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Detecting and Minimizing Node Failure Context in Wireless Sensor Network

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ABSTRACT

Node failure detection in mobile wireless networks is very challenging due to node movements, the network may not be always connected, and the resources are limited. In this project, propose solutions to address the challenge specific to sensor networks, to design a fault tolerant, energy efficient monitoring system in a distributed manner. In proposed concept focus on fully distributed monitoring algorithms, objective to minimize the number of overall pollers while bounding the false alarm rate. To increase the energy efficiency and reduce the monitoring overhead, take the hop-by-hop aggregation opportunities in sensor network. When building the monitoring architecture, focus on the fundamental tradeoff between the number of monitoring nodes (i.e., poller) the false alarm rate. To achieve the optimal aggregation path problem and propose an opportunistic greedy algorithm, which achieves an approximation ratio

Keywords : Wireless, Sensor Network, ACK, MIS, Poller

I. INTRODUCTION

Mobile wireless networks have been used for many mission critical applications, including search and rescue, environment monitoring disaster relief, and military operations. Such mobile networks are typically formed in an ad-hoc manner, with either persistent or intermittent network connectivity. Nodes in such networks are vulnerable to failures due to battery drainage, hardware defects or a harsh environment. Detecting node failures is important for keeping tabs on the network. It is even more important when the mobile devices are carried by humans and are used as the main/only communication mechanism. Node failure detection in mobile wireless networks is very challenging because the network topology can be highly dynamic due to node movements. Therefore, techniques that are designed for static networks are not applicable. Secondly, the network may not always be connected. Therefore, approaches that rely on network connectivity have limited applicability. Thirdly, the limited resources (computation, communication and battery life) demand that node failure detection must be performed in a resource conserving manner. One approach adopted by many existing studies is based on centralized monitoring. It requires that each node send periodic "heartbeat" messages to a central monitor, which uses the lack of heartbeat messages from a node (after a certain timeout) as an indicator of node failure. This approach assumes that there always exists a path from a node to the central monitor, and hence is only applicable to networks with persistent connectivity. In addition, since a node can be multiple hops away from the central monitor, this approach can lead to a large amount of network-wide traffic, in conflict with the constrained resources in mobile wireless networks. Another approach is based on localized monitoring, where nodes broadcast heartbeat messages to their onehop neighbors and nodes in a neighborhood monitor each other through heartbeat messages. Localized monitoring only generates localized traffic and has been used successfully for node failure detection in static networks. However, when being applied to mobile networks, this approach suffers from inherent ambiguities when a node A stops hearing heartbeat messages from another node B, A cannot conclude that B has failed because the lack of heartbeat messages might be caused by node B having moved out of range instead of node failure. In this paper, we propose solutions to address the challenge specific to sensor networks, to design a fault tolerant, energy efficient monitoring system in a distributed manner. The whole architecture is build upon the poller-pollee structure, where sensors self-organize themselves into two tiers, with pollees in the lower tier and pollers in the upper tier. The pollees send status reports to the pollers along multihop paths, during which the intermediate nodes do the aggregation to reduce the message overhead. Each poller makes local decisions based on the received aggregated packets, and forwards its decision towards the sink. When building the monitoring architecture, we focus on the fundamental tradeoff between the number of monitoring nodes (i.e., pollers) and the false alarm rate. We have evaluated our schemes using extensive simulation in both connected and disconnected networks (i.e., networks that lack contemporaneous end-to-end paths). Simulation results demonstrate that both schemes achieve high failure detection rates, low false positive rates, and incur low communication overhead. Compared with approaches that use centralized monitoring, while our approach may have slightly lower detection rates and slightly higher false positive rates, it has significantly lower communication overhead (up to 80% lower). In addition, our approach has the advantage that it is applicable to both connected and disconnected networks.

II. METHODS AND MATERIAL

Related Work

Most of the previous work targets at minimizing the number of pollers only, because selecting more pollers will enhance the difficulty of tracking the status of each poller and thus increase the network management cost. However, in a lossy environment, the false alarm rate can be adversely affected by a smaller number of pollers. For example, if the number of pollers is too small, some pollees will be too far away from the poller, and then the chance of link transient failure will be higher and the false alarm rate will be larger. To balance the tradeoff between the number of pollers and false alarm rate, we propose a distributed deterministic algorithm, which uses two parameters k1,k2 to guide a better distribution of poller and pollee; i.e., no two pollers are less thank1 hops away from each other, and no pollee is more thank2hops away from its poller. This property enables us to minimize the number of pollers while bounding the maximum false alarm rate. We discuss how to set up these parameters and further reduce the message overhead based on a randomized technique. Many schemes adopt probe-and-ACK (i.e., ping) or heartbeat based techniques that are commonly used in distributed computing. Probe-and-ACK based techniques require a central monitor to send probe messages to other nodes. When a node does not reply within a time-out interval, the central monitor regards the node as failed. Heartbeat based techniques differ from probe-and-ACK based techniques in that they eliminate the probing phase to reduce the amount of messages. Several existing studies adopt gossip based protocols, where a node, upon receiving a gossip message on node failure information, merges its information with the information received, and then broadcasts the combined information. A common drawback of probeand- ACK, heartbeat and gossip based techniques is that they are only applicable to networks that are connected. In addition, they lead to a large amount of network-wide monitoring traffic. In contrast, our approach only generates localized monitoring traffic and is applicable to both connected and disconnected networks. As other related work, the study of detects pathological intermittence assuming that it follows a two-state Markov model, which may not hold in practice. The study of localizes network interface failures with a very high overhead: it uses periodic pings to obtain end-to-end failure information between each pair of nodes, uses periodic trace routes to obtain the current network topology, and then transmits the failure and topology information to a central site for diagnosis.

