Wireless Sensor Networks for Environmental Monitoring Using Cluster Based Routing

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Abstract: Wireless Sensor Networks (WSNs) have attracted the attention of many researchers. Wireless Sensor Networks (WSNs) are used for various applications such as habitat monitoring, automation, agriculture, and security. Since numerous sensors are usually deployed on remote and inaccessible places, the deployment and maintenance should be easy and scalable. Wireless sensor network consists of large number of small nodes. The nodes then sense environmental changes and report them to other nodes over flexible network architecture. Sensor nodes are great for deployment in hostile environments or over large geographical areas. An energy efficient hierarchical cluster-based routing protocol for continuous stream queries in WSN. We introduce a set of cluster heads, head-set, for cluster-based routing. The head-set members are responsible for control and management of the network. On rotation basis, a head-set member receives data from the neighboring nodes and transmits the aggregated results to the distant base station. For a given number of data collecting sensor nodes, the number of control and management nodes can be systematically adjusted to reduce the energy consumption, which increases the network life.

Keywords: WSNs, sensors, sensor nodes, cluster, routing and data transfer

1. Introduction

Wireless sensor networks have recently come into prominence because they hold the potential to revolutionize many segments of our economy and life, from environmental monitoring and conservation, to manufacturing and business asset management, to automation in the transportation and health care industries. The design, implementation, and operation of a sensor network requires the confluence of many disciplines, including signal processing, networking and protocols, embedded systems, information management and distributed algorithms. Such networks are often deployed in resource-constrained environments, for instance with battery operated nodes running. These constraints dictate that sensor network problems are best approached in a hostile manner, by jointly considering the physical, networking, and application layers and making major design tradeoffs across the layers. Sensor networks extend the existing Internet deep into the physical environment.

Wireless sensor networks are a trend of the past few years, and they involve deploying a large number of small nodes. The nodes then sense environmental changes and report them to other nodes over flexible network architecture. Sensor nodes are great for deployment in hostile environments or over large geographical areas. The sensor nodes leverage the strength of collaborative efforts to provide higher quality sensing in time and space as compared to traditional stationary sensors, which are deployed in the following two ways: · Sensors can be positioned far from the actual phenomenon, i.e. something known by sense perception. In this approach, large sensors that use some complex techniques to distinguish the targets from environmental noise are required. Several sensors that perform only sensing can be deployed. The position of the sensors and communications topology is carefully engineered. They transmit time series of the sensed phenomenon to central nodes where computations are performed and data are fused.

2. Literature survey

A wireless sensor network (WSN) has important applications such as remote environmental monitoring and target tracking. This has been enabled by the availability, particularly in recent years, of sensors that are smaller, cheaper, and intelligent. These sensors are equipped with wireless interfaces with which they can communicate with one another to form a network. The design of a WSN depends significantly on the application, and it must consider factors such as the environment, the application□s design objectives, cost, hardware, and system constraints. We give an overview of several new applications and then review the literature on various aspects of WSNs.

2.1 Evolution of Sensor Nodes

There has been a long history for (remote) sensing as a means for humans to observe the physical world. For example, the telescope invented in the 16th century is simply a device for viewing distant objects. As with many technologies, the development of sensor networks has been largely driven by defense applications.

2.2 Military Networks of Sensors

Since the early 1950s, a system of long-range acoustic sensors (hydrophones), called the Sound Surveillance System (SOSUS), has been deployed in the deep basins of the Atlantic and Pacific oceans for submarine surveillance. Beams from multiple hydrophone arrays are used to detect and locate underwater threats. Recently, SOSUS has been replaced by the more sophisticated Integrated Undersea Surveillance System. Networks of air defense radars can be regarded as an example of networked large scale sensors. Both ground-based radar systems and Airborne Warning and Control System (AWACS) planes are integrated into such networks to provide all-weather surveillance, command, control, and communications.

2.3 Next Generation Wireless Sensor Nodes

2.3.1 WINS from UCLA

In 1996, the Low Power Wireless Integrated Micro sensors (LWIMs) were produced by UCLA and the Rockwell Science Center. By using commercial, low cost CMOS fabrication, LWIMs demonstrated the ability to integrate multiple sensors, electronic interfaces, control, and communication on a single device. LWIM supported over 100 Kbps wireless communications at a range of 10 meters using a 1 mW transmitter. In 1998, the same team built a second generation sensor node the Wireless Integrated Network Sensors (WINS). Commercial WINS from Rockwell Science Center each consists of a processor board with an Intel Strong Arm SA1100 32-bit embedded processor (1 MB SRAM and 4 MB flash memory), a radio board that supports 100 Kbps with adjustable power consumption from 1 to 100 mW, a power supply board, and a sensor board. These boards are packaged in a 3.5"x3.5"x3" enclosure. The processor consumes 200 mW in the active state and 0.8 mW when sleeping.

2.3.2 Motes from UC Berkeley

While WINS offer relatively powerful processing and communication capabilities, other research efforts have been developing smaller and cheaper nodes with less power consumption. The Mica family was released in 2001, including Mica , Mica2, Mica2Dot, and MicaZ. While Mica still used an 8-bit 4 MHz microcontroller (ATmega103L), it offered enhanced capabilities in terms of memory and radio, compared with preceding products. Mote architecture allowed several different sensor boards, or a data acquisition board, or a network interface board to be stacked on top of the main processor/radio board. The follow ups to Mica, Mica2 and Mica2Dot were built in 2002 with an ATmega128L microcontroller that reduced standby current (33 mW active power and 75 μW sleep power). One year later, MicaZ was produced with a Chipcon CC2420 wideband radio module that supported 802.15.4 and ZigBee protocols, with a data rate up to 250 Kbps. This radio module also supported on-chip data encryption and authentication.

