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Enhancing Surveillance and Security of Oil Pipelines Transportation Using Wireless Sensor Network

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Abstract: Surveillance and safety is immensely important in general, while explicitly in case of critical applications, such as oil carrying pipelines from wells to refinery and then to the sea ports for further transportation. Surveillance and safety systems with different combinations already has been proposed for critical infrastructures to make them safe and sound. A huge gap is still there to monitor those critical systems in real time and keep them protected from any kind of unwanted approach. Our paper will propose a robust real time surveillance and secure system, for critical oil pipeline infrastructures, with combination of conventional network and wireless sensor network along with microwave network. Our proposed system shows a significant improvement with eleven times more efficient to conventional system by reducing leakage and loss reporting time to control center. Based on simulation tests investigation, proposed system will be more efficient to detect any threats in real time and can report to central control room without any further delay.

Key words: Wireless Sensor Network WSN % Security % Surveillance % Microwave Network % Critical Infrastructure

INTRODUCTION

Oil and gas has key role in world's economy, it's transportation mainly depends upon huge pipeline infrastructures. Oil producing countries like Saudi Arabia are heavily depend upon more than (152 K) KM of oil pipelines laying on and underground. Saudi Arabia is producing more than ten 10 Million Barrels on daily basis[1] and transportation of this massive quantity oil is mainly based on huge pipeline infrastructure. That pipeline infrastructures caries oil from wells to refineries and then to the sea ports, for further transportation. Moreover, Saudi Arabia is now considered the world's largest producer of desalinated water supplying major urban and industrial areas through pipeline infrastructure which has length for more than 4,800 km. Although making this transfer of oil, gas and water safe and smooth using modern up-to-date technology and tools, is the main concern of the Saudi government. However, there are still possibilities of internal damage to pipelines, which may be caused due to any terrorist attack, theft or any other natural factors.

The literature reveals that currently Saudi Armco is the largest company for oil exploring, transferring to the ports. It also manages and controls the pipeline infrastructures by monitoring the pressure and keeping constant level of pressure at different points and also by dividing oil pipelines into different segments. The company still uses the physical patrolling with Armco employed teams to monitor its safety [1]. It is believed that a new era technologies like wireless sensor network can play significant role in improving the process of monitoring such important pipelines.

Sensor network is becoming an increasingly important requirement in a variety of applications [2-5]. Examples are target detection, surveillance of enemy activities in a battle field, health, chemical use and counter terrorism. Some other examples are environment and habitat monitoring, home automation, traffic control, etc. Another possible example is using wireless sensor networks for protecting and monitoring pipeline infrastructure systems especially for oil, gas and water huge pipeline infrastructures [6- 9].

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This research proposes a method to improve the existing oil pipeline surveillance, security and monitoring system in terms of cost, quality, efficiency and reliability. This is achieved by incorporating WSN based system with the existing system. This is because WSN sensor nodes are capable to measure a given physical environment in great detail [10]. A wireless sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific actions. Unlike conventional networks, sensor networks depend on dense deployment and co-ordination to carry out their tasks. These unique characteristics make sensor network more beneficial and ease in use over the traditional network.

Related Work: WSN in the oil and gas industry [11], shed some light on a model of tracking flow-induced vibration to provide means of detection and early warning of integrity loss in pipelines network [12]. Marcello Cinque propose a model for pipeline monitoring, but the technical information is limited only with this.[13] Changos *et al* proposed a method for calculating number of sinks and sensors required for pipeline monitoring [14]. Liudong report some findings of a laboratory based test program to evaluate the potential for vibration sound emission detection in pipelines integrity monitoring [15]. Wenyu Cai *et al.* present a system for the monitoring large diameter bulk-water transmission pipelines [16]. The above review concludes that in public domain literature limited information are available for WSN based pipelines security, condition and information monitoring.

