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An Optimized Data Reporting Protocol for Wireless Sensor Networks

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Abstract:
Wireless sensor network (WSN) is a wireless network consisting of spatially distributed sensor nodes using to monitor physical or environmental conditions. In many application scenarios, the data collecting element (mobile sink) cannot move freely in the deployed area.In such approaches the mobile sink moves to predetermined sojourn points and query each sensor node individually.A sensor node can conveniently identify its hop count distances to these landmarks. This approach is much more flexible in terms of sinks' movement, but incurs significant control message overheads. SinkTrail is a proactive data reporting protocol that is self-adaptive to various application scenarios, and its improved version SinkTrail-S reduces the control message overheads. In SinkTrail, mobile sinks move continuously in the field in relatively low speed, and gather data on the fly and it establishes a logical coordinate system for routing and forwarding data packets. Each sensor node selects next hop with the shortest logical distance to the mobile sink. The proposed work is based on data collection assisted by mobile sink and to improve energy efficiency, the proposed work introduces a cluster based topology, where data collection will carryout by cluster head to mobile sink. In this approach every sensor node forwards data report to corresponding cluster head, cluster heads then report to mobile sink, which will consume less energy comparatively as well as it will possibly decrease the region travelled by mobile sink.

Key words*: Wireless sensor network, mobile sink, cluster head, data gathering, logical coordinate*

1. Introduction

Wireless Sensor Network (WSN) is a type of wireless network, consists of a collection of tiny devices called *sensor nodes*. The main tasks of sensor nodes are typically; (i) sample a physical quantity from the surrounding environment, (ii) process (and possibly store) the acquire data, and (iii) transfer them through wireless communications to a data collection point called *sink node* or *base station*. Wireless sensor network with sensor nodes work together to detect a region to collect data about environment.Typical WSNs are composed of a large number of sensor nodes which transmit the sensed information to the sink. Since a sensor node is constrained by a device with limited power supply, recharging sensor nodes is often infeasible. One of the most important challenges in large-scale WSNs is energy efficient algorithms, since sensor nodes have restricted energy. For example, if some sensor nodes fail due to insufficient power, then WSNs may not fulfill their functions properly. Therefore, less energy consumption of sensor nodes and maximize the lifetime of the entire network have significant importance in the design of sensor network protocols.

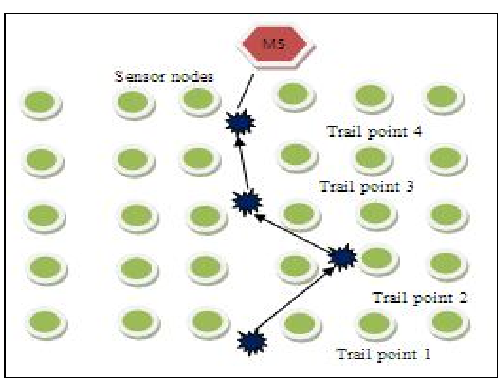

Figure 1: Data gathering with one mobile sink

Most of the traditional WSN architectures consist of static nodes, which are densely deployed over a sensing area. Recently, several WSN architectures based on mobile elements (MEs) have been proposed. Mobility in WSNs also introduces significant challenges which include;

- Contact detection: It is necessary to detect the presence of a mobile node correctly and efficiently. The communication is possible only when the nodes are in the transmission range of each other.
- Mobility-aware power management: If the mobile element path is known or can be predicted with certain accuracy, sensor nodes can be awake only when the mobile element in their transmission range.
- Reliable data transfer:Since the mobile element available contact duration with a sensor node might be short, the number of messages correctly transferred to the sink is important. The mobile sink might be move during data transfer; the message exchange must be mobility-aware.
- Mobility control:A policy has to be defined for the path and the speed or sojourn time of mobile element in order to improve network performance.

Sink Trail is a proactive, greedy data forwarding protocol that is self-adaptive to various application scenarios [1]. In this approach for gathering data from the network the mobile sinks move continuously in the field and broadcast control messages at certain points known as "*footprints*" of a mobile sink. Sensor nodes use each footprint as a virtual landmark for identify its hop count distances to these points and keep it as a vector form coordinates called trail references. The trail references are used to guide data reporting without knowledge of the physical locations and velocity of the mobile sink. The combination of hop count distances is the sensor node's coordinate in the logical coordinate space. The coordinate of the mobile sink is its hop count distances from the current location to previous virtual landmarks. Sensor node can use destination coordinate and its own coordinate to identify shortest logical distance to the mobile sink.

