to cover the faulty ones. Using dense sensor networks with a high number of nodes and/or using wide acoustic transmission range, the network can maintain connectivity and the sensed information can be transported through the network to its destination even with the existence of some node failures. For example, each node in Figure 1.1 can communicate with two nodes to the left and two nodes to the right. If for example node 3 and 5 are damaged, node 4 can still send its sensed data through nodes 2 or 6.

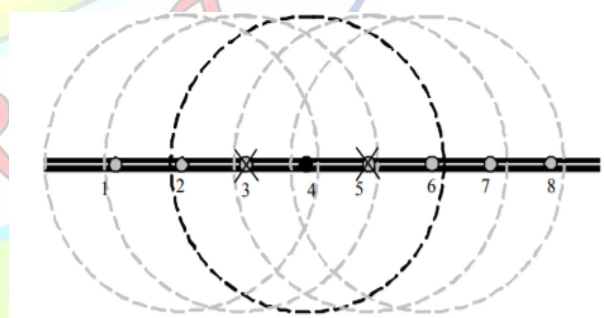

Figure 1.1 Reliability in dense sensor networks

Each sensor node for monitoring pipelines is usually equipped with an acoustic transceiver, a processor, a battery, memory, and small storage in addition to one or more sensor devices. Power consumption is critical to the life span of pipeline communication systems. Pipeline systems are usually installed to be used for many years. Therefore the associated communication systems should also be long lived. Unlike wired networks where the power is not at all a constraint in building the system, network designers have to consider power as one of the main constraints in the wireless system. Power in a node can be consumed when data is sent through the transceiver, when the transceiver is turned on waiting to receive data from

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other nodes, when sensor devices are turned on, and when the processor is active. Careful scheduling of these resources is needed to optimize power consumption.

Although increasing the range can provide better reliability, more energy will be consumed from the nodes. A dynamic configuration for the wireless transmission range can provide better power management. Example of this configuration is in Figure1.3. In this network, nodes 3 and 5 are dead. Therefore, the wireless range for node 4 is increased to reach nodes 2 and 6 while other nodes use a smaller transmission range to reduce the power consumption.

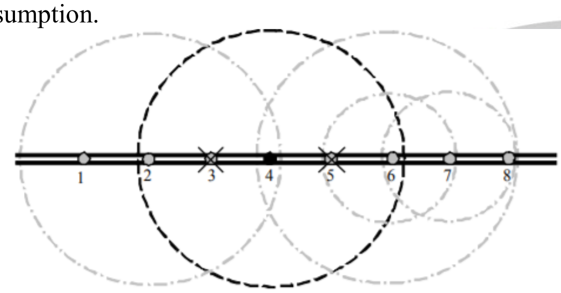

Figure 1.3 Automatic wireless/acoustic range

In addition, nodes are used to route information from other nodes to the NCC. As a result, nodes close to the NCC will consume more power than other nodes since they will route more packets. All nodes will have the same level of sensing activity; however, closer nodes to the NCC will consume more power due to more packet routings. One of the main issues for wireless/acoustic networks when used to monitor pipelines is the optimal design of a network protocol that balances the power consumption of batteries on the nodes with and without node failures. This balancing is crucial to extend the life of the network.

One approach to enhance the reliability of underwater acoustic sensor networks for pipelines is to divide the network into multiple parts. In each part, there is a surface buoy that is linked with one of the underwater sensor nodes through a wire as shown in Figure 1.4. Each surface buoy is equipped with a radio communication system to transfer collected information to the NCC. The collected information can be transferred either directly through satellite communication links or using radio multi-hop communication among the available surface buoys. All acoustic sensor nodes need to transfer their sensed information to the nearest neighboring node linked to one of the surface buoys.

Generally, underwater acoustic networks suffer some major problems [4-5]. First, the available bandwidth is very limited among the nodes. The bandwidth of underwater acoustic channels depends on both the distance and frequency. Communication among nodes located within the range of a few tens of kilometers may have a bandwidth of only a few kHz. The bandwidth can be increased to a hundred kHz, if the nodes involved are located closer (i.e., within several tens of meters). Second, propagation delay of acoustic signals underwater is very high and variable. It is around five orders of magnitude higher than that in radio frequency channels. Third, due to the characteristics of the underwater channel, high bit error rates and connectivity losses can be encountered. Forth, battery power is consumed and it is difficult to renew or replace. In addition to the power needed to operate the nodes and their transceivers, in underwater communication advanced signal processing techniques are needed to reduce the impact of underwater communication characteristics; however, these signal processing techniques will consume more power and will reduce the life of the nodes' batteries

