ABSTRACT

Wireless sensor networks (WSN) consist of tiny sensor nodes that can communicate with each other to perform sensing and information processing tasks. Sensors are already known to play a noteworthy role in a wide arena of daily life, like environmental pollution control, habitat monitoring, natural disaster monitoring etc. Despite this fact, a little has been paid towards utilizing this technology for subsurface exploration. Subsurface Exploration basically refers to the extraction of hydrocarbons from the oil field. In fact, subsurface exploration is a very established field which has been practiced for a very long time now. It can be observed from the statistics that with the increasing rate of consumption of extracted hydrocarbons there has been no significant increase in the quantity and quality of natural resources extracted. In view of this the oil companies are not only constantly looking towards new sources of oil but also to improve the production of existing wells. Further, available facts indicate that only 30% (approximately) of the oil is recovered from an available field & the rest of 70% remains un-extracted due to lack of information.

The thrust of thesis is on deploying wireless sensors in the oil field so as to make an estimate about the geo distance to which oil is spread. Further, the performance of a sensor network depends to a large extent on the sensor field coverage and its lifetime is determined by its energy consumption. Therefore, the need of an energy-efficient and fault tolerant self-organizing network is apparent. This thesis presents algorithms for coverage and connectivity-centric sensor node
deployment, as well as techniques for energy-efficient routing and information processing. The contributions of this thesis are in four important directions related to deploying wireless sensors in subsurfaces: 1) **Effective sensing coverage** 2) **Energy-aware routing of information** 3) **Efficient information processing** 4) **A robust and self-organizing network**.

The thesis first presents an algorithm as an improved approach for sensor deployment to effectively cover the geometry with minimum number of sensors. The very first sensor is deployed at a random location and then this sensor location is used to compute the next placement of sensor nodes. The proposed deployment algorithm computes the new locations for upcoming sensors on the basis of location of previously deployed sensor to enhance the overall coverage. The proposed algorithm provides high coverage with a minimum number of sensor nodes.

The thesis next presents a query driven routing strategy that aims to correlate diverse sensor input generated beneath the earth. The proposed communication strategy behaves as a multistage data collection system that clubs the data from various sensors and the same can be used to detect and track comprehensive events that go unnoticed using conventional drilling and mining tools. The strategy would be able to describe dynamic behavior of complicated subsurface and its exploration, allowing us to detect real time events and differentiate among various events happening simultaneously, that need to be addressed on priority basis. The strategy is a unique contribution to subsurface exploration technology as none has proposed the deployment and hence communication strategy for this field, in particular.
The next section of the thesis contributes a unique application of Extended Kalman Filtering (EKF) technique for processing sensitive information because sensor readings are usually imprecise due to strong variations in environment and also, computation has to be much more energy efficient than communication that otherwise would shorten the lifespan of network. Out of the various filtering algorithms available, EKF is being chosen, primarily because it works well both in theory and practice and moreover, it is able to minimize the variance of estimation error i.e. filters noise from the actual signal more accurately. Simulation results show that considerable noise is being filtered and ample energy is saved by using the proposed approach. The simulations also illustrate the built-in advantages of filtered information, reduced noise and hence reduced communication bandwidth.

During the course of this research, the need of energy aware self-organising network was identified. In view of this context, the thesis presents a novel node replacement algorithm for wireless sensor networks in sub-surface. A distributed algorithm is proposed to call for fault tolerance (backup) nodes to compensate for breakage in communication connectivity and loss of sensing coverage either due to node failures or nodes drifting away from their specified location. In addition to collecting data from sensor nodes, the deployed node acquires meta-information regarding their geo-location, which will be used to determine the correctness of deployed network topology.

In summary, this thesis provides an important link between the crucial problems of coverage, connectivity, energy management, and self-organization in wireless sensor networks deployed especially in subsurfaces. However, the proposed
work may be extended to any other non-deterministic environments too. It is expected to lead to even more efficient protocols for node deployment, state management, and recovery protocols for energy-constrained and failure-prone sensor networks. Further, keeping in view the extreme harsh conditions prevailing in subsurface, the demand is to devise a novel security mechanism which will make communication within sensors more scalable, robust & efficient.