To minimize the flooding effect of control messages, message suppression [1]is used with the SinkTrail approach. The cluster based topology can improve scalability and energy efficiency. In cluster based topology the cluster head will collect the data from each sensor node and transmitted to the mobile sink.In a wireless sensor network might be contain large populations of sensors; it's a natural possibility that hundreds or even thousands of sensor nodes will be involved.In order to improve network lifetime the specialized energy-aware routing and data gathering protocols offering high scalability should be applied.

To satisfy the scalability objective and energy efficiency and network lifetime in large-scale WSN environments, grouping sensor nodes into *clusters* has been widely used. The corresponding hierarchical routing and data gathering protocols are used for data fusion and aggregation. And this fusion and aggregation are usually done by a special node called the cluster head (CH), which leads to a two-level hierarchal structure where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit their data to the corresponding CH nodes. The CH nodes aggregate the data and transmit data to the base station (BS) either directly or through the intermediate communication with other CH nodes.Since the CHs spend energy at higher rates than the other sensor nodes, the cluster heads are periodically reelected in order to balance the energy consumption among all the network nodes.

2. Related Work

Recent researches have shown data sinks' mobility in sensor network has been a topic of various practical interests and applications in data collection. Most of the researches were focuses on control overheads introduced by a sink's movement. The straight way solution is to track a moving mobile sink by broadcasting mobile sink's current location to the whole network. If the amount of data from the network is less the Sink oriented approach has very effective. For enabling fast data forwarding, the two-tier data dissemination structure used in in TTDD protocol [3]. A restricted flooding method has been proposed inFodor and Vida´cs [4] which reduces the communication overheads. The DRMOS proposed by Park et al. [5] that divides sensors into wake-up zones to save energy. The path of a mobile sink is restricted to move following a circle trail in deployed sensor field to maximize data gathering efficiency has been proposed by Luo and Hubaux [6]. These papers in which the mobile sink path has been confined.Another solution is mobile sink can presents at random places in the network, but it might be relies heavily onnet work topology and density, and suffers scalability issues when all data packets need to be forwarded in the network. Another category of methods, considered controlled mobile sink mobility and advanced planning of mobile sink's moving path called Mobile Element Scheduling (MES) algorithms [7].

Although the MES methods effectively reduce data transmission costs, they require a mobile sink to cover every node in the sensor field, which makes high latency in data gathering in large scale networks.The SinkTrail protocol provides almost no constraint on the moving trajectory of mobile sinks and more flexibility to change field situations.

SinkTrail protocol with message suppression minimizes the flooding effect of control messages without confining a mobile sink's movement, thus is more attractive in real-world deployment. It is possible to use different prediction techniques enhance data reporting. The data reporting using logical coordinates rather than geographic coordinates represented in vector form called trail references which helps data reporting without knowing the physical locations of the mobile sink.

3. System Model

The data reporting protocol uses unique logical coordinate representation for tracking mobile sinks without detail of physical location of mobile sink.

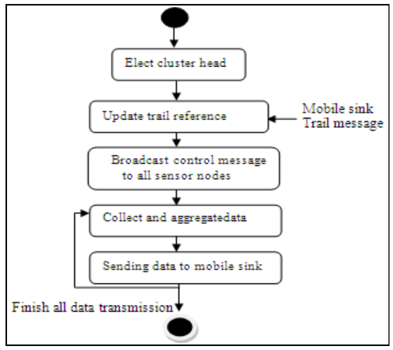

Figure 2: State transition diagram for cluster head

The data reporting protocol gather data with one or multiple mobile sinks with low complexity and energy consumption. TheSinkTrail protocol and SinkTrail-S protocols have been designed to use with cluster based topology for energy efficient data gathering.Cluster head has four functional states. In the first stage the cluster head broadcast message to its group sensor nodes. In the second stage it collects and aggregate data and makes a data report to be sent to the mobile sink. In the third state when the first trail message is received in the cluster head, itupdates trail references corresponding to the mobile sink's trailmessages. In the fourth statethe cluster headdecides how to report data packets to the mobile sink and forward the data packets. After reporting, the mobile sink transmits the data to the base station.

