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Architecture for Running Multiple Applications on a Single Wireless Sensor Network: A proposal

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Abstract. Wireless sensor networks have gained much attention from researchers as well as from the industrialists in the recent past. Usually, wireless sensor networks are deployed per application based. This limitation has restricted its deployment in commercial applications, which require to running multiple applications on a single wireless sensor network infrastructure. In this paper, we propose a simple architecture for running multiple applications on a single wireless sensor network. Our proposed system is based on the middleware concept in which an application manager module controls the switching among different applications with the help of a mobile agent.

Keywords: Wireless Sensor Network, middleware, multiple applications, sensor

1 Introduction

A wireless sensor network (WSN) is a special kind of ad hoc networks that consists of a number of low-cost, low-power wireless sensor nodes, with sensing, wireless communications and computation capabilities [1], [2], [3]. These sensor nodes communicate over a short range via a wireless medium and collaborate to accomplish a common task, like environmental monitoring, military surveillance, and industrial process control [3]. Wireless sensor networks have open up for new opportunities to observe and interact with the physical environment around us. They enable us now to collect and gather data that was difficult or impossible before [4]. With the advancement of wireless sensor network technology fueled by dropping cost of sensor nodes, it is expected that the future world will be very much dependable on this wireless technology. It is expected that the wireless sensor networks will find wide applicability and increasing deployment in the future.

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However, usually most of the wireless sensor networks deployments so far are application specific due to resource constraints like limited amount of memory, computation power and energy source of sensor nodes [5]. Due to these limitations, most of the previous works on wireless sensor networks have been aimed at how to decrease the energy consumption thereby improving the life time of the network. This nature of a single application support of wireless sensor networks have tremendously limits their commercial deployment in many real life applications where multiple applications support by a single wireless sensor network is required. Although, the energy consumptions contribute to the total cost of the wireless sensor network but there are other aspects such as application development, maintenance and return-of-investment which equally contribute to the total cost of the wireless sensor networks [6]. In this research, we argue that a single wireless sensor network should support multiple applications so that it increases the return-of-investment and usefulness of the system.

The rest of the paper is organized as follows: Section 2 brings out some real life scenarios which motivate this research, section 3 explores some similar research done previously on the same topic, section 4 describes our proposed system with algorithms and flowchart and finally we conclude in section 5 describing implementation plan of our proposed system.

2 Motivation Scenarios

In this section, we bring out two scenarios where and in which situation the proposed system could be used in real life deployment of wireless sensor networks.

Scenario A

Consider a corporate industry that employs a wide range of sensors for monitoring different applications. Since the wireless sensor network are usually application specific running one application per wireless sensor network, the minimum requirement for setting up a single wireless sensor network would be, one sink node, several sensing nodes, cluster heads if heterogeneous nodes are deployed and the system which manages the network. Let us look at below scenarios:

1. The security department wants to set up wireless sensor network based intrusion detection system using surveillance camera in the corporate premises.

2. The maintenance department wants to set up wireless sensor network to monitor the temperature in the premises in order to prevent fire.

3. The top level management wants to monitor the air quality (pollution level) in the premises.

For the above three applications, the organization requires three different wireless sensor networks to provide three different services. The total investment cost will be reduced if all these three applications can be made to run simultaneously on a single wireless sensor network infrastructure.

Scenario B

Let us assume that the department of forest had set up wireless sensor network to detect and monitor the forest fire in the region of interest. After few years, the department even wants to monitor the illegal timber extraction from that same forest. In this situation, the cost of setting up the wireless sensor network to monitor the illegal timber extraction could be reduced if we can make use of the existing wireless sensor network infrastructure which monitors forest fire.

If we observe the above two scenarios, we would find different applications which requires different treatments. We can group these applications into three categories as inspired by [7] as environment data collection, security monitoring and mobility management. So, when a single sensor network infrastructure runs multiple applications, we will be faced with different challenges because the requirements and characteristics of each application are different and needs to be satisfied individually. Another important issue is how to share the common resources among multiple applications without compromising the performance of any individual application. Closely observing the requirements to be fulfilled for the individual application, we have come out with two main research questions as shown below:

i How to design a system or an architecture which supports multiple applications running simultaneously and at the same time fulfilling the individual applications' requirements?

ii How to collect and disseminate specific data from/to a particular application which needs a distributed and scalable routing protocol?

In this paper, we mainly focus on the first research question, how to design a system which supports multiple applications satisfying their individual requirements.

3 Related works

In this section, we describe some of the similar works previously done. Running multiple applications on a single wireless sensor network can be possible in two ways.