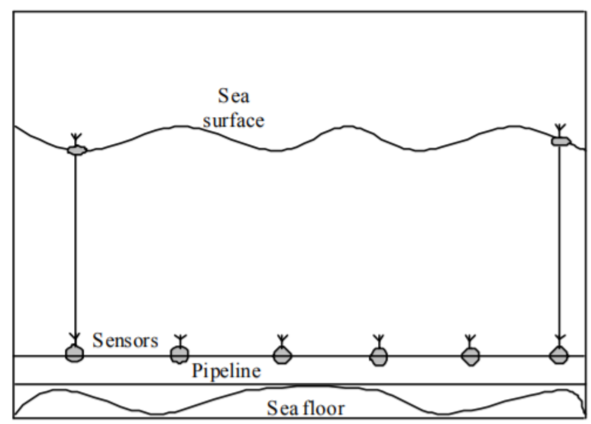

Figure 1.4 Underwater acoustic sensor network

Acoustic communication is used for monitoring vibrations in the Langeled Pipeline installed at a depth of 800–1,100 meters on a hilly and rocky seabed. Several segments of the pipeline are not in contact with the seabed. With strong sea currents, high vibrations may be induced in these free spans. This introduces high and risky pressure on the pipeline segments. Consequently, it was a requirement to monitor vibrations on the pipeline. A wireless sensor network was installed on the pipeline to monitor vibrations [30]. The monitoring network consists of autonomous synchronized wireless acoustic nodes. These nodes use acoustic Clamp Sensor Packages (CSP) that are mounted to the pipeline at regular intervals and a Master Sensor Packages (MSP) that monitors the vibrations in longer pipeline free spans. The CPSs are equipped with batteries

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that last for six months. Remote operating vehicles (ROV) are used to replace dead nodes. This type of monitoring network requires periodic and costly maintenance due to the use of batteries for operating the nodes.

Maroua Abdelhafidh et al proposed a hybrid clustering algorithm based on K-means and Ant Colony Optimization (ACO); called K-ACO to improve the WSN Lifetime. Efficient energy consumption is imperatively required to maintain the continuity of the network and to allow an adequate interconnection between sensor nodes deployed in the harsh environment. In this context, to maximize the Lifetime of the WSN under Water Distribution system domain is a primordial objective to ensure its permanently working and to enable a promising solution for hydraulic damage detection according to diverse performance metrics

Muteb Alsaqhan et al presented the work of developing a low- complexity, power-efficient, scalable node for linear wireless sensor networks. The developed system is intended primarily water pipeline leakage detection applications. This work mainly tackles the communication part of the system. A sensing node that is equipped with a sensor, a microprocessor, and an XBee Radio is integrated. Moreover, an algorithm is devised to detect the occurrence of a leakage event, localize it, and communicate it to the data center. Nodes communicate between each other in a daisy-chain manner, which implies a simple and low-power communication scheme. The system is implemented and tested showing positive results about detecting and localizing water leakage events.

Nasir presented a human centric cyber physical framework architecture of our in-pipe water monitoring and feedback system. This system comprises of the physical water distribution infrastructure, together with the hardware and software supported intelligent agents for water allotment, leak detection and contamination spread control. An agent-based approach for connecting the cyber and physical layers is selected, where the agents get information from sensors monitoring the physical components and provide this information to the cyber system. The Hidden Markov Models (HMM) are briefly discussed to determine water consumption patterns and make decisions for cyber and physical systems.

Ahmed M. Alotaibi et al proposed an energy-efficient cooperative scheme for a group of mobile wireless sensor nodes deployed inside the pipeline. The nodes are supposed to run cooperatively in order to save their resources. It is assumed that only one node shall remain active for a specific period of time while all other nodes are in sleep mode. As soon as the active node completes its cycle, it goes to sleep while another node is triggered by its timer to wake up and continue the process. The proposed scheme is evaluated for energy consumption by respective nodes with the help of a mathematical model.

II. System Model

Our main design objective is to maximize the network lifetime of our WSN model taking into account the coverage properties in order to obtain continuous monitoring process with the appropriate coverage. Moreover, we are going to propose an hybrid mechanism based on a K-means clustering algorithm, allowing an efficient sensor node deployment and taking into account the coverage constraint, with a data aggregation technique that allows the Data Redundancy Elimination (DRE). This amalgamation of various smart techniques aims to maximize as much as possible the network lifetime with the optimal data transmission.