3.1. Logical Coordinate Space Construction

At first, all the trail references are initialized to [-1,-1, ...*-1]* of size d_v. After the mobile sink *S* enters the field, it moves to its first trail point π_1, and broadcasts a trail message to all the sensornodes in the network. The trail message<msg.seqN,msg.hopC>is set to <1, 0 >, indicating that this is the first trail message from trail point one, and the hop count to *S* is zero. The nodes nearest to *S* will be the first ones to hear this message. To check the "freshness" of a message, a node $n_i$needs to compare the sequence number carried in this trail message with its λ, which represents the latest sequence numbers $n_i$has seen. And λ is reset to -1 after each data gathering process finishes. If this is a new message, the λ variable will be updated by the new sequence number. And node n_i's trail reference *vi* is updated as follows. First, every element in $v_i$is shifted to left by one position. Then, the hop count in the received trail message is increased by one, and replaces the right-most element e_i^{dv}in v_i. After $n_i$updatesits trail reference, this trail message is rebroadcasted with thesame sequence number and an incremented hop count. The same procedure repeats at all the other nodes in *N*. Within one move of *S*, all nodes in the network have updated their trail references according to their hop count distances to *S*'s trail point π_1. If a node receives a trail message with a sequence number equals to λ, but has a smaller hop count than it has already recorded, then the last hop count field in its trail reference is updated, and this trail message is rebroadcasted with the same sequence number and an incremented hop count. Trail messages that have sequence number less than λ will be discarded to eliminate flooding messages in the network. During the data gathering procedure, a node's trail reference needs to be updated every time a new trail message is received.After each node in the network received $d_v$distinct trail messages, the logical coordinate space is established.

3.2. Destination Identification

The mobile sinkwill stop at convenient locations. These sojourn places of a mobile sink, named trail points in SinkTrail algorithm, and are footprints left by a mobile sink. These footprints are used as a virtual land mark to decide the hop count of a mobile sink. A logical, d_v -dimensional coordinate space is then established. The mobile sink's hop count distances to its previous dv -1 footprints are always
$K(d_v - 1), K(d_v - 2), \ldots, K$, and 0 to its current location. Therefore the logical coordinate $[K(d_v - 1), K(d_v - 2), \ldots, 0]$ represents the current logical location of the mobile sink. The movement of mobile sink does not necessary require to have linear.

3.3. Data Forwarding

Once a cluster head has updated its trail reference,itinitiates the data reporting process.Every sensor node in the network maintains a routing table of size $O(b)$ consisting all neighbors' trail references. This routing table is built up by exchanging trail references with neighbors, and it is updated constantly. Although trail references may not be globally identifiers, since route selection is conducted locally, they are good enough for the SinkTrail protocol. When a node has received all its neighbors'trail references, it calculates their distances to the destination reference according to the *2-norm* vector calculation, and choose the neighbor node with the smallest distance as next hop to relay data. If there is a tie then randomly choose one.

3.4. SinkTrail-S Protocol Design

In a large-scale sensor network, thesensor nodes that are far away from a mobile sink may not be significantly affected by a single movement of the mobile sink in which sensor node will compare the current hop count distance to a mobile sink with the most recently received one. If these two are same, it indicates the path length through the node to the mobilesink is still same, making it unnecessary to rebroadcast this trail message.When a cluster head has finished data reporting and forwarding, trail reference updating becomes meaningless and results in huge waste of energy each node maintains a state variable in its memory. When a cluster head finishes data reporting, it marks itself as "finished," and informs all its cluster nodes.

4. Impact of Cluster Based Topology with Message Suppression

In order to control message overhead, a cluster based topology has been proposed where the data collection is carried out by the cluster head to the mobile sink, which consumes only less energy. In this approach, a cluster head will be elected based on the energy of each sensor node. Every sensor node forwards data to the cluster head and it will aggregate the collected data. Afteraggregation, it transmits the data to the mobile sink.Sensor nodes are organized into clusters and form the lower layer of the network. At the higher layer, cluster heads collect sensing data from sensors and forward data to the outside data sink. These types of layered hybrid networks are more scalable and energy-efficient. In a homogeneous network, where all nodes have identical capability and energy at the beginning, some of the nodes are selected to serve as cluster heads. However, cluster heads will inevitably consume more energy than other sensor nodes. To avoid the problem of cluster heads failing faster than other nodes, sensor nodes can become cluster heads periodically.