Proposed Work

In this project propose solutions to address the challenge specific sensor networks, to design a fault tolerant, energy efficient monitoring system in a distributed manner. The whole architecture is build upon the poller-pollee structure, where sensors selforganize themselves into two tiers, with pollees in the lower tier and pollers in the upper tier. The pollees send status reports to the pollers along multihop paths, through which the intermediate nodes do the aggregation to reduce the message overhead. Each poller makes local decisions based on the received aggregated packets, and forwards its decision towards the sink. When building the monitoring architecture, we focus on the fundamental tradeoff between the number of monitoring nodes (i.e., pollers) and the false alarm rate. To balance the tradeoff between the number of pollers and false alarm rate, we propose a distributed deterministic algorithm. To increase the energy efficiency and reduce the monitoring overhead, we take the hopby- hop aggregation opportunities in sensor networks. Overall the proposed work advantages are optimal aggregation path to minimize the transmission energy, to increase the energy efficiency and reduce the monitoring overhead and it is nontrivial to determine which aggregation path should be used in order to achieve better aggregation.

SYSTEM MODEL

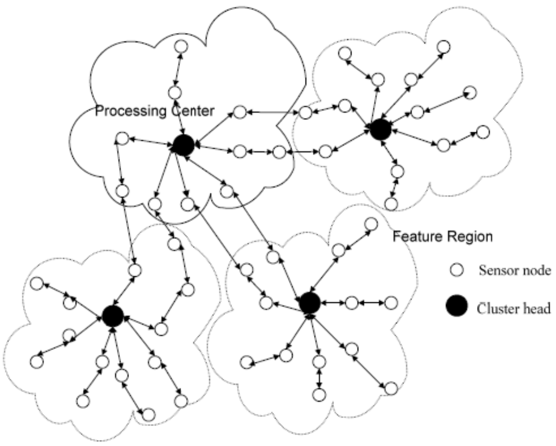

Figure 1 : Architecture of Cluster formation

Modules

- Network setup
- Link Creation
- Aggregation
- Aggregation Aware Monitoring
- Location Estimation

1. Network Setup

The two widely used operational modes of the poller-pollee structure, where each poller can either poll the pollee and wait for a reply (i.e., reactive mode) or let the pollee send reports periodically (i.e., proactive mode). As the proactive mode cuts the monitoring traffic by half compared with the reactive mode.

Link Creation Each Link is a logical link, which could be multiple hops of physical links. As a result, the status reports destined to the same poller have the opportunity to be aggregated at every intermediate node.

2. Aggregation

To do aggregation, each intermediate node may have to wait for reports to arrive from the downstream nodes. Due to the regular pattern of the monitoring traffic, the aggregation rules can be well defined without adding extra delay. The poller, pollees, and the physical link between them form a tree. If a node is at the edge of the tree, it is called an edge node; otherwise it is called a non-edge node.

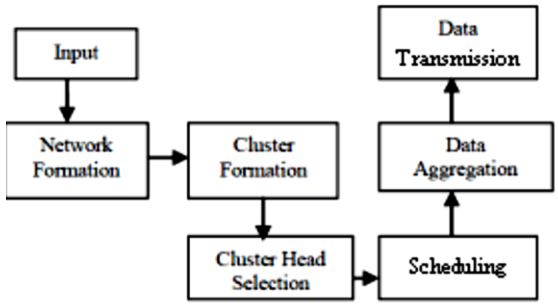

Figure 2 : System Architecture

3. Aggregation Aware Monitoring

The Aggregation Aware Monitoring can be simply stated as follows. Each pollee schedules a report to the same poller every t. Each non-edge pollee collects reports from each of its children and sends an aggregated report (including its own) to the same poller every t, with the aggregation ratio s; Each poller makes the decision about each pollee's status every Td, and informs the sink when necessary. It is required $t \leq Td$.