The reliability modeling of wireless sensor networks has been identified [16]. Mainly, addressed the current limitations and posed the reliability requirements for dynamic structure monitoring using wireless sensor network [17]. AboElFotoh *et al.* approached the problem of modeling and evaluate the coverage oriented probability of WSN subject to common cause failure [18]. Xing and Michel defined a WSN reliability measure considering the aggregate flow of sensor data into a sink node [19]. Chiang *et al.* dealt with the problem of reliability and security modeling in an integrated manner [20]. S. Hadim *et al.* proposed and evaluated scalable architecture of WSN nodes for increased availability [21]. S. Hadim *et al.* shed some light on the problem of reliability modeling for large scale wireless sensor network [22]. Akan and Akyildiz presented an even-to-sink transport protocol for reliable transport in wireless sensor network [23]. Zaman N and Azween Abdullah presented solution to pointing any particular point with WSN [24].Noor Zaman, Low Tung Jung *et al.* suggested secure and reliable solution using WSN [25]. However, it should be noted that due to the unique arrangements of the wireless sensors in the case of pipelines monitoring none of the above mentioned models can be adopted for such a case. Based on the above review it may be observed that the topic of continuous real time security and informative reliability of wireless sensor network for pipelines monitoring has not been approached. The proposed system, in this paper, focuses on the continuous surveillance and security with real time information for the critical pipeline infrastructure.

Proposed Approach: As described earlier with introduction section that mainly oil transportation in Saudi Arabia based on huge pipeline infrastructures. Which infrastructures are normally combination of different sizes, shapes curves and diameters as shown in Figure 1. Those pipelines lay down on earth close to the refineries and underground with little depth in between wells and refineries for their safety and security. Most of the time, surveillance and security for those pipelines is done through manual patrolling and monitoring.

Usually it is harder to confirm its security in real time, when monitoring is done manually with the help of patrolling mechanism by dividing pipeline infrastructures in different distance segments of few kilometers distance each. Manually monitoring through patrolling is not efficient at all and only gives 70% results precisely even in day time during clear weather. While it provides less accuracy in night time and specially in bad weathers. Our proposed system will work with combination of conventional network and wireless sensor network along with microwave communication technology for best and very timely surveillance and security results. The proposed system would be able to detect, identify and localize major anomalies such as theft, terrorism, damage or any disturbance of the pipeline infrastructure in real time. We divided pipeline infrastructure in small segments of 5 Kilometers each in length. Sensor nodes are distributed along pipeline infrastructure with little depth to monitor any unwanted event occurred around pipelines with reasonable coverage radius as shown in Figure 2. for straight laying pipelines. While Figure 3. Shows multi curved pipeline lay down with logical different distance segments.

Fig. 1: Oil Refinery with Laying Pipeline structure.

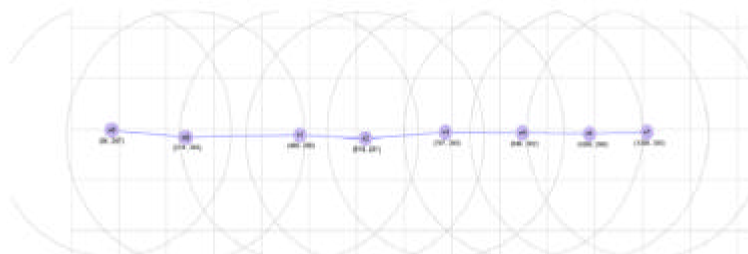

Fig. 2: Simple Pipeline Structure for Oil Fields.

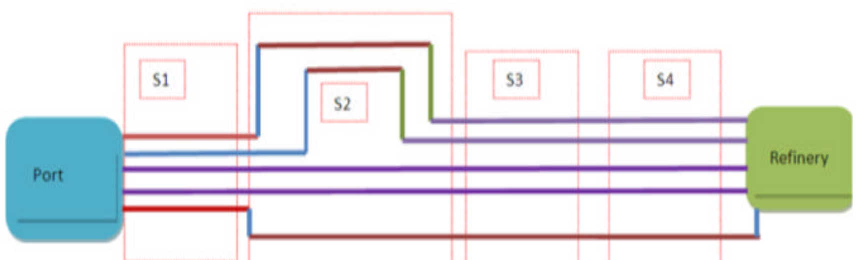

Fig. 3: Curved Pipeline Structure Divided into different Segments.

