Exploring the Feasibility of Mobile Agents in Sensor Networks in Non- Deterministic Environments

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Abstract

Wireless Sensor Networks is an adhoc collection of numerous distributed, integrated sensing devices which are capable of sensing and responding to various environmental phenomenons. The data collected by each sensor is communicated through the network to a single processing center that uses all reported data to determine characteristics of the environment or detect an event. The paper begins by providing an outline of the concept of sensor networks and the various research challenges associated with them. Thereafter it covers one of the research issue, i.e communication and talks about how to introduce the concept of agents in order to enhance the data dissemination feature of sensor networks. The paper concludes by proposing a framework for the same.

Keywords: *Software Agent, data dissemination, Wireless Sensor Networks*

1. Introduction

A Wireless Sensor Network (WSN) is a special class of ad hoc wireless network that consists of a large number of spatially distributed small, low-cost nodes capable of intelligent sensing [1,2,3].These cooperative, dense and distributive networks , outfitted with tiny sensing devices, called *motes* communicate the sensed data to a single processing center that uses all reported data to determine characteristics of the environment or detect an event. A typical WSN contain hundreds or thousands of these sensor nodes, and these sensors have the ability to communicate either among each other or directly to an external base station (BS). Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external BS(s).A BS may be a fixed or mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data.

WSNs are used in a wide spectrum of applications like military and civil applications such as target field imaging, intrusion detection, weather monitoring, security and tactical

surveillance, distributed computing, detecting ambient conditions such as temperature, movement, sound, light, or the presence of certain objects, inventory control, and disaster management. Creating a network of these sensors can assist rescue operations by locating survivors, identifying risky areas, and making the rescue team more aware of the overall situation in a disaster area. Various types of applications supported by WSNs can rightly be segregated in 3 broad categories:

- **Event Driven** (Source Initiated): The source sensor monitors for a given event (sensors are generally designed for specific applications) and reports it to base station. eg : Earthquake, forest fire , military.
- **Poll Driven** (Sink Initiated): The base station (or the cluster head) polls the source station whenever the information about a particular event is required. eg : wind Speed during the storm.
- **Period Driven** (Source Initiated): The source sensor reports the status of a particular event or region to the base station at regular intervals of time. eg : Weather Tracking , Traffic control.

The subject of WSN is increasingly fascinating people both from industry and acadmecia because of its unique features that make them stand ahead of conventional networks. First of all, Sensor networks can be ruggedly deployed in any (deterministic or non-deterministic) area. Numerous efficient techniques have been proposed for deployment of sensors in remote jungles, volcano sites, oceans, beaches etc. In places like these, numerous Sensors can be air dropped which later form ad hoc network between them to communicate the data to the sink node / base station. Secondly, these networks are adaptable to changing connectivity (eg: addition of more nodes, failure of existing nodes etc) as well as changing environmental stimuli. Thirdly, there are very less frequent topological changes in WSNs in contrast to other traditional wireless networks as most of the nodes in these networks remain stationary after deployment(except for a few mobile nodes).

2. Research Challenges

In spite of the diverse applications, sensor networks pose a number of unique technical challenges due to the following factors:

- **Ad hoc deployment:** Most sensor nodes are deployed in regions, which have no infrastructure at all. A typical way of deployment in a forest would be tossing the sensor nodes from an airplane. In such a situation, it is up to the nodes to identify its connectivity and distribution.
- **Unattended operation:** In most cases, once deployed, sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes.
- **Undeterred:** The sensor nodes are not connected to any energy source. There is only a finite source of energy, which must be optimally used for processing and communication. An interesting fact is that communication dominates processing in energy consumption. Thus, in order to make optimal use of energy, communication should be minimized as much as possible.

- **Dynamic changes:** It is required that a sensor network system be adaptable to changing connectivity (for e.g., due to addition of more nodes, failure of nodes etc.) as well as changing environmental stimuli. Thus, unlike traditional networks, where the focus is on maximizing channel throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime as well as the system robustness [7]

3. Communication In Wireless Sensor Networks

Communication in WSNs usually consists of source nodes which sense the data and return it to sink nodes over multiple hops. Sink nodes may be ordinary sensor nodes or specialized base stations with greater resources. Sensor networks facilitate "large-scale, real-time data processing in complex environments". Sensor networks, once deployed, remain unattended, untethered and have limited battery power. Energy conservation during routing is an overriding concern in these networks because such networks are often located where it is difficult, if not impossible, to replenish the energy supply of a sensor. The overall objective is thus to propose/design an approach which could maximize the lifetime (earliest time at which a communication fails) or the capacity of the network (amount of data traffic carried by the network over some fixed period of time).

