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Heterogeneous Distributed Sensor Networks (HDSN)

Al-Sakib Khan Pathan and Choong Seon Hong

ABSTRACT

A new deployment model of distributed sensor network is presented where sensors with different functional types participate at the same time. In this model the sensors are associated with different deployment sets but they cooperate with each other within and out of their respective sets. We term this network model as Heterogeneous Distributed Sensor Network (HDSN). The heterogeneity here refers to the functional heterogeneity of the sensors participating in the network. The advantages of such network model and potential research scopes are also discussed.

INTRODUCTION

Wireless Sensor Network (WSN), composed of hundreds or thousands of inexpensive, low-powered sensing devices with limited computational and communication resources provides a lucrative interface to the real world for acquiring specific type of data from a particular area of interest (AOI). The raw data collected from such a network are analyzed to extract important information about that particular area and are often used for taking important decisions. Considering today's advancements and achievements, the applicability of sensor network is very broad. With the capabilities of today's sensors, many applications can be benefited a lot. Now we have varieties of sensors which can monitor temperature, pressure, humidity, soil makeup, vehicular movement, noise level, lighting condition, the presence or absence of certain kinds of objects, mechanical stress level on attached objects, and other properties. These tiny devices could be used for surveillance in military and public-oriented applications, target tracking, environmental monitoring, patient monitoring in hospitals, disaster management and warning systems, and in so many other applications.

With the rapid advancements of wireless technologies and sophistication of sensing technologies, many innovative applications could be thought of using the sensors. Though most of the applications focus on collecting a specific type of data, for some applications it is necessary to acquire different types of data from the same geographical region. As an example, a volcano monitoring application may require thermal, seismic, and acoustic data from the same geographic location. Though only one type of data may be satisfactory for such an application, using various types of data could be more beneficial for extracting accurate and timely information. Especially for disaster management and warning systems, military applications, and medical applications, use of multiple types of data can come as a blessing. To facilitate such types of applications which need more than one type of data, ExScal mote [1], [2] is designed by CrossBow Inc. and Ohio State University. This mote is basically an extension of well-known MICA2 mote [3] which supports multiple sensors (i.e., sensing units) on the same radio board. However, instead of using this type of multipurpose node in the network, using different types of nodes in the same area could be more efficient considering the utilization of memory, processing, and energy resources of the sensors. We will provide more points later to support this argument. The key point here is that whatever the configurations of the sensors are, heterogeneous data are often required for some applications which can increase the complexity of tasks in the network. Hence, efficient methods are required for dealing with all aspects in such applications.

HETEROGENEOUS DISTRIBUTED SENSOR NETWORK (HDSN)

Typical '*heterogeneity*' in sensor network is considered based on the capabilities of the sensors in the network or more specifically based on the memory, processing power, and transmission range of the radio [4], [5]. Larger transmission range requires more energy. So, in most of the cases the heterogeneity is defined considering the dissimilarities in the energy level, processing power, and transmission range. However, in our case the heterogeneity refers to the dissimilarities in the functions of the sensors. Say for example, type 1 sensors sense temperature, type 2 sensors sense seismic signals, type 3 sensors sense magnetism, and so on. In our model, different types (different sensing parameters) of sensors may even have similar capabilities, but that doesn't help to give the network a '*homogeneous*' tag.

We term our model network as Heterogeneous Distributed Sensor Network (HDSN), where sensors of various functional capabilities form different functional groups. There could be T types of sensors in the deployed network (where $T = 1, 2, 3, \ldots \xi$). The value of T is set based on the application at hand and classification of sensors is done prior to their deployment. The network is called homogeneous when $T = 1$, that means there is only one type of sensor in the whole network. For deploying the entire network, first a number of different types of sensors are taken and they are assigned different ids based on their functional types.

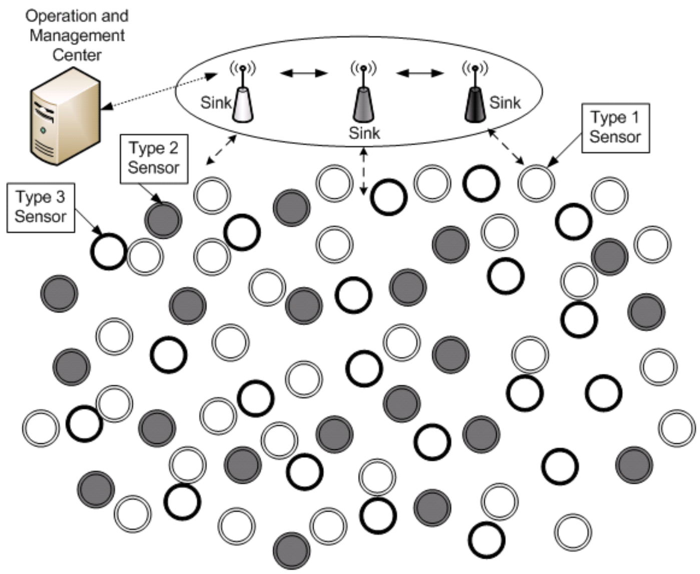

Figure 1. An example of Heterogeneous Distributed Sensor Network (HDSN) deployment. Here, T=3. Three types of sensors are dispersed over the same target area. Same types of sensors form a deployment group (for example, all the gray sensors (Type 2) form one network-wide deployment group (DG))