One way is to run all the applications simultaneously and the other way is to run applications in a predefined sequence. The application concurrency in wireless sensor networks can be divided into two categories [8]:

- Application concurrency at the node level
- Application concurrency at the network level

Concurrency at node level involves executing multiple applications at the processor of the node. As an example, a system could check a sensor to decide whether data is available and processes the data right away, and at the same time checks the transceiver for data packet availability, and immediately processes the packet [5]. On the other hand, application concurrency at network level can be either of the following ways. Running multiple applications simultaneous on a single network infrastructure or running different applications in a predefined sequence. The sensor nodes can be preprogrammed for each application or the application code can be distributed to the nodes by using some mobile agents after deployment during run time.

In [5] and [8], different applications running on a single network in a predefined sequence is proposed. It uses a mobile agent to switch ON and OFF the running application and a configuration agent to take care of updates and reconfigurations of nodes. This system is aimed at scenarios like forest fire detection and monitoring of fire fighters after the fire is detected. In this type of scenario, it is possible to have a sequential execution of the services, where one group of sensors is made to sleep while the other group is running. Although, switching the group of sensor nodes to sleep mode increases the life time of the network, however, the main drawback of the system is that the event happening during the sleep mode may not be detected. As an example, the fire may not be detected if the fire is occurred during the group of sensors which is supposed to detect fire is in sleep mode. The proposed system tries to overcome this drawback by making all the applications run simultaneously.

In [6], an architecture based on scoping technique is proposed. A scope is defined as a group of nodes that are specified through a membership condition. The proposed architecture stresses that the sensor nodes are not addressed individually by some addresses, but by their properties or context. Based on the scope, the system creates subsets of nodes within the network. The membership conditions are specified at different levels, e.g. like properties of nodes. In this way, the scoping suggests how to separate different tasks both at the node level and the network level.

A multiple service support wireless sensor network based on routing overlay is proposed in [9]. It mainly focuses on the routing issues by deploying different sink nodes for different applications. The similar approach is also discussed in [10]. In [9],

the nodes are made to registers with the applications with the help of application join message advertise by the applications. In this way, different groups of nodes are formed for each application. The intermediate node which receives messages for application, to which it is not registered, act as a relay and forward the message to the nodes nearer to the gateway. It is assumed that the nodes which are nearer to the gateway are made to act as relays whereas the nodes which are far away from gateways are made to act as sensing nodes, in order increase the lifetime of the network.

Our research proposal is inspired by Agilla [11] where it adopts a mobile agent-based system where programs are composed of mobile agents and move across the nodes in the network during run time. However, in contrast to Agilla, our mobile agent will not be moving continuously across the nodes. We use the mobile agent to distribute the application codes when we set up new application only. More detail description regarding the proposed system is given in the following sections.

4 Proposed Architecture

In this section, we give an overview and system design aspect of our proposed architecture for running multiple applications simultaneously on a single wireless sensor network infrastructure.

4.1 System Overview

Usually wireless sensor nodes are preprogrammed to accomplish a specific application due to their limited resources [8]. These limitations have restricted wireless sensor networks to be deployed commercially where multiple applications are required to be run on a single wireless sensor network infrastructure. After deployment of the wireless sensor nodes it would be very difficult to collect and re-program the nodes to suite the changing requirements. It is also observed that the cost of sensor would be decreasing as per the current trend and the rate of advancement on the field of electronics. With this technological advancement, it is anticipated that the many commercial organizations and industries would be deploying wireless sensor network and would be running concurrent applications on a single wireless sensor networks in order to reduce the management cost and increases the utilization of the system.

In view of the above anticipation, we propose to design a wireless sensor network architecture which can run multiple applications simultaneously. In our system we propose to deploy sensor nodes which are not preprogrammed, meaning that they are not application specific. The system is composed of four phases: i) Deployment of

nodes and formation of clusters phase, ii) Application registration phase, iii) Information dissemination phase and iv) Data Collection phase. These different phases are described in the following section.

4.2 System Design

The proposed system is inspired and motivated from the middleware concept of Agilla [11]. But, in our proposed system we use a mobile agent in two ways: one to distribute the application code when the particular application is deployed for the first time and other to enable the next application after the one application completes its task or any abnormal events occurred in the network. The system considers an application manager module which controls and coordinates the running of multiple applications and distribution of application codes with the help of mobile agent. In contrast to the proposal in [5], where running multiple applications is solely based on predefined sequence; our system uses a partial predefined sequence. Instead of switching the nodes between active and sleeping mode, we switch between active and passive mode. This will help us to monitor all the environments irrespective of the modes of nodes. We call passive mode when the nodes are sensing but not transmitting whereas in active mode nodes can transmit as well as sense. The decision on which application will be in active mode will be decided by the sequence in the application manager and the abnormal events detected in the field, and the priority is given to the former. Before describing the working of the system, we would like to bring out some of the assumptions we make in the proposed system:

- The sensor nodes can be programmed for different applications.
- How many number of sensing and cluster head nodes required are predefined?
- The nodes which act as cluster heads are more powerful than the sensing nodes
- Only one sink or base station (PC) node is available.