4. Literature Review: Problem Area Defined

Extensive research has already been done in the area of Wireless Sensor Networks. Iyengar and Brooks [12] and Culler and Hong [9,10] provide good overviews of the breadth of sensor network research topics as well as of applications for sensor networks. This research work focuses on some of the algorithmic issues [13] of sensor network's routing. There is an abundance of algorithmic research [10] related to wireless sensor networks. At a high level, the developed algorithms may be categorized as either centralized or distributed [14]. Because of the limited memory, compute and communication capability of sensors, distributed algorithms research has focused on localized distributed algorithms-distributed algorithms that require only local (e.g., nearest neighbor) information.

Jiang and Manivannan [11] in their work have dealt with the issues involved in designing efficient routing protocols, identifying several important desired features of a routing protocol and comparing and contrasting the existing routing protocols with respect to these features. The authors have given a very simple classification of the routing protocols [6] based on various criteria's. viz: (1) Depending on how the sender of a message gains a route to the receiver (like Proactive protocols, Reactive protocols and Hybrid protocols), (2) According to nodes participating style (like Direct communication, Flat communication and Clustering protocols), and (3) Depending on whether a routing protocol is location aware or not (like Location aware and Location-less protocols).

Bandyopadhyay and Coyle [8] in their work proposed Energy Efficient Hierarchical Clustering (EEHC), which is a randomized and distributed clustering algorithm. It is used for organizing sensors within network in a hierarchy of clusters. In the clustered setup, there exists a processing center which can be one of the normal sensors or one with extra resources available within it. The end level sensors responsible for collection of data, within the network, are connected to data processing center through a hierarchy of cluster heads. The algorithm works in a bottom-up fashion, which makes a calculation of the communication cost involved. The cost involved between a transmitting sensor and the final receiving processing unit, consists of energy consumed for transmission from sensor node to level 1 cluster head, then from level 1 to level 2 cluster head, and so on, finally from highest level cluster head to the processing unit itself. The energy consumed as calculated in this protocol depends on the parameters p (probability that a called volunteer cluster head becomes actual cluster head) and k (used for cluster head election on each level).

Balkrishnan et.al [7] in their work presented Low-Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based routing protocol which, aims at minimizing global energy consumption in sensor network by randomized rotation of local cluster heads, such as to evenly distribute the energy load among the sensors. In each round of process, clusters are organized in a set-up phase, followed by a steady-state phase. After a definite time, which is determined in advance, the next round begins. During the process of clusters creation, every node decides in favor or against becoming cluster head for the current round. Each node chooses values, which lies between possible probability values i.e. 0 and 1. This value is then compared with T(n), which is based on the recommended percentage of cluster heads for the network and the number of times the node has become cluster head in past. While [7,8] had been example of cluster-based routing, having two different types of nodes (cluster heads and normal sensing nodes), researchers have proposed and implemented flat routing too , in which all nodes are essentially designated the same responsibilities and proposed Geographical and Energy Aware Routing (GEAR). This is an energy proficient algorithm which makes use of energy aware neighbor selection to route a packet towards the target region without flooding. Braginsky and Estrin [10] proposed Rumor Routing, which is a well-organized technique to distribute queries to nodes that observed events of interest in the network. This method proves significant power cost reductions due to logical compromise between flooding queries and flooding event notifications within network. The idea behind Rumor Routing is to create paths leading to each event. The algorithm makes use of a set of long-lived agents that create paths directed towards the events they encounter.

Currently, most energy-efficient proposals in wireless sensor network (WSN) are based on the client/server computing model, where each sensor node sends its sensory data to a back-end processing center or a sink node. Because the link bandwidth of a WSN is typically much lower than that of a wired network, a sensor network's data traffic may exceed the network capacity.

Most of the work so far makes use of the typical client/server architecture for communicating the information between the sink and various source nodes. In a multihop environment, where the sink reaches the source numerous hops, such type of communication is

insecure. This problem of lack of security gets elevated in the case where sensors are deployed in non-deterministic environments. If even a single sensor node is hacked on the path, the destined data gets corrupted and possibly misconveyed.

In the light of the above mentioned factors, the use of ***mobile agents*** in data dissemination & database querying of sensor networks is proposed.

