Chapter I

INTRODUCTION

1.1 WIRELESS SENSOR NETWORKS

Wireless Sensor Networks (WSNs) are special class of adhoc networks \([54,56,61]\) which has helped humans to extract information even from the insurmountable areas of the globe. These networks are equipped with small sensing devices called sensors which sense the information from the environment and transmit the same to the sink module depending upon the application. This unique combination of software and hardware together has revolutionized the telecommunication industry in the last 2 decades.

WSNs are deployed in large groups and these deployed nodes collect, process and cooperatively pass this collected information to a central location. Because of these inimitable features of nodes, WSNs are finding applications in variety of domains such as traffic monitoring, target tracking, observing environmental changes in real time and so on.

The potential of WSN was realised by researchers and academicians decades ago and as a result several protocols leading to substantial improvements in terms of energy, routing and lifetime of WSN have been exclusively developed for this integrated technology. However, despite the above listed developments, literature indicates that energy supply and communication bandwidth limit the life of sensor nodes. Therefore the need of strategies overcoming these limitations resulting into improvements of the lifetime of the network and efficient use of limited bandwidth are highly apparent.

1.2 SOFTWARE AGENTS

The term agent comes from greek ‘agein’, which means to drive or to lead \([40]\). In the realm of computer science, it is defined as “an intelligent software unit capable of
transferring code and data to the processing end” [74]. It is placed within an environment and is able to recognize the environment through sensors and react upon it with the help of effectors. To define them more precisely, “software agents are intelligent software units that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in doing so, employ some knowledge or representation of the user's goals or desires” [104].

Infact, the fundamental characteristics of software agents which includes both the basic features of autonomy, reactivity, pro activity and advanced, human-like features like beliefs, desires, intentions and commitments have fascinated researchers to explore and integrate these units into WSN.

A special class of these intelligent software units, called mobile agents [75,139] are able to migrate from one machine to another under its own control and can suspend execution any time. They are capable of executing on heterogeneous machines situated at different locations, sense and take decisions of their own to achieve the delegated targets. These mobile entities are a promising candidate for communication in WSNs. They are a natural extension to remote procedure call (RPC) [142] approach used for communication in WSN and offers various advantages like asynchronous interaction, robustness, fault tolerance, dynamic adaptation and efficiency to name a few.

1.3 MOTIVATION AND GOAL

WSNs are finding applications in both deterministic and non-deterministic environments [54] where, deterministic environment is the one which is reachable and in which the sensors are deployed in a pre-defined manner. The data and/or information in such cases are routed through pre-defined paths. On contrary, non-deterministic environments are not easily reachable and the sensors are usually deployed randomly in such environments. Though extensive research has been done in the field of deterministic WSN, the researchers have been silent in the case of non-deterministic environment. There are several challenges to be dealt with in this domain like improving the lifetime of network, energy efficient node deployment,
connectivity, coverage, sink hole problem etc. [24,47,135]. In addition to the various challenges listed above, one of the major challenges is to find an energy efficient alternative to the conventional routing paradigm i.e. the client server approach because this model is tagged with several problems like excessive use of bandwidth, longer delay in transmission and most importantly the transfer of raw and redundant data to the sink. This disproportionate amount of sensory data if delivered can cause unpunctual delivery, immense energy consumption and load maladjustment among sensors. The problem gets alleviated when the sensors are deployed in non-deterministic environments where once deployed, sensors remain unattended during their whole lifetime. The above stated limitations of client server computing model applied in WSN thus demand for the inevitability of exploring and designing intelligent frameworks and hence the motivation.

The work aimed to design an efficient communication strategy for improving the lifetime of the network. In order to achieve this objective, following goals have been identified which formulated the base of research work:

- To design a framework for communication in event driven applications of non-deterministic WSN.

- To perform information processing on the sensed data at the source nodes.

- Evaluation & comparison of proposed framework with its agent based counterparts.

1.4 DESIGN CHALLENGES

A grave study of the existing propositions in the realm of WSN reveals that the following issues need to be addressed in order to meet the above stated goals:

- Optimal Clustering: Though clustering is used in hierarchical WSN, most of the approaches are spatial based approaches which can result in messier and longer routes.
**Solution:** In order to perform clustering in an efficient manner, a mobile agent based event driven clustering approach has been proposed which uses reliability of participating agents and the residual energy of the motes to make clusters.

- **Efficient Communication of Randomly Deployed Sensor Nodes:** In a non-deterministic WSN where nodes are randomly deployed, mobility of the nodes can lead to dynamically changing links and unpredictable random topology. A need of mobility controlled communication is thus apparent.

  **Solution:** Though mobility of sensing units (regular nodes or sink) leads to above mentioned problems, it is inevitable for certain applications. The work thus makes use of mobile agents for moving within the network, thereby restricting the mobility of sensors.

- **Filtering at Source Node:** The data being sensed at the source node is usually corrupted with noise. Transmission of such raw data to the sink causes wastage of bandwidth.

  **Solution:** The work makes use of Extended Kalman Filter (EKF) for filtering the data at the place where it is sensed so that only relevant information is communicated over the network.

- **Redundant Data:** As sensors are deployed randomly, they are spatially correlated and the probability of sensing and transmitting the redundant data is very high.

  **Solution:** The work has proposed an agent based fusion approach for in-network processing. This approach ensures that only significant information is being given to the sink.
• **Security of Data:** Most of the data which is transmitted through the wireless channel is unencrypted and thus prone to channel attacks. There is a strong need of adding a layer of security to data transmission.

  *Solution:* The work has proposed a security mechanism in which the transmitted data is encrypted before transmission and decrypted for aggregation/fusion.

### 1.5 ORGANIZATION OF THESIS

The thesis is principally carved up into six chapters as listed below:

**Chapter 2** provides the details about the background study that was carried out to pursue this research work. It begins by presenting a detailed study of WSN ranging from its origin to real time applications and routing protocols. This chapter later throws light on the details of exploring the feasibility and deploying mobile agents in the area under consideration i.e. WSN.

**Chapter 3** provides an insight into the literature review which motivated this research work. The very nascent idea of associating agents with WSN has emerged because of a thorough study of the available literature which indicated that research should be carried forward in four different phases i.e. mobility controlled communication, clustering, filtering and fusion. This chapter provides the backdrop of existing works pertaining the mentioned phases and further explores the possibility of improvements.

**Chapter 4** furnishes a four phased novel approach which is presented in the light of drawbacks in the existing work. This chapter discusses the first two phases of the proposed approach. It begins by discussing the improved energy efficient approach for the randomly deployed sensors which considers random pause time of nodes at a given location. It further discusses the implementation and analysis done to compare the proposition. In the second phase, an agent based clustering approach for clustering the randomly deployed sensors is given which forms the second phase of the work. This phase also presents a novel itinerary determination approach of the mobile agent
within the cluster. Phases 3 and 4 of the proposed work are being described in depth in the next chapter.

**Chapter 5** initially presents a unique application of Extended Kalman Filter (EKF) for filtering sensitive information available with the sensors. The motivation for carrying out this work is imprecise sensed data owing to real time fluctuations in environment and also the need for energy efficient computations in addition to efficient communication. After filtering the data at each of the sensor node individually, it is being encrypted and fused at the intra cluster level and henceforth transmitted to the clusters above in the hierarchy for onwards routing. This accounts for the fourth and last phase of the proposed work. The chapter concludes by presenting a case study of a non-deterministic application and evaluation of the proposed multi agent framework with its counterparts.

**Chapter 6** concludes the outcome of the work. It summarises the major achievements of the research work and elucidates the scope for future work in this domain.