A Method for Fault Management in Wireless Sensor Networks with Mobile Sink Nodes

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Abstract. As the previous fault management methods do their duties based on the model for data transmission not considering mobile sink nodes, they do not appropriately deal with the case where the failure in mobile sink nodes happens. To address this problem, this paper suggests the method for fault management based on TTDD, the model for data transmission in a wireless sensor network with sink mobile nodes. In simulation, we compare the proposed method with SNMS and Sympathy. The result shows that our method is better than the previous ones in the aspect of data loss rate. Our future work includes research on the case of mobile sensor nodes.

Keywords: Wireless Sensor Network, Fault Management, Sink Node, Mobility

1 Introduction

With the recent advances of sensor and wireless communication technology, small-sized sensor nodes characteristic of low power and low cost have been developed, thus many researches on wireless sensor networks(WSNs) are done[1]. WSNs are applied to various areas such as science, military, medicine, commerce according to usage purpose.

Sensor nodes usually have hardware and software constraints in terms of operation ability, memory capacity, power supply, and communication processing due to their small size. Among them, power supply is the largest obstacle, which is caused by difficulty of recharge. By this reason, a fault is likely to happen in WSNs, and it affects information collection. As sensor nodes are deployed in an open space, malicious enemies easily attack them. And, since communication is performed by radio, enemies intrude into a sensor network easily and affect its function such as routing. Moreover, sensor nodes are used to monitor outside environments, and they often suffer from natural disaster. So, these reasons make us handle the faults in WSNs differently compared to traditional networks.

Fault management necessary to a network management system is an important function in WSNs. In particular, fault detection is a significant element to security and performance as well as fault management. If a management program determines malicious source to fault, we can trigger a security service. If a fault is an accident or a natural failure, we can activate a backup node to alternate a fault node.

The previous methods for fault management include SNMS(Sensor Network Management System)[2] and Sympathy[3] to debug sensor networks. The upper two methods do not consider a sensor network with mobile sink nodes. Therefore, in this paper, we propose a fault management method for a sensor network with mobile sink nodes.

The remainder of this paper is as follows. In section II, we describe related work. In section III, we present a fault management method using TTDD[4] which is a model for a sensor network with mobile nodes. In section IV, we compare our proposed method with SNMS and Sympathy and analyze simulation results. We conclude in section V.

2 Related Work

2.1 SNMS [2]

We investigate network architecture, query system, and event logging system of SNMS. Firstly, The SNMS network architecture is as follows. As SNMS is intended to collaborate with an application and continue operating when application fails, a management system for SNMS contains its own networking stack which can run in parallel with the application's. The SNMS networking architecture supports two traffic patterns, which are Collection and Dissemination. Collection is a traffic pattern which obtains fresh data from the network. And, Dissemination is one which distributes management commands and queries.

Secondly, SNMS has a query system. One of the key contributions of SNMS is a middle layer that easily exposes interesting attributes of sensor nodes to human eyes, over a deployed multihop network. As the number of the upper attributes is large, SNMS provides a runtime query system by which subsets of these attributes may be selected for collection. This system is operated by TinyOS components and intended to be simple and robust.

Thirdly, SNMS has an event logging system for tracking the situation of sensor networks. While the query system performs the continuous user-driven monitoring of known parameters, post-mortem analysis and real-time monitoring of unexpected events need another fundamental management system. The SNMS event logging system supports program-driven notification of one-time events. This event logging system is also structured according to the SNMS design principles of minimal footprint, simple and robust design, programmer-initiated direct naming, dynamic schema generation, and user control.

2.2 Sympathy[3]

We investigate Sympathy in terms of architecture. Sympathy detects and localizes failures using information from all network nodes, including both resource-constrained TinyOS-based motes and resource-rich linux-based sinks. Sympathy code on motes simply transmits metrics and responds to occasional queries. On the other hand, detection and localization of failures runs on sinks.