In this type of network, since every sensor node may possibly become a cluster head, each of them has to be "powerful" enough to handle incoming and outgoing traffic and cache sensing data, which will increase the overall cost of the entire sensor network. Furthermore, selecting cluster heads dynamically results in high overhead due to the frequent information exchange among sensor nodes. Some efforts have been made to improve the intrinsic disadvantage of homogeneous networks by introducing a small number of resource rich nodes. Basic sensor nodes have limited communication capability and mainly focus on sensing the environment, whereas resource-rich nodes are equipped with more powerful transceivers and batteries. In resource-rich nodes act as cluster heads, and the network is organized into a two- layered hierarchical network. However, it is generally difficult to deploy powerful cluster heads to appropriate positions without learning the network topology.

5. Performance Analysis

Cluster based topology with message suppression can be implemented by using NS2 in a personal computer running in fedora 13 with specification of 1.5GHz,harddisk of 40GB,RAM of 256MB as the minimum requirement. Performance analysis can be represented based on the graph.The graph can be plotted based on

- Throughput.
- Packet Delivery Ratio.
- Average energy.

Initially every graphs should be starts with 0 which demonstrates that there is no more communication,when 5th second start the communication should takes place, that time values will be increasing,when communication stops the values remains constant or turned to 0.

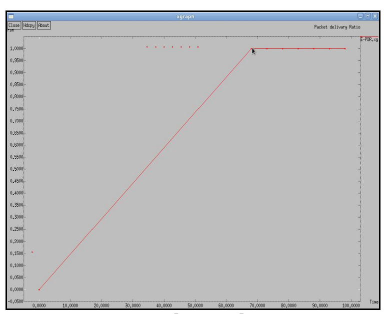

Figure 3: Packet Delivery Ratio

In Packet Delivery Ratio (PDR) graph the x-axis indicates time and y-axis indicates the packet delivery ratio values,it should be within 0 to 1. The packet delivery ratio can be defined as total number of packets received by total number of packets sent.

- *PDR= Total number of packets received /Total number of packets sent*

Network Throughput refers to the volume of data that can flow through a network. Network Throughput is constrained by factors such as the network protocols used, the capabilities of routers and switches, and the type of cabling, such as Ethernet and fiber optic, used to create a network. Network Throughput in wireless networks is constrained further by the capabilities of network adapters on client systems. Throughput can be defined as the amount of bytes received by interval.

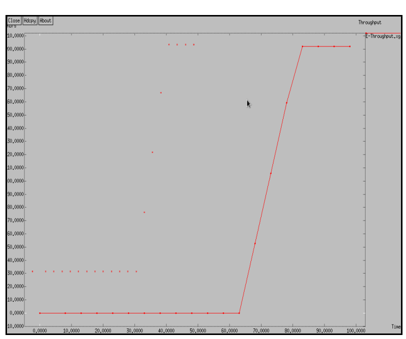

Figure 4: Throughput

- Throughput=Amount of bytes received/Interval

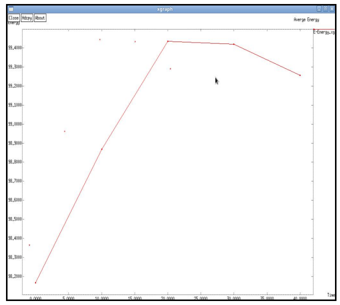

Figure 5: Average energy

After data reporting and gathering, the energy of each sensor node decreases. The energy consumption can be reduced by controlling the message overheads. The cluster-based approach is one of the most important technique to reduce energy consumption in wireless sensor networks. The energy saving is a challenging fact in the wireless sensor networks.

6. Conclusion

SinkTrail-S with clusterhead topology can increase the energy efficiency and minimize the message overhead.Data aggregation is one of the important methods for saving energy in senor network.Nodes are grouped into clusters,leads to hierarchical routing and data gathering protocols have been regarded as the most energy efficientapproach to support complexity in WSNs. The hierarchical cluster structures facilitate the efficient data gathering and aggregation that reduces the total amount of communications as well as the energy consumed.The main objective of the protocol lies on how to transfer the data through shortest path and how to efficiently gather data from the network.Furthermore, the combined need for energy efficient data gathering and to reduce control message overhead (with regard to the cluster formation procedure)theappropriate transmission of data by using clustering algorithmproposed.The proposed SinkTrail-S protocol can be integrated with the Green-Seeker system which can be used in large-scale multihop sensing on demand and automate spray systems for optimal fertilizer and irrigation management.

7. References

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