Figure 1 shows a graphical model of a Heterogeneous Distributed Sensor Network (HDSN). In this figure, T=3. Like any other Distributed Sensor Network (DSN), it has a large number of sensors covering a large area. Also we assume that the sensors could frequently be added or deleted from the network. In the figure, we show three different sinks collecting data from three different deployment groups (DGs). A deployment group (DG) is composed of only one type of sensor and it spreads over the entire area of the network. Each of the DGs covers the whole AOI and works independently. However, the data packets from a sensor in one DG could be relayed by a sensor in another DG. So, practically in this sample HDSN, there are three distributed sensor networks of different functionalities which are working individually but side-by-side cooperating with each other for data transmissions and network operations. However, for collaborating for a particular task, the neighboring sensors must be the members of the same deployment group. That means even if two dissimilar sensors are neighbors to each other, they can only help for forwarding each other's packets but cannot take part in the same collaborative task. Figure 2 illustrates this. In the figure, three nodes 1, 2, and 3 are neighbors to each other but each of them is from a different network-wide DG. They can just relay each other's packets if needed, but cannot participate in the same task.

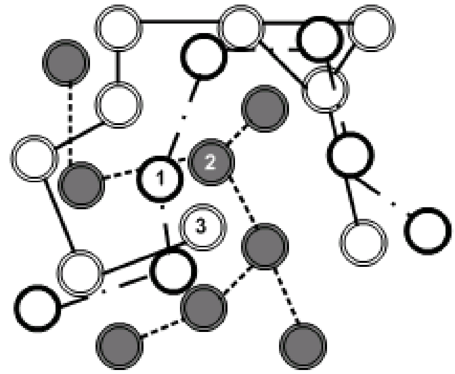

Figure 2. Nodes in different DGs are neighbors to each other but are not able to take part in the same task. For a given collaborative task, two neighbors must be of the same functional type. The distinguishable connecting lines show the achievable associations between any pair of nodes of same type

WHY HDSN?

Now, an important point of argument can be that, instead of using multiple nodes over the same area, similar benefit could be achieved by using multipurpose nodes (like ExScal motes) in the network. Sometimes (not always) it might even be more cost effective solution than our approach. However, considering all pros and cons, we have found that the use of large number of homogeneous multipurpose nodes (for collecting heterogeneous data) is less efficient than our approach. The considerable points for this are:

- In HDSN, a particular DG could be kept in sleep mode whenever necessary while other DGs can keep functioning (Say for example, in Figure 1, Type 1 sensors are kept in sleep mode for a certain period of time). As the deployment of sensors is dense, the connectivity of the whole network is supposed to be supportable even if a particular DG is in sleep mode. This feature can help for maximizing the lifetime of the overall network as in such case at least one DG could be preserved for a long time even if the energies of other types of nodes are exhausted. On the other hand, ExScal type nodes need continuous wake mode when any of the sensing units on the same radio board is functioning. This eventually causes continuous consumption of energy resource. Putting this type of multipurpose node in sleep mode means all of the sensing units become idle at the same time.
- For assigning different security levels for different types of sensed data, HDSN is a good platform. Different security levels could be set for different DGs based on the requirements and/or functions of the sensors.
- HDSN offers a great advantage over multipurpose node-based network in case of physical capture attack. If a physical intruder intends to hamper the sensing of different parameters in a particular location, it needs to destroy

all types of sensors in that location. For example, in our shown model the attacker needs to destroy at least three sensors from a particular section of the network. On the other hand, for a network consisted of multipurpose nodes, destroying one node is enough to destroy three sensing units assigned for a particular spot. The later is definitely a relatively easier task for a physical intruder.

- In HDSN, different sinks associated with different DGs can gather and analyze specific data separately. They can even collaborate with each other after extracting the gist from the collected data. This facility is not available in case of using ExScal type motes. In many cases, multiple types of readings from multipurpose nodes can somewhat increase the complexity of tasks for the sink as it has to classify and reorder incoming data prior to using them.
- Overall, the HDSN model could provide better structure for managing the entire network as a particular DG could be handled for various purposes separately without hampering the functions of other DGs.

POTENTIAL RESEARCH SCOPES

This work opens the door for research on other associated issues in HDSN. For example, handling heterogeneous traffic, prioritized data, maintaining heterogeneous levels of security, quality of service of heterogeneous data, lifetime maximization of deployment groups, etc. could be some of the interesting research issues for HDSN.

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