The actual localization process is composed of the following four stages. At the first stage, ongoing stage, the sink collects metrics from other nodes in the system. Metrics include information transmitted as part of normal communication, such as sampled data, and information transmitted actively by Sympathy code running on motes. As soon as Sympathy receives any packet, it looks for failures by analyzing this metric stream, looking for insufficient data received from any node. If any failure is detected, Sympathy diagnoses the root cause of the failure by analyzing metrics and running tests. Common root causes include a node crash or reboot, no node has a route to the sink because the sink has no neighbors, or the sink is not receiving data because the node is not receiving requests. At the fourth stage, after determining the root causes for all existing failures in the system at that time, Sympathy assigns each failure a localized source. Localized source is one of the three sources, which are Self, Path, and Sink.

The metrics which Sympathy collects and the root causes to which it assigns failures are based on a simple insight. In the absence of failure, network flows are conserved. Thus, when data is lost, it must be getting lost somewhere in the network, and finding the location of loss is a good approximation to finding the true cause of the failure.

3 The Method of Fault Management Considering Mobile Sink Nodes

In this section, we propose the method of fault management in WSNs with mobile sink nodes. For this, we look into TTDD(Two-Tier Data Dissemination)[4], which is a routing model of WSNs to support mobile sink nodes. Next, we present a method to detect faults and recover from them using TTDD.

3.1 TTDD141

The procedure to disseminate data in TTDD is as follows. As soon as a source generates data, it starts preparing for data dissemination by building a grid structure. The source starts with its own location at one crossing point of the grid, and sends a data announcement message to each of its four adjacent crossing points. Each data announcement message finally stops on a sensor node which is the closest to the crossing point specified in the message. The node stores the source information and further forwards the message to its adjacent crossing points except the one from which it received the message. This recursive propagation of data announcement messages notifies those sensors that are closest to the crossing locations to become the dissemination nodes of the given source.

Once a grid for the specified source is built, a sink can then flood its query within a local cell to receive data. The query will be received by the nearest dissemination node on the grid, which then propagates the query upstream through other dissemination nodes toward the source. Requested data will flow down in the reverse path to the sink. Fig. **1** shows the basic process of data dissemination in TTDD.

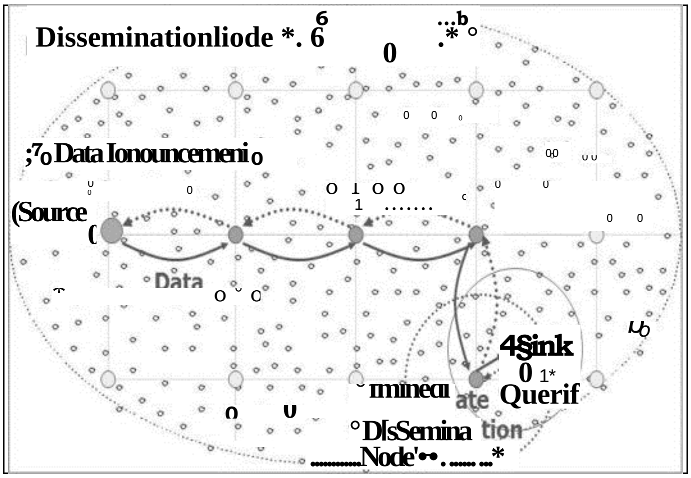

Fig. 1. The basic process of data dissemination in TTDD

3.2 Fault Management Using TTDD

The proposed method performs fault management through fault detection, fault identification, and fault recovery in **TTDD.**

Fault Detection. To facilitate fault detection, a module to collect metrics is installed on both sink nodes and sensor nodes selected as crossing points. The module on sink nodes collects metrics related to themselves, while the module on crossing points collects metrics related to sensor nodes of crossing points.

