ADAPTIVE CLUSTERING BASED UNDERWATER WIRELESS SENSOR NETWORK COMMUNICATION

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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

Introduction

Underwater Pipelines

Underwater pipelines continue to prove its usefulness and necessity to so many countries and the world at large due to the fact that these pipelines are not only mediums used to transfer water, petroleum and natural but also connectors of power plants, oil and gas wells, refineries and even shipping ports between countries. Some may even call these pipelines an irreplaceable asset to the world's economic stability and growth. Hence, subsea pipeline monitoring and protection are of great importance to the world. One of the major means of monitoring the different types of pipelines is sensor networks. Sensor networks are a group of tiny devices powered by batteries that monitor and record environmental conditions in any number of environments from a hospital lab to out in the sea. They carry out pipeline communication and transmit the collected data for analysis through the internet, a specialized industrial network or an enterprise WAN or LAN.With the increasing demand for energy and water in the World; petroleum, natural gas, and water resources and facilities have become important assets for most countries. Maintaining the economic progress of most countries is strongly dependent on maintaining and protecting these resources and facilities. One of the main and important facilities for these resources are the pipelines used to transfer water, petroleum, and natural gas. These pipelines are considered one of the main infrastructures between producer and consumer countries. Protecting the pipeline infrastructures is one of the main issues facing these countries. Furthermore, oil and gas industries in the World heavily depend on pipelines for connecting shipping ports, refineries, oil and gas wells, and power plants. For example, there are around 500,000 miles of oil and gas pipelines in the United States that also extend into Canada and Mexico. These pipelines play a critical role in the U.S. economy. This pipeline infrastructure is mainly for providing energy supply to the U.S. Pipelines can be installed above the ground, under the ground, or underwater. Several long underwater pipeline systems are used for different applications around the World. One of the longest pipelines in use is the Langeled Pipeline that extends for 1,200 km from the Ormen Lange field in Norway to the Easington Gas Terminal in England under the North Sea and used to transfer natural gas to England [3]. This pipeline started operating in October 2007 and can carry 25.5 billion cubic meters per year and supplies around 20% of the natural gas demand in England. Another long pipeline is located between Qatar and UAE under the Arabian Gulf and owned by Dolphin Energy Limited of Abu Dhabi [4]. It is used to transfer processed gas from Qatar's offshore North field to the UAE.reliability of the sensor networks used for underwater monitoring and not on the physical pipeline protection. Three reliability factors are used to compare the architectures in terms of network connectivity, continuity of power supply for the network, and the physical network security.

Underwater Wired Sensor Networks

Currently, most pipeline sensors are connected using wired networks. Wired networks are either copper or fiber optic cables. The wired networks are usually connected to regular sensor devices that measure specific attributes such as flow rate, pressure, temperature, sound, vibration, motion, and other important attributes, see Figure 1. The wires are not used for communication only but also to transfer electrical power to different parts of the pipeline system to enable the sensors, actors, and communication devices to function. Power for the pipeline resources and networks can be provided by different sources: Solar Energy, Pipeline Flow Energy, Other External Energy

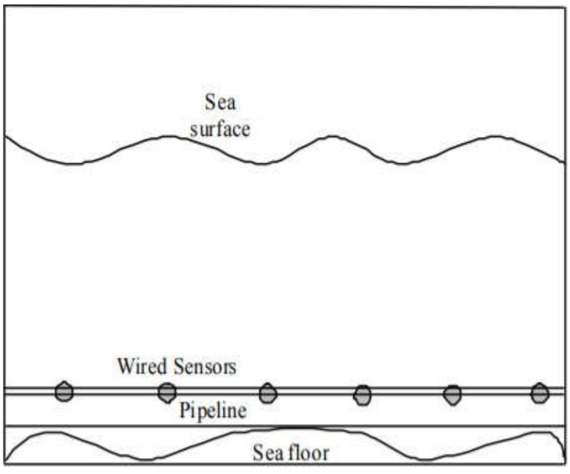

Figure 1 Under Water Wired Sensor Network

Wired networks are considered the traditional way for communication in pipeline systems. They are easy to install and provide power supply for through the network wires. However, there are a number of reliability problems related to using wired networks with regular sensors for monitoring pipelines. These problems are: If there is any damage in any part of the wires of the Network, the pipeline communication system will be completely or partially damaged. This depends on how the wired network is organized and used. If the communication is done in one direction on the wire, then a single cut on the wire will disconnect all the nodes after the cut from the NCC. If the communication is two-directional then the negative impact on the communication is less as some nodes will use one direction for communication while the nodes after the cut can use the other direction. In this case the NCC needs to be connected to both ends of the network. However, if there are two or more cuts in the network, then all nodes between the cuts will not be able to communicate with either of the NCC. In addition, if there is a power outage, some of the nodes may not be able to operate.