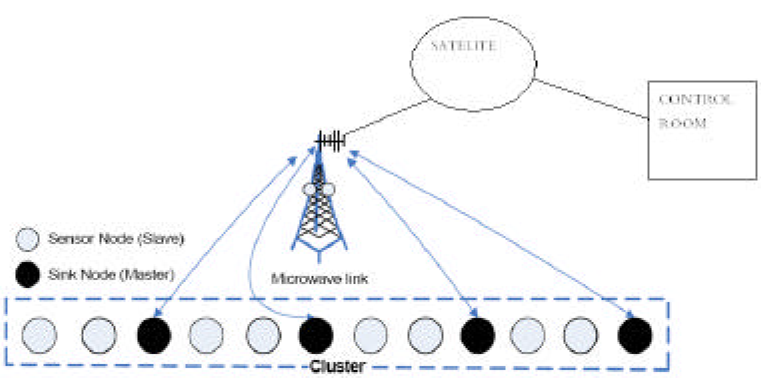

Fig. 4: A Proposed System Architecture.

Table 1: Simulation Parameters.

Net work area	200m*200m or 400m*400m
Number of sensor	100 or 400
Sensor distribution	Uniform radom
Location of sink	Center of area
Radio range	40m
MAC layer	IEEE 802.11
Unusual enent sources	4
Routione data sources probability	*p*
Failure rate	*f*
Time-out constant >	1/*r*
Dealy for retransmission M	0.02*s*
Data rate of nuusual events	8*U*
Data rate of routine data	8*R*

Our proposed system architecture is showed in Figure 4. The proposed system consists of sensor nodes, sink nodes, base station as well as control room which might be located at head office. Each of these performs certain tasks. For example, the wireless sensor nodes timely monitor the oil pipelines and report to the sink node if any leakage, breakage or any theft activity occurs. Sink node in its turn transfers the collected data to the base station (tower with microwave). Then, base station transfers such data along with its current calculated location to the satellite. A central control room receives all such data from the satellite. The proposed system covers all these processes in few seconds with its exact information of the problem site. Therefore, it is believed that this mechanism would boost the security at real time and improve the surveillance and security of the proposed oil transferring system.

Simulation and Results: The proposed system was simulated through well know Network Simulator (NS-2) and tested results were compared with conventional available security systems. Following simulation parameters were taken into account, as shown in Table 1.

RESULTS

Patrolling is the primary surveillance and security mechanism, by dividing pipeline areas in different segments. Patrolling can only be little efficient in case of day time with clear weather, while it is really hard for night and rough weather. Another mechanism to check the leakage or fault for oil pipeline is to check it pressure at different segment during patrolling and at different sub control centers. Both mechanisms are not most efficient and unable to report any damage of loss within limited time. Our proposed system will minimize the leakage loss by reporting it in real time and also it will work with all weather with efficiency and without dependability. We tested our system by applying various simulation tests under different conditions and assumptions. The results are described in following section after considering its two main cases, such as any leakage caused due to erosion or any other reason and leakage may caused due to any unwanted activity like terrorist attack or theft activity. The describe result based on three important factor such as Event Occurrence Time EOT, Existing System Access Time ESAT and Proposed System Access Time PSAT.

Leakage Caused Due to Erosion or Due to Pressure Blockage: This case may causes, any slight or immense leakage due to erosion or pressure blockage at any time. Erosion may cause slight leakage, while pressure blockage may cause immense leakage at any time. It is harder to find out timely both kind of losses, through conventional surveillance mechanism and even more harder to find out with rough weather and during nights. We conducted different simulation tests for these cases considering them with different locations and with different timings including fair and rough weather. Simulation results show a significance difference between conventional and proposed reporting system to the control center, as showed in Figure 5. for slight and immense level leakage. Which includes surveillance and security with excellent access time.