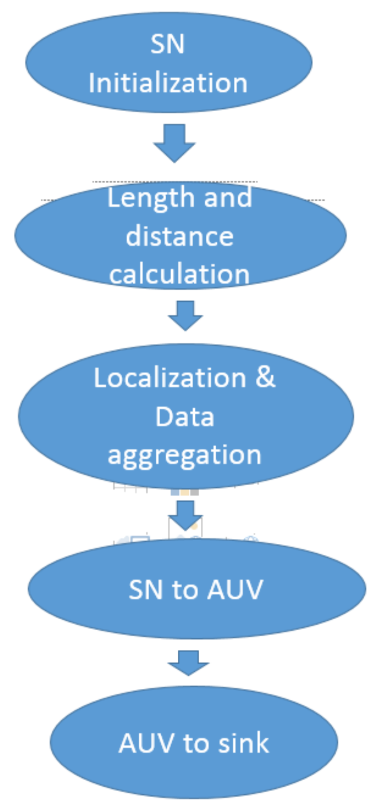

Figure 4.1 proposed system

In order to maintain a maximum NL, we propose an hybridmethod, as detailed below, to solve the energy consumptionproblem based on data aggregation and k-

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means clustering algorithm.K-means method (algorithm 1): This algorithm knownasunsupervised clustering algorithm [14] is used todivide the whole WSN of N sensor nodes into k clustersbased on the distance of Cluster Head (CH) and the otherSensor Members (SMs) of the group, reduce the numberof the transmitted packet data and savethe consumedenergy.the K-means clustering aims tominimize an objective function.In this case, a squared errorfunction given by the following equation:

$$OF = \sum_{j=1}^{K} \sum_{i=1}^{N_{nbr}} D_{ij} \quad ,with \;\; D_{ij} = \left\| S_i^j - CH_j \right\|^2$$

Algorithm 1: k-means clustering algorithm

4.1.1 Data Redundancy Elimination (DRE) for Data aggregation:

A cluster-based approach is the deployed strategy for data aggregation. In fact, in each cluster, resulted from the previous step, with its selected set of sensor nodes, DRE technique, as depicted in algorithm 3, is applied in order to eliminate redundant data either from different sensor nodes at the same time or from the same sensor node at various time steps.

Data Aggregation phase: Data Redundancy Elimination (DRE): Within each obtained cluster, redundant data is reduced by applying a pattern code technique that minimize the used bandwidth and the consumed energy during data gathering.

Advantages

Maximize the network lifetime of our LWSN model taking into account the coverage properties in order to obtain continuous monitoring process with the appropriate coverage

This amalgamation of various smart techniques aims to maximize as much as possible of network lifetime with the optimal data transmission

Also, to reduce the quantity of transmitted data and to minimize the energy consumption.

III.Simulation And Results

5.1 SYSTEM REQUIREMENTS

- Operating System : Red hat Linux 9
- Tool needed : Network Simulator 2
- Packages needed: ns-allinone
- Languages : TCL (Tool Command Language), C++

5.2 NETWORK SIMULATION

In communication and computer network research, network simulation is a technique where a program models the behavior of a network either by calculating the interaction between the different network entities (host/routers, data links, packets, etc) using mathematical formulas, or actually capturing and playing back observations from a production network. The behavior of the network and the various applications and services it supports can then be observed in a test lab,

Various attributes of the environment can also be modified in a controlled manner to assess how the network would behave under different conditions. When a simulation program is used in conjunction with live applications and services in order to observe end-to-end performance to the user desktop, this technique is also referred to as network emulation.