The metrics used in fault detection are as follows. The metrics collected at sink nodes are 'Packets received by sink node', 'Immediate dissemination node list', `Dissemination table', 'Last timestamp'. The metrics collected at sensor nodes of crossing points are 'Neighbor crossing point list', 'Routing table', 'Received packet', `Transmitted packet', 'Good receipt of packets', Tad receipt of packets'. Also, the metrics collected at sensor nodes other than crossing points are 'Neighbor node list', `Update time'.

Metrics collection is initiated by timer, which rings once every designated time. After metrics collection begins, collection modules check whether metrics are sufficiently collected. If not sufficiently collected, the modules decide for fault to happen.

Fault Identification. If a fault is detected, a module for fault identification investigates the fault cause. The fault cause is decided according to the collected metrics. Table **1** shows fault causes associated with metrics.

Table 1. Fault causes associated with metrics

Fault cause	Metrics
Node failure	Last timestamp, Transmitted packet
Node rebooting	Update time
No Neighbor	Immediate dissemination node list, Neighbor crossing point list, Neighbor node list
No path	Dissemination table, Routing table
Bad path to crossing point	Received packet
Bad path to sink node	Packets received by sink node
No path to crossing point	Routing table
No path to sink node	Dissemination table

Fault Recovery. After a module for fault identification finds out all about faults, a module for fault recovery informs users about the detected fault contents through log files, fault cause, metrics related to the fault, and statistical data. Users try to recover from faults by the method of node substitution, node rebooting, and so on.

4 Simulations and Results

In this section, we perform simulations comparing our proposed method with SNMS and Sympathy in the aspect of data loss rate and analyze the results. The size for simulation is 100 x 100(m), and the number of nodes is 200. The initial of each node is 0.25(J), and transmitted data size is 2000(bit).

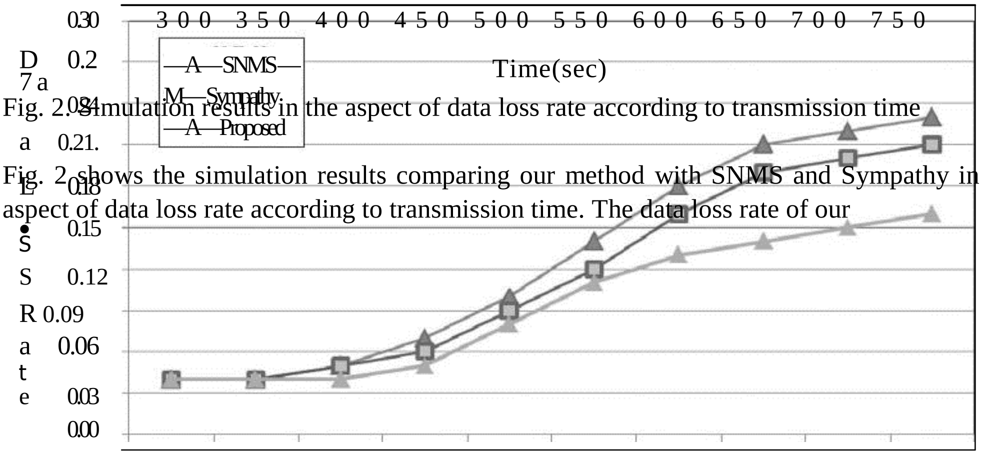

Fig. 2. Simulation results in the aspect of data loss rate according to transmission time

Fig. 2 shows the simulation results comparing our method with SNMS and Sympathy in the aspect of data loss rate according to transmission time. The data loss rate of our method increases less sharply than SNMS and Sympathy, so we find out that our method do fault management better than the previous ones.

5 Conclusion and Future Work

In this paper, we proposed the method for fault management based on TTDD, the model for data transmission for a wireless sensor network with sink mobile nodes. In simulation, we compare the proposed method with SNMS and Sympathy. The result shows that our method is better than the previous ones in the aspect of data loss rate. Our future work includes research on the case of mobile sensor nodes.

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