Maroua Abdelha fidh 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 X Bee 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.

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.

Existing System

Two types of threats may occur in pipeline infrastructures: intentional and non-intentional. Intentional threats can be for reasons like terrorism or illegal tapping. Pipelines in the Middle East for example are principally at risk of terrorist attacks. This is one of the main ongoing security problems in Iraq. In another example, in 2002 there were over 900 attacks on the Cano Limon oil pipeline that caused losses of around 2.5 million barrels of crude oil [6]. In addition, the pipeline was out of service for 266 days due to the fact that part of the pipeline were blown up some 170 times in 2001.The Cano Limon oil pipeline is owned by Occidental Petroleum Corp and the Colombian state oil company Eco petrol. It transports around 110,000 barrels of crude oil a day from the Cano Limon field to the Caribbean coastal town of Covenas. Oil pipelines have also been repeatedly attacked in Nigeria. In some cases the attacks caused major damages and death of some people. The problem of illegal tapping is known in the South East Asia region. In one case a company was losing about $4m worth of oil a year through illegal tapping from an underwater pipeline [6] It was a very difficult and time consuming process to inspect the pipelines and find the locations and types of damages inflected by the hurricanes. Non-intentional threats can also happen due to defects in the pipeline systems. These defects can be leakage or high pressure in the pipelines. Any defect or damage in underwater pipelines may result in major environmental and economic consequences. To reduce the impact of these consequences, underwater monitoring systems can be used. These systems can provide effective and fast detection mechanisms to discover defects and respond to them in a timely and more effective manner. There are a number of technologies to monitor, maintain and protect pipelines. Examples of these technologies are sensors, mobile robots, algorithms. Most of these technologies are designed specifically for detecting and locating pipeline leakage, corrosion. There were some efforts to develop algorithms and methods for detecting defects such as leakages in pipelines. These algorithms and methods are based on the availability of networks along the pipelines. All these efforts are not to develop reliable and fault tolerant networks that monitor pipelines as we discussed in this paper, but rely on the existence of reliable networks. One example is Pipe Net. Pipe Net is a wireless sensor network for monitoring large diameter bulk-water transmission pipelines. The network collects hydraulic and acoustic/vibration data at high-sampling rates. Algorithms for analysing the collected data to detect and locate leaks were developed. In [17], a method was developed to detect faults for oil pipelines. In this method, Rough Set was used to reduce the parameters of a pipeline system. Artificial Neural Network (ANN) with three levels is used to form a detection model. In addition, a general framework using acoustic sensor networks to provide continuous monitoring and inspection of pipeline defects was developed [18]. In this framework sensor networks can detect, localize, and quantify bursts, Leaks, and other anomalies in pipelines. Acoustic wave propagation theory, distributed control, and statistical signal processing are used to analyse signals for defects detection and localization. All these methods can be also used with the sensor network architectures proposed in this paper.

In another project, a wireless sensor network for a team of underwater collaborative autonomous agents has been developed [19]. This system was developed to locate and repair scale formations in tanks and pipeline within inaccessible areas such as underwater environments. We have previously developed a framework and protocols for monitoring above-ground long pipelines using wireless sensor networks [20]. Although several of the mentioned projects are based on different network technologies, none of them studied the reliability issues of sensor networks for monitoring long underwater pipelines.

These sensors can be used to counter the threat of sabotage and terrorism for naval bases, commercial ports, as well as oil platforms by detecting unwanted divers, swimmer, and SDV. These commercial products can also be used as part of some of network architectures developed in this paper for monitoring underwater pipeline

Proposed Design

In this project, a WSN is deployed to monitor the WPS used to transport water from"Ain Sebseb" reservoirs of the Tunisian Chemical Group to the industrial factory distant by 50 Km. 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.

In order to maintain a maximum NL, we propose an hybrid method, as detailed below, to solve the energy consumption problem based on data aggregation and k-means clustering algorithm. K-means method (algorithm 1): This algorithm known as unsupervised clustering algorithm [14] is used to divide the whole WSN of N sensor nodes into k clusters based on the distance of Cluster Head (CH) and the other Sensor Members (SMs) of the group reduce the number of the transmitted packet data and save the consumed energy. The K-means clustering aims to minimize an objective function. . In this case, a squared error function given by the following equation:

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

Software Specification

System Requirements

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

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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