5. Software Agents: Design of Rational Systems

A software agent is an object of the environment that can access the members of that environment to perform the specific task. With the help of sensors, the operational agent senses the input from the environment and produces the output accordingly with the help of effectors. Henceforth, an agent can be considered as not only more than a simple object but also much intelligent than a component. It is actually a program that automates a series of computations on behalf of a user even when the user is not connected to a network. The term "agent" describes a software abstraction, an idea, or a concept, similar to OOP terms such as methods, functions, and objects. The concept of an agent provides a powerful way to describe a complex software entity that is capable of acting with a certain degree of autonomy in order to accomplish tasks on behalf of its user. But unlike objects, which are defined in terms of *methods* and *attributes*, an agent is defined in terms of its behavior.

There are numerous software agents which contribute to achieve energy efficient data dissemination in sensor networks. The current body of search focuses on mobile agents to achieve a secure and efficient communication. Mobile agents are mainly characterized by autonomy, adaptability and mobility. The main factor which encourages the development of mobile agents is that they reduce communication cost. Mobile agents have increased flexibility provided by mobility and the agent itself can be send to the server for direct computation. Large amount of raw information transferred in order to determine their relevance can be very time-consuming and clog of the networks. Mobile agent approach trades server computation and cost for savings in network bandwidth and client computation. MA approach is advantageous when the server's CPU is not a bottleneck. It gives performance optimization for distributed operations that involve heavy network delays and/or weak connectivity; extended autonomy in terms of existing support for asynchronous execution and disconnected operations. It provides a natural development environment for implementing free market trading services. The flexible distributed computing architecture and mobile agents provides a radical and attractive rethinking of the design process.

6. Proposed Work

The paper proposes the use of ***mobile agents*** in sensor networks for energy efficient secure route discovery and relaying of data from source nodes to the base stations so as to maximize the lifetime of networks. The architecture basically uses mobile agents (MA) ability to carry processing codes that allow the computation and communication resources at the sensor

nodes to be efficiently harnessed in an undefined area. The MAs should adjust their behaviors depending on quality of service needs (e.g. data delivery latency) and the network characteristics to increase network lifetime while still meeting those quality of service needs. The aim of the work would be to dedicate MAs to introduce security of data being transferred over the network. It also reduces the information redundancy and communication overhead at all levels so as to prolong network lifetime. The architecture is as depicted in figure 1.

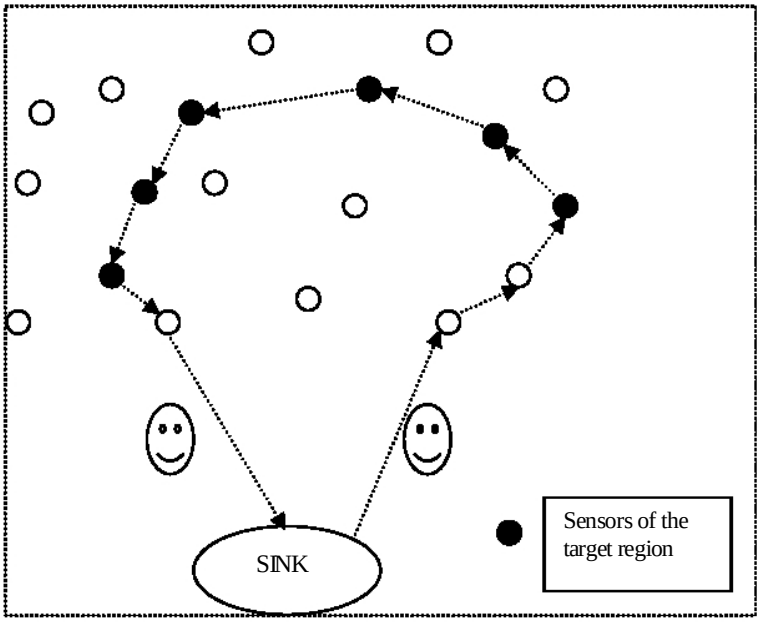

Figure 1: Agent Based Architecture

Consider a Poll Driven application of a Sensor Network. The sink sends the Mobile agent in the target region (depicted by filled ovals) to gather the information. The agent reaches the target region through multiple hops. Here it performs a 3 step process to retrieve and process the information:

Step 1: Registration: The agent checks the target node for integrity and authenticity using information being provided by the sink node. Once the authenticity check is performed, the information is collected for further processing

Step 2: Association: The process of registration is followed by processing of the information gathered and removing the redundant /unwanted information . This process generally starts from second node onwards.

Step 3: ***Fusion:*** The process information is fused into the sink node to take appropriate action.

7. Conclusions

This paper initially threw light on the scope and need of mobile agents in sensor networks and later proposed a feasible framework for information processing in sensor network using mobile

agents. Future work intends to explore similar research areas and intends to propose the agent-based solutions for such challenges.

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