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Effective fault detection and routing scheme for wireless sensor networks ☆,☆☆

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ABSTRACT

In a wireless sensor network (WSN), random occurrences of faulty nodes degrade the quality of service of the network. In this paper, we propose an efficient fault detection and routing (EFDR) scheme to manage a large size WSN. The faulty nodes are detected by neighbour node's temporal and spatial correlation of sensing information and heart beat message passed by the cluster head. In EFDR scheme, three linear cellular automata (CA) are used to manage transmitter circuit/ battery condition/microcontroller fault, receiver circuit fault and sensor circuit fault representation. On the other hand, L-system rules based data routing scheme is proposed to determine optimal routing path between cluster head and base station. The proposed EFDR technique is capable of detecting and managing the faulty nodes in an efficient manner. The simulation results show 86% improvement in the rate of energy loss compared to an existing algorithm.

1. Introduction

Wireless sensor networks (WSNs) are ad hoc networks that encompass small inexpensive low power devices [1], distributed in large number at a remote geographical region, in office buildings or in industrial plants [2]. A WSN is used widely in such environments for monitoring the environment, which includes air, soil and water, habitat monitoring, military surveillance [3], inventory tracking, condition base maintenance and in many more cases [4].The main components of a sensor node are a microcontroller, transceiver circuits, memory, power source and one or more sensors. The microcontroller is mainly responsible for data processing and managements of other components of sensor nodes [5]. Transmitter and receiver are combined in a single device known as transceiver. Transceiver is responsible for data receiving and data transmission. The most relevant kind of memory is on-chip memory of a microcontroller. Low capacity memory chip is used for data buffering. The power is stored in batteries, both rechargeable and non-rechargeable and these are the main sources of power supply for sensor nodes. The sensor of a node is a hardware device that is responsible for measuring physical data of the parapet which is to be monitored [6].

As the sensor nodes are powered by battery and in turn they have limited power source and at the same time these nodes are deployed at harsh and hostile environment, the sensors are prone to failure. Faulty sensor nodes may cause wrong data sensing, erroneous data processing and incorrect data communications [3]. The faults in WSN nodes occur due to failure of any one of its hardware components as discussed above. Based on various faults node status in WSN can be divided into two types; *healthy* and *faulty* (shows in Fig. 1). A node is defined as *faulty* if its battery power reaches the threshold limit or if its microcontroller does not work or if transmitter circuit of transceiver is not working properly. In a node, if the transmitter

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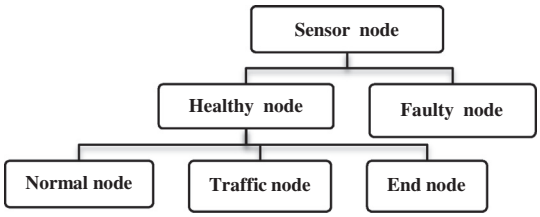

Fig. 1. Classification sensor nodes with respect to fault.

circuit is not healthy, even though all other hardware components are in good shape, the node is declared as *faulty node*. The *faulty node* must be replaced by new node. Otherwise, its responsibility has to be shared by other available *healthy node*. The *healthy node* may again be categorised into three groups: *traffic node*, *normal node* and *end node*. In a *healthy node*, where transceiver is operational but the sensor device is malfunctioning, then we may use this node as *traffic node*. A *traffic node* can act as a router in multi hop wireless data communication. The *normal* healthy node, where all components of sensor nodes are in good shape, may be used for any types of job in WSN. In the *end node*, the receiver circuit of transceiver is malfunctioning, hance it can sense the parameter of the monitoring field and able to transmit data to the base station via other node. However, the *end node* cannot receive the data from any other node. Therefore, it cannot be used as router in WSN. In this paper, we have proposed a cellular automaton based faulty network management scheme. The CA is installed in all the nodes, which work on the basis of local information. The cluster head takes decision after gathering the fault information about its member nodes' responsibilities and sends them instructions by passing the appropriate CA rules vector. Next, an energy efficient data routing technique is proposed for data transfer using *normal* and *traffic* node with the help of L-system rule.

The rest of the paper is organised as follows: a classification and a comprehensive survey of fault detection techniques in WSNs is presented in Section 2. Section 3 describes the problem formulation. Section 4 describes proposed EFDR approach. Section 5 reports the data routing technique. Experimental results are discussed in Section 6. Finally Section 7 concludes the paper.

2. Related work

Fault detection techniques in wireless sensor network are major domain of research now a days. In the present time, fault detection and recovery is an important topic of wireless ad hoc sensor network. In this section, we will briefly review the existing fault detection approaches in WSN. In the existing fault detection techniques the most important factor is faulty node detection and recovery with minimum energy loss. Fault detection techniques in WSN are broadly classified into two categories: centralised and distributed approach.

2.1. Centralised approach

The centralised approach is most common solution to recognise the defective sensor nodes in WSN. In centralised approach; the central node is responsible for identifying the faulty sensor nodes in WSN. WinMS technique [7] first provides a centralised fault management approach in WSN. WinMS introduces a middle manager sensor node approach with global view of the network. The middle manager continuously monitors the network states with regular time interval. In WinMS, a predefined fault management policy has been stored into middle manager. The manager node executes corrective and preventive management events according to predefined management policies. In this model, the middle manager detects and localise faulty sensor nodes by analysing anomalies. In WinMS the middle manager node identifies the fault and link qualities with the help of topological information and the energy information of nodes. Other centralised fault detection techniques in WSN are described in [8]. The WinMS and other centralised approaches are suitable for certain applications of the network. However, these techniques have various limitations. These are not scalable for large size sensor networks. In large size sensor network a large number of nodes are managed by the manager node and thus huge message passing is required. In centralised approach, due to huge message passing, sensor nodes' life time is very small. On the other hand, due to centralised mechanism all the traffic load is directed to the central point because every node is communicated to middle manager node. The middle manager losses its energy rapidly due to large traffic handling. Therefore, distributed fault detection techniques are introduced to overcome the problems of centralised approach.

2.2. Distributed approach

In distributed approach, faulty nodes are identified by local decision-making. Fault detection managers are evenly distributed in the whole network. The main goal of distributed approach is to permit a node to make certain levels of fault detection decision before communicating to the central node. Therefore, a local node can make more decisions. Small number of

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