2.3.3 Medusa from UCLA

The design philosophy and operational space of motes are quite different from those of WINS. On one hand, motes are designed for simple sensing and signal processing applications, where the demand for computation and communication capabilities is low. On the other hand, WINS are essentially an embedded version of PDAs, for more advanced computationally intensive applications with large memory space requirements. To bridge the gap between the two extremes, the Medusa MK-2 sensor node was developed by the Center for Embedded Networked Sensing (CENS) at UCLA in 2002. One distinguishing feature of Medusa MK-2 is that it integrates two microcontrollers. The first one, ATmega128, is dedicated to less computationally demanding tasks, including radio base band processing and sensor sampling. The second one, AT91FR4081, is a more powerful microcontroller (40 MHz, 1 MB flash, 136 KB RAM) that can be used to handle more sophisticated, but less frequent signal processing tasks (e.g., the Kalman filter). The combination of these two microcontrollers provides more flexibility in WSN development and deployment, especially for applications that require both high computation capabilities and long lifetime.

3. Cluster based routing

Hierarchical cluster-based routing scheme is suitable for habitat and environmental monitoring applications. The routing scheme is based on the fact that the energy consumed to send a message to a distant node is far greater than the energy needed for a short range transmission. We extend the LEACH protocol by using a head-set instead of a cluster head. In other words, during each election, a head-set that consists of several nodes is selected. The members of a head-set are responsible for transmitting messages to the distant base station. At one time, only one member of the head-set is active and the remaining head-set members are in sleep mode. The task of transmission to the base station is uniformly distributed among all the head-set members.

First, we describe a few terms that are used in defining our protocol. A cluster head is a sensor node that transmits an aggregated sensor data to the distant base station. Non-cluster heads are sensor nodes that transmit the collected data to their cluster head. Each cluster has a head-set that consists of several virtual cluster heads; however, only one head-set member is active at one time. Iteration consists of two stages: an election phase and a data transfer phase. In an election phase, the head-sets are chosen for the pre-determined number of clusters. In the data transfer phase, the members of head-set transmit aggregated data to the base station. Each data transfer phase consists of several epochs. Each member of a head-set becomes a cluster head once during an epoch. A round consists of several iterations. In one round, each sensor node becomes a member of head-set for one time.

3.1 States of a sensor node

The damaged or malfunctioning sensor states are not considered. Each sensor node joins the network as a candidate. At the start of iteration, a fixed number of sensor nodes are chosen as cluster heads; these chosen cluster heads acquire the active state. By the end of election phase, a few nodes are selected as members of the head-sets; these nodes acquire associate state. At the end of an election phase, one member of a head-set is in active state and the remaining head-set members are in associate state. In an epoch of a data transfer stage, the active sensor node transmits a frame to the base station and goes into the passive associate state. Moreover, the associate, which is the next in the schedule to transmit to the base station, acquires the active state. During an epoch, the head-set members are distributed as follows: one member is in active state, a few members are in associate state, and a few members are in passive associate state.

3.2 Election Phase

In the proposed model, the number of clusters, k, are pre-determined for the wireless sensor network. At the start, a set of cluster heads are chosen on random basis. These cluster heads send a short range advertisement broadcast message. The sensor nodes receive the advertisements and choose their cluster heads based on the signal strengths of the advertisement messages. Each sensor node sends an acknowledgment message to its cluster head. Moreover, for each iteration, the cluster heads choose a set of associates based on the signal analysis of the acknowledgments.

A head-set consists of a cluster head and the associates. The head-set, which is responsible to send messages to the base station, is chosen for one iteration of a round. In an epoch of an iteration, each member of the headset becomes a cluster head. All the head-set members share the same time slot to transmit their frames. Based on uniform rotation, a schedule is created for the head-set members for their frame transmissions; only the active cluster head transmits a frame to the base station. Moreover, a schedule is created for the data acquisition and data transfer time intervals for the sensor nodes that are not members of the head-set.

3.3 Data Transfer Phase

Once clusters, head-sets, and TDMA-based schedules are formed, data transmission begins. The non-cluster head nodes collect the sensor data and transmit the data to the cluster head, in their allotted timer slots. The cluster-head node must keep its radio turned on to receive the data from the nodes in the cluster. The associate members of the head-set remain in the sleep mode and do not receive any messages. After, some pre-determined time interval, the next associate becomes a cluster head and the current cluster head becomes a passive head-set member. At the end of an epoch, all the head-set members have become a cluster head for once. There can be several epochs in an iteration. At the end of an iteration, the head-set members become non-candidate members and a new head-set is chosen for the next iteration. Finally, at the end of a round, all the nodes have become non-candidate members. At this stage, a new round is started and all the nodes become candidate members.

4. Conclusion

Unlike other networks, WSNs are designed for specific applications. Applications include, but are not limited to, environmental monitoring, industrial machine monitoring, surveillance systems, and military target tracking. Each application differs in features and requirements. The measurement of temperature and light parameters through Crossbow Sensor Kit by using MoteView and MoteConfig environment has been done. The sensors or nodes are placed at different locations and the environmental parameters of that locations are measured. TinyOS is a very extensive and complex system. It has many applications and tools that need to be studied before one can fully understand the entire system. The results of our quantitative analysis of the proposed hierarchical cluster-based routing protocol indicate that the energy consumption can be systematically decreased by including more sensors in a head-set. For the same number of data collecting sensor nodes, the number of control and management nodes can be adjusted according to the network environment. In future work, the variation in the head-set size for different network conditions will be investigated. This work will be extended to incorporate non-uniform cluster distributions.

5. References

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