Figure 5, is presenting a set of result in combination of slight and immense losses at same time. Slight loss may caused because of erosion while immense loss may caused resulting of any pressure blockage within the pipeline. First (06) events with Figure 5 are showing slight leakage, while last (06) are results are showing immense leakage investigation. In both cases, PSAT is significant over ESAT. On comparison of PSAT with ESAT for first set of slight leakage, we found the reporting time is (380) Seconds for ESAT, while PSAT has 38 Seconds only to report the event to the control room. We found PSAT is 10 times more efficient then ESAT. As, described earlier that ESAT works with patrolling and pressure drop mechanism, which required enough time to notice any leakage or loss even when weather is cl. On other hand PSAT works in real time based on WSN along microwave technology.

Terrorist Activity to Sabotage Pipeline: This assumption works for any terrorist or theft activity to sabotage the pipeline at any time. This activity not only destroy

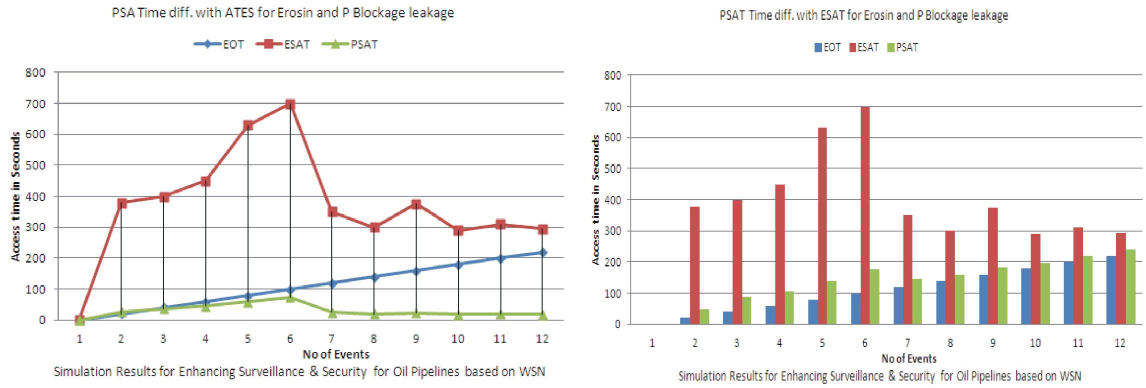

Fig. 5: Simulation Results For Enhancing Surveillance & Security for Oil Pipelines.

