Providing a Model For Error Tolerant Management in Wireless Sensor Network

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Abstract

The place of network nodes would change in wireless sensor network; therefore, network topology will change over the time. Also, energy resources are limited in those networks and network terminals would be more exposed to physical risks because they are mobile network. Error tolerant plays a significant role in designing these networks. In order to design an error management system for wireless sensor network, it's necessary to classify and model different errors regarding these networks. So, it is necessary to provide a model that can depict and trace errors on different level of wireless sensor network so that we can reorganize the network upon it. It would be possible that existing data in the network don't reach the destination for many reasons such as, radio interference, lack of synchronization, checking the battery, or disconnection between nodes. In this paper, we will study and classify errors in wireless sensor network specially the network nodes. We would also provide a classification of the wireless sensor network components and error related to any of those components, which previously a few details have been discussed about it. Then, we propose an fault model by studying the errors and evaluating errors of different components of wireless sensor network.

Key words: error tolerant, wireless sensor network, hierarchical error model

Introduction

A wireless sensor network is consisted of a large number of senor nodes widely distributed in the environment and collect information from that environment. By the way, protocols and algorithms of sensor networks must have the ability of self-organizing. The other unique feature of sensor network is their ability to collaborate and coordinate the sensor and nodes. Each node has a processor on its board and first, it does a series of primary and simple processing on its obtained information and then it sends semi-processed data instead of sending all the raw information to the center or to the nodes in which is responsible for information processing and conclusion. Indeed, potency of wireless sensor network is their ability to use a large number of small nodes that can be assembled and organized and be used in various cases like simultaneous routing, monitoring environmental condition, health structures and equipment of a system. The nature of the communication and data delivery in sensor networks is inherently unpredictable and prone to failure.Therefore, it would be essential to provide error tolerant techniques for distributed sensor applications [2]. Error tolerant plays a significant role

in supporting the use of distributed sensors as well as other performance criteria such as energy saving, latency and accuracy and it has the ability to preserve the sensor network's feature without any interruption due to the failure of sensor nodes. There are some good solutions of error tolerant for these failures, but they have been proposed for a certain level of network. Thus, there is no comprehensive model for identification and modeling of different levels of the network (all levels). Some methods have addressed hard ware failures and some have been only focused on error detection in the communication paths and the others have examined clusters and intra-clusters. This paper would provide a comprehensive model for identification and modeling failures in different levels of network. The paper is organized as follows: wireless sensor network components have been examined in section 2. In third section, the proposed model troubleshooting for these networks is defined and the hierarchical model for analyzing the reliability of sensor networks would discussed in forth section, and section 5 is the conclusion of the paper.

2. Wireless Sensor Network Components and Their Errors

Layers of sensor networks are: nodes, communication paths, sink and base station. An error in any layer of network may lead to some errors in upper layers. Finally, if the application in control station where the data of the wireless sensor network are given to the user gets in trouble due to a bug in software or in hardware, all the system will get into trouble. We will focus on errors that might occur from nodes to sinks [4].

2-1. Nodes Errors

Node is one of the main components of the network consisting sensors, processing unit, wireless transceiver, power supply and memory unit. Each of hardware and software components can work improperly and leads to a node error. We will examine errors of every component in this section [5&6].

a) Errors of Power Supply (Battery)

- Resource limitation: when the battery of a node reaches a certain level, the sensor may make a mistake resulting in hardware problem and also software ones.
- Finishing of the battery life: short battery life is due to energy limitation and makes it flat.
- Battery reaches the initial threshold and crossing it: once the battery reached a critical level, running condition has been transferred and the farthest node has controlled the condition and the node would fail.
- Battery voltage changes: the required battery voltage would not provide for proper action of the sensor.

b) Errors of the Senor Unit

- Non calibration of the sensors: the sensors designed by hardwares
- Offset error: caused by calibration error, which makes the sensors different to a fixed amount.
- Environmental factors: some effects such as temperature, humidity, soil moisture, solar radiation, pressure, etc. are involved in sensor effectiveness.
- Downtime and interruption of the sensor: sensor lifetime may terminate for natural reasons or due to completion of power.
- Lack of coordination between sensors: the sensors report location and the time they feel to the sink node, it is clear that if the sensors do not have a common time scale, for example, they do not match or not parallel, will not be properly estimated. By the way, the incorporation of the network data would be resulted through a lack of interaction between the accuracy (long) distance between the sensor reading and the number of sensors ending in failure.
- Finishing the power supply of the sensor, causing it to be disabled.

c) Errors of the memory unit

- Memory limitation: nodes may not have enough memory to store the code for all potential services.
- Lack of coordination: To avoid redundancy, between the sender node should co-ordinate with the amount of data sent to the memory.
- No overhead or memory overflow
- The fragmentation of the memory functional domain: If there is a free block in the address domain, which is limited by the domain, causes scattering the memory functional domain; this can limit artificial resources because the blocks making it are not assignable to the main core.
- Create a bug in memory: removing the operators and memory core due to lack of protection of the troubled activities can causes data loss. Bugged modules can also destroy other modules' feature and status.
- Breakdown of the memory blocks: this would vary what can be read into the memory with the actual data.
- Whole memory failures: failures that led to memory loss and impossibility of the memory use.
- Finishing of the battery power supply.