The proposed system has four phases:

1. Deployment of nodes and Cluster Formation

In this phase, we deploy sensing and cluster head nodes in the region of interest. The formation of cluster needs clustering algorithms which scales with the huge number of nodes as we may have to deploy a large number of nodes to have equal coverage of each application within the cluster. There are two main types of clustering in wireless sensor network, homogeneous and heterogeneous network clustering of sensor nodes [12]. A homogeneous sensor network consists of sensor nodes with identical hardware configurations and capabilities where as a heterogeneous sensor network consists of two types of sensor nodes; one with low power and low processing

capabilities; mostly used as sensing nodes, and the other type which is more powerful in terms of resources and processing power; usually used as cluster head [5].

2. Application Registration Phase

This phase is mainly concerned with the assignment of application task to the sensing nodes. The sink node (base station) advertises the application identifiers of the available applications to the cluster heads. The cluster heads, upon receiving the applications identifiers would be assigning the application identifiers to its member nodes assuring that equal representation of all the applications is made within its own cluster.

3. Information Dissemination Phase

In the third phase, sink node invokes the application manager, which in turn will set one of the applications active and check if the application is made active for the first time. If so, it sends the application code as well as the information via a mobile agent to the cluster heads. If the application is not a new, which means its code is already distributed, only then the information to switch to active mode is sent. With this, we make one of the applications active at one instance and the rests are in passive mode. Here, we assume that each application code has critical section, where we define threshold values which when exceeds; the application goes to active mode automatically even if it is in passive mode, thereby informing the cluster head through transmitting the sensed data. This, we call as abnormal event or abnormal operation.

4. Data Collection Phase

Once the one of the applications is switched ON to active mode, the sensing nodes will start sending the data to the base station via cluster heads. In the process if abnormal event occurs, then the current active application will be suspended, and the cluster head will inform the base station which in turn will invoke application manager to handle the situation. In normal condition, the running application will continue till its task is completed or till its allocated time expires, after which the next application will be switched ON to active mode and this process continues.

Flowchart, depicting the scenario when the application A1 is active while other two applications A2 and A3 are in passive mode is shown in figure 1. For simplicity, we have considered three applications A1, A2 and A3, but it can be used for any number of applications.