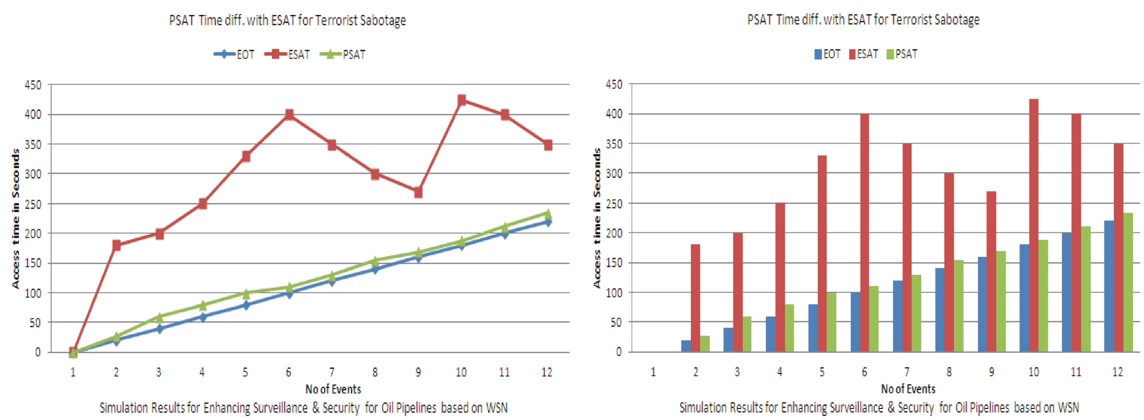

Fig. 6: Comparison of PSAT with ESAT in case pipeline Sabotage

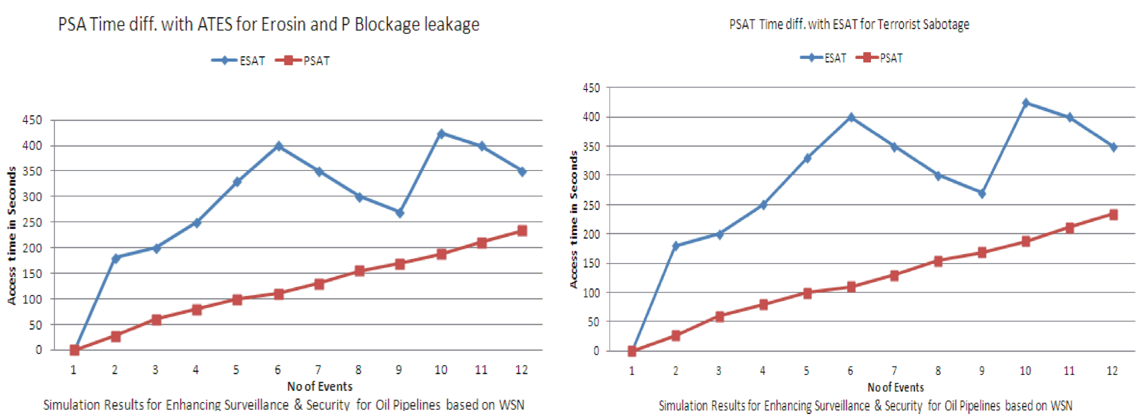

Fig. 7: Overall performance of PSAT over ESAT

pipeline infrastructure, but at same time it might prevent its continuous flow. This case can be notified little quicker through conventional systems, as the pressure of pipeline will decrees rapidly which can be monitored at gauges with different sections, even though it will be more than (6) times slow response comparable to PSAT. As, PSAT will have and additional capability also, to monitor pipelines and report the control system before sabotage. Sensor nodes distributed around the pipelines and they can monitor any unwanted event without any delay and can transfer that data to control room with through sink and Microwave technology. Figure 6. shows significant difference between ESAT and PSAT in case of terrorist activity.

Overall Performance Comparison of PSAT and ESAT: After conducting and investigating different simulation test, it can be observed very clearly from the results that PSAT is most efficient then ESAT in each case. The overall performance significance difference can be shown in Figure 7.

It shows two different comparisons for PSAT and ESAT with different case for different event reporting time. PSAT is most efficient to report any unwanted even to the control room 11 times more efficiently then ESAT in each case and PSAT also shows its performance well round the clock in all weathers without any delay. On other hand ESAT has more delay for reporting and at the same time it has different timings for different nature of events. ESAT reporting times also heavily affected due to weather conditions and night visions. These results and investigations confirms our earlier suggestion, that the reliability of monitoring oil pipelines can be further increased if a mechanism of joined wireless sensor network with the conventional trends and microwave network is applied. Another major benefit offered by such combined system is the capability to monitor the critical pipeline infrastructure in real time under any hard circumstances, which is a leading edge over the ESAT.

CONCLUSION

This research proposed a mechanism for surveillance and security of oil pipelines infrastructures. Different simulation tests were conducted to verify the proposed approach, under different circumstance by considering two different cases such as, to check slight or immense leakage because of erosion and pressure blockage in the pipeline. Under second case, considered any unwanted activity to sabotage the pipeline for shorter or longer to stop the flow of oil. Research results shows a significant difference of (11) times more efficiency of proposed PSAT approach over conventional ESAT approach. PSAT approach confirms more efficient surveillance and security of oil pipelines and in addition PSAT also provide less reporting time to the control room over ESAT by reporting mechanism to control room in minimal or in real time.

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