4. Location Estimation

By localized monitoring, Node only knows that it can no longer hear from other neighbor nodes, but does not know whether the lack of messages is due to node failure or node moving out of the transmission range. Location estimation is helpful to resolve this ambiguity based on location estimation, N1 obtains the probability that N2 is within its transmission range, finds that the probability is high, and hence conjectures that the absence of messages from N2 is likely due to N2's failure; similarly, N1 obtains the probability that N3 is within its transmission range, finds that the probability is low, and hence conjectures that the absence of messages from N3 is likely because N3 is out of the transmission range. The above decision can be improved through node collaboration. For instance, N1 can broadcast an inquiry about N2 to its onehop neighbors at time t + 1, and use the response from N4 to either confirm or correct its conjecture about N2. The above example indicates that it is important to systematically combine localized monitoring, location estimation and node collaboration, which is the fundamental of our approach. The false alarm results from the lossy nature of the wireless links. The failure characteristics of the wireless link has been studied by analyzing the packet traces over the real sensor test bed. Due to the observed bursty and transient error pattern, the wireless link can be modeled as a continuous time Markov chain we have established the relationship between the false alarm rate and distance. As our work focuses on how to build a poller-pollee architecture, it is independent of the underneath link model. Therefore, we take the result of and apply it here. Assume the link failure rate is fl, and use F(h, Td)to denote the false alarm rate when the pollee is hhops away from the poller, and the detection timer at poller is Td.

III. RESULTS AND DISCUSSION

The Minimum Poller Selection Problem

In this section, we formulate the poller selection problem as NP-hard and propose distributed algorithms.

A. Problem Formulation

We consider a network of n sensors, where all sensors are capable of being either pollers or pollees. At first hand, we want to select the minimum number of nodes as pollers so that the management cost of pollers can be minimized. On the other hand, if the number of pollers is too small, some pollees will be many hops away from a poller, thus increasing the false alarm rate. Therefore, our goal is to strike a balance between the number of pollers and false alarm rate. Since the pollers may also fail, we associate each pollee with $\omega \geqslant 1$ pollers. Each pollee maintains pointers to the different pollers but sends status report to only one poller at a time. When the poller fails, the associated pointers should be outdated and the next poller on the list will be used.

B. Distributed Poller Selection Algorithms

The construction of poller-pollee structure shares some similarity with the traditional clustering scheme, where a poller is similar to a cluster head. However, there is fundamental difference between them. First, the traditional clustering schemes are singlehopped, but the pollee should be within some bounded hops of its poller. Second, with multihops between the poller and pollees, aggregation is used to reduce the monitoring traffic, which is not considered in clustering schemes. Third, each pollee may be associated with $\omega \geqslant 1$ pollers to be fault tolerant, whereas each cluster member only has one cluster head. Thus, the traditional clustering scheme is only a special case of the single-hop poller-pollee structure with ω=1. Below, we first propose a distributed deterministic poller selection algorithm, and then present a hybrid algorithm to further reduce the message overhead. 1) The Randomized Algorithm: The randomized algorithm is presented as a baseline for comparison. Each node elects itself as a poller with probability ρ. Pollers then announce their poller status within k hops. Sensor nodes that did not elect themselves as pollers will be pollees. The randomized algorithm is very simple, yet it may produce some pathological scenario where multiple pollers may cluster together in some area and no poller exists in some other area. To address this problem, we propose a deterministic algorithm.

Algorithm 1 Deterministic Poller Selection Algorithm

```
Input: a graph G(N, E), k1, k2
Output: a Poller Set Ser, a Pollee Set See
Procedure: Determine(k1, k2)
1: Initialize the status and the timer
2: Broadcast locally to get k1-hop neighborhood information
3: if timer not expired then
4:     if id is the smallest among k1 hop unlabeled neighbors then
5:         broadcast pollerID = id within k2 hops, exit
6:         /*Ser = Ser ∪ {id}*/
7:     end if
8:     wait until a packet is received or the timer is expired
9:     if pollerID received then
10:        broadcast polleeID within k1 hops, exit
11:        /*See = See ∪ {id}*/
12:    end if
13:    if polleeID received then
14:        update the unlabeled List within k1 hops, reset timer and go to 4
15:    end if
16: else
17:    go to 5
18: end if
```

C. The Deterministic Algorithm

The proposed deterministic algorithm based on the distributed maximal independent set (MIS) algorithm. An Independent Set is a subset of nodes with which there is no edge between any two nodes. The set is a MIS if no more edges can be added to generate a bigger independent set. In the deterministic algorithm, the concept of MIS is extended to the multihop environment. Two parameters k1,k2 are used to govern the distribution of the pollers and pollees, to ensure that no two pollers are less than k1 hops from each other and no pollee is more thank2 hops from its poller. That is, the poller set Ser is a k1-hop MIS, in which no two nodes are less than k1hops away from each other.

IV.CONCLUSION

In this paper, we focus on the distributed design of monitoring and aggregation algorithm for wireless sensor network. Based on the poller-pollee structure we first proposed fully distributed algorithms to select the minimum number of pollers while bounding the false alarm rate. Then a greedy aggregation scheme was proposed to reduce the messages overhead due to monitoring. Theoretical analyses and extensive simulations show that the deterministic algorithm can flexibly control the pollerpollee distribution property to bound the false alarm rate, it can reduce the message overhead significantly, and the greedy aggregation scheme decreases the monitoring traffic. As future work, we plan to evaluate our schemes using real-world mobility traces and in scenarios with irregular transmission ranges. Our approach relies on location estimation and the usage of heartbeat messages for nodes to monitor each other. Therefore, it does not work when location information is not available or there is communication blackouts.

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