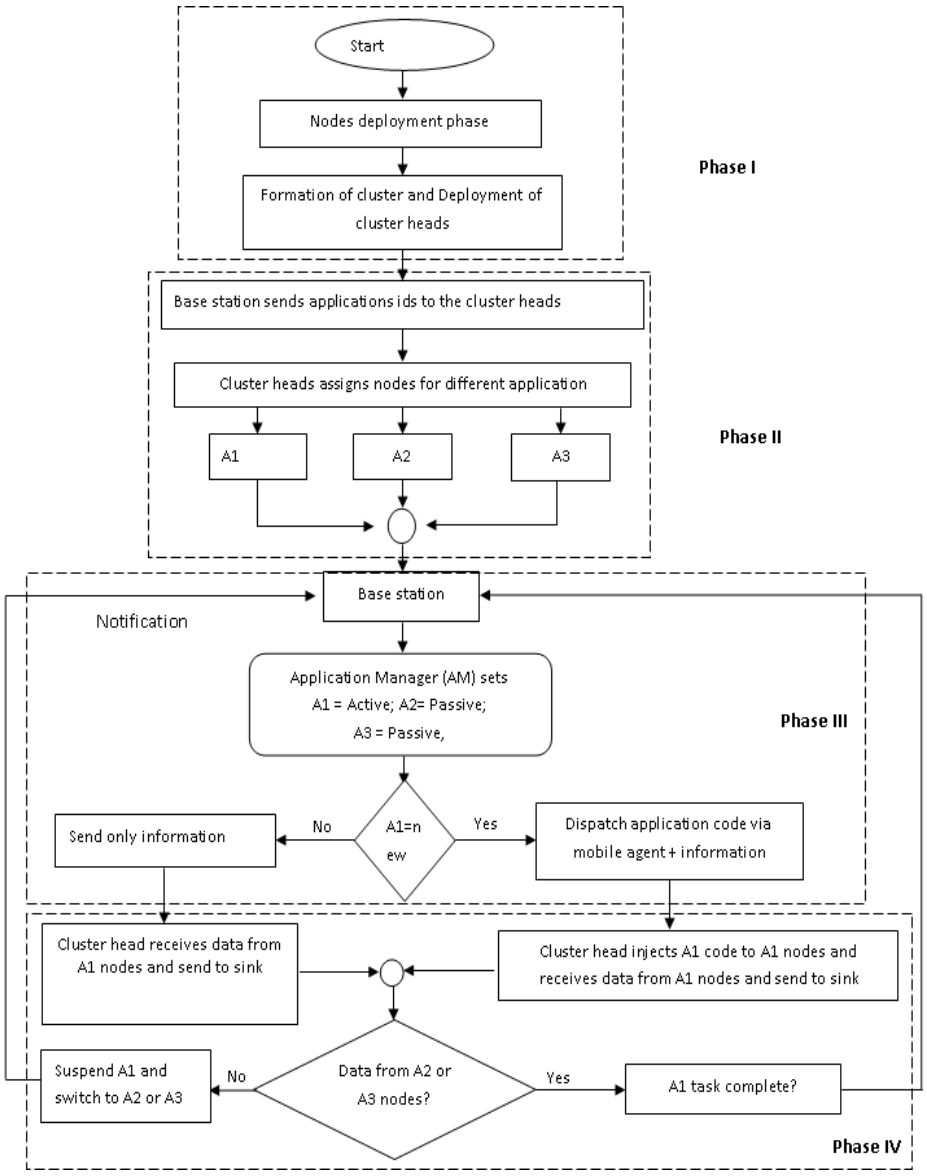

Fig. 1. Flowchart, depicting an operation scenario where application A1 is active, while applications A2 and A3 are in passive mode.

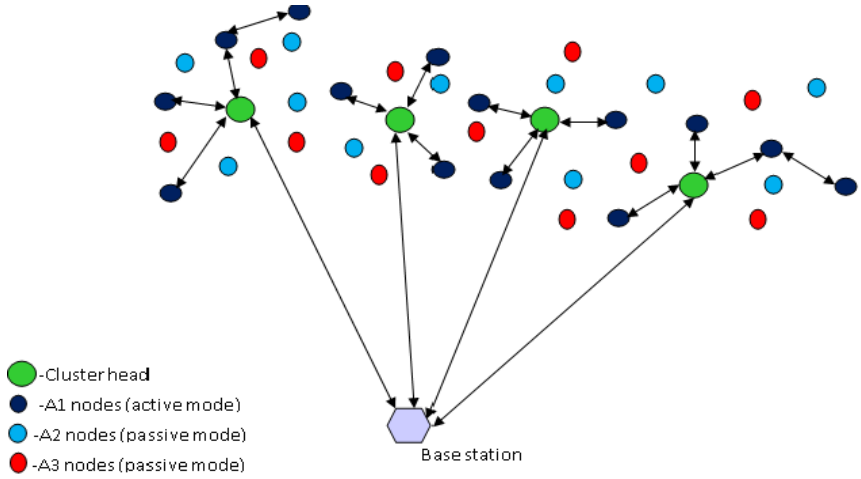

Fig. 2. Normal operation, A1 active while A2 and A3 are in passive mode.

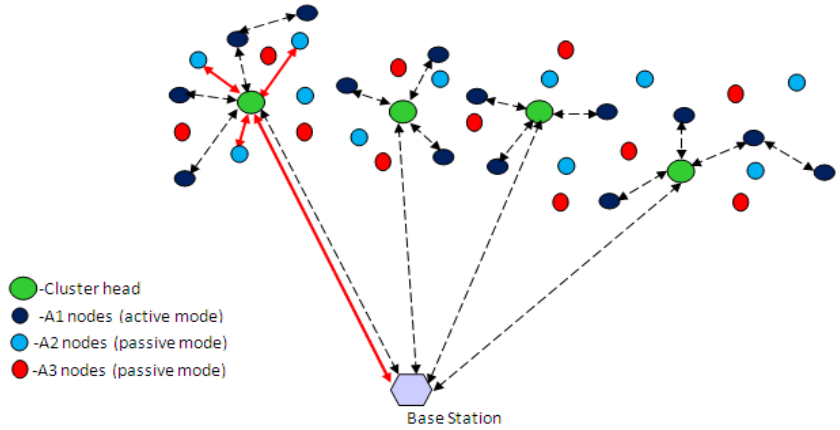

Fig. 3. Abnormal operation, while A1 is active, A2 detects an abnormal event.

5 Conclusion and Future works

It is observed that most of the works done on the sensor networks till date are targeted for a single application; user or the query is using the network at one time. This, not only increases the cost of investment by deploying duplicate infrastructure when an organization needs to monitor multiple applications, users or queries but also the resources are not fully utilized. In this paper, we have presented simple sensor network system architecture which aims to supporting multiple applications on a single wireless sensor network infrastructure. This not only will increase the utilization of the infrastructure but will also minimize the running and investment cost

of the whole system. It is based on the middleware concept where the module called application manager coordinates and control the running of multiple applications on a single wireless sensor network. In the future, we plan to develop a test bed so as to show the concept of our proposed system and verify the system for scalability and reliability with the help of simulation.

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