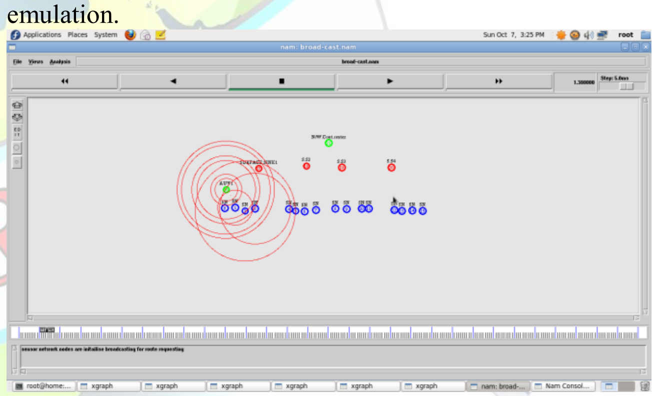

Figure 4.1 AUV to Sensor Communication

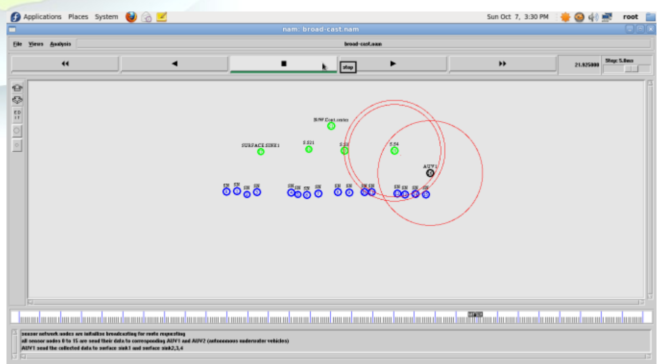

Figure 4.2 AUV Final Data Transmission

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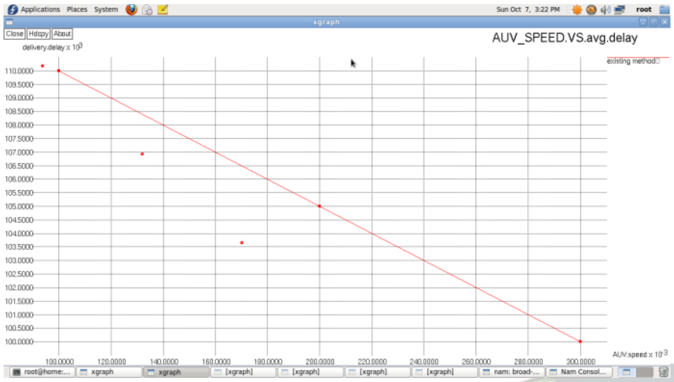

Figure 4.3 Speed versus Delivery Ratio

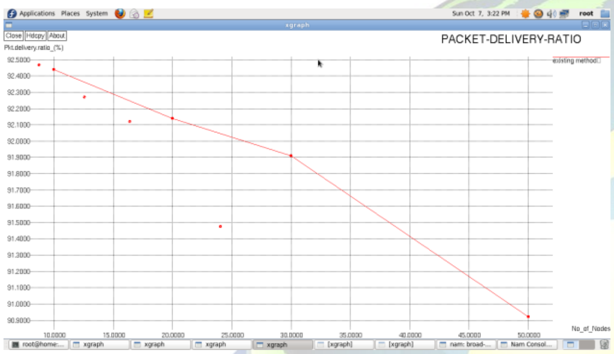

Figure 4.4 Number of Node versus PDR

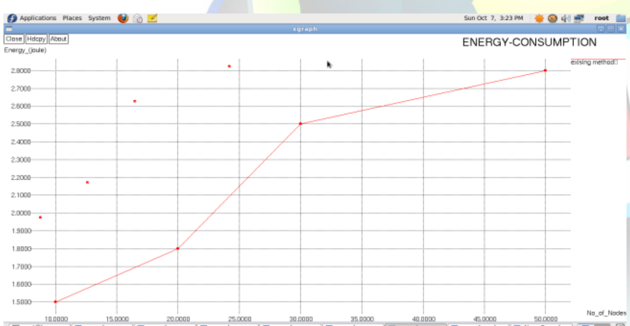

Figure 4.5 Number of Node versus Energy

IV. CONCLUSION

Wireless sensor networks (WSNs) have been widely deployed in many areas. Water pipeline monitoring is among the areas where WSNs have a great effect on their supervision. However, it is critical to control the power consumption of the sensor nodes to achieve the maximum WSNs' operation time .In this Project, Proposed the use of an AUV to collect data from SNs, which are used to monitor underwater pipelines. The AUV moves back and forth along the pipeline and collects data when it comes within transmission range of an SN. The AUV then transmits the collected data to the surface sinks located at the ends of the ALSN. Typically, acoustic communication technology is used to provide the needed connectivity. In this work a Data Elimination Redundancy technique was detailed and implemented in order to eliminate redundant data either from different sensor nodes at the same time or from the same sensor node at various time steps Energy-efficient and Secure Pattern based Data Aggregation (ESPDA) proposed. Then, efficient data aggregation allowing the redundancy elimination at the cluster and sensor node level improves more the results and reduces the energy consumption.

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