D: Errors of the processing unit

- Low Bit Rate: practically, because of other limitations, rate of information processing in the nodes, is relatively low.
- Lack of coordination of the programs and operations : some of wireless sensor network applications, immediately communicate an event to the sink node, which in turn requires that the nodes are already synchronized at all times.
- Problem in the core of the operating system and software of wireless sensor networks: application error can easily disturb functional status of the system and other software components in nods.
- Finishing Power Supply Processor: hardware power optimization and software is a complex problem, especially is considered a barrier for processor cores.
- CPU failure.
- The loss of the processor flash memory: This memory is used to excite and measure the CPU and save CPU overhead to avoid creating overflow and error. When the CPU is idle, downloads and calculations are done in this area. Therefore, CPU cycles are reduced and the processor speed is increased.

E) Error of the sending unit:

- Lack of coordination of the network receiver interface to receive the message and forwards it to the host domain.
- Problems of wireless communication and the communicative media: nods communication in sensor network is done via the radio media, infrared and optical that in some communications, such as infrared, manufacturing is easier and it costs lower but it acts only in a direct line.
- Noise: it would cause damage or loss to the forwarded data.
- Low Bit Rate: practically, because of other limitations, data transmission rates of the nodes are relatively low.
- Termination or reduction in transmitter energy resources: This leads to weakening of the forwarding signal.
- Loss of sending and receiving data.

2-2. Communication path error

Routing is one of the essential parts of a wireless sensor network which is essential for data collection

from the sensor, configuration and updating software and also coordination among nodes. Errors in routing layers can lead to messages loss or discard. In wireless sensor networks, communication paths between nodes are of too low power. Radio interference can also cause paths between nodes to be erroneous. Other route errors are causal connections between messages and although nods have full communication path, but the message will not be sent to the desired destination. A software bug in the routing layer can cause a wasted rotational direction or send the message to an incorrect destination [7, 8].

2-3. Sink Errors

Sink is a tool placed on the higher layer of the network and collects all the data generated in the network and transmits it to a monitoring and control system. This unit does not have much different with nods. As the matter of fact that sink is in charge of receiving the data and transmitting them to the task bar and does not need processing the data, with only a stronger receiving and transmitting unit rather than nodes and in most cases it doesn't have sensor unit, but in some cases, the better to cover an area and save the number of nodes, nods are also used ad sensor. Sink components can be prone to error. When these components fail, an error occurs in large networks that the data generated by the nodes, is not available. For example, the energy of the sink is very important, if a nod loses its battery, no data will not reach the base station; so, some solutions have been proposed for solving this problem, for instance, solar cells are used in hot and dry region and in some cases when the solar cell is not useful, satellite communications are used [9].

2-4. Base Station Error

The system is a computer or can even be a digital recorder such as a DVR having the task of recording changes in their security systems or controlling the amount of radiation in the radiation control system [9].

3. Proposed Fault Model for Wireless Sensor Networks

In this section, we propose a fault model by the studding error components of wireless networks and classifying them. This model not only describes the whole network's error but also the flaws in the sub-systems. The model includes five classifications: crash, omission, timing, value, arbitrary.

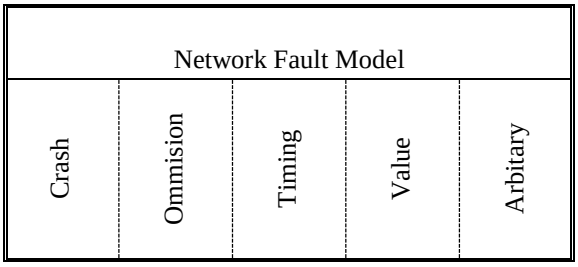

Figure (1):the fault model for wireless sensor network

Here, according to the types of errors and the proposed model, the components of a wireless sensor network can be modeled as follows:

Table (1): error model of wireless sensor network

Back-end	Sink	Network	Node	Defects / Error type
Application or communication failure	Deterioration of the sink because of its components failure	Communicative link disconnection	Node corruptions	Crash
×	Noise in satellite communications	Radio parasite	Resource constraints Noise and parasite Create a memory bug	Omission
×	lack of synchronization components of nodes with other nodes	No synchronization of the communication lines	Lack of synchronization components of nodes with other nodes	Timing
Loss of data due to crash	Damage of the sink data because of the failure of one of its components	The impact of noise in the communication channel signals	Failure memory blocks Limited energy source Noise in the transmitter	Value
Other failures	Other failures	Other failures	Other failures	Arbitrary

Table(2): model of node error in wireless sensor network

sender	**processor**	**memory**	**sensor**	**battery**	Failure place / Default kind
Failure of sender unit Check the power source	Processor failure Check the power supply	Memory failure Check the power supply	Downtime and outages Check the power supply	End of life	Crash
The problem of communication media Noise	The problem of the core OS	Performance range Create bugs	Failure to calibrate the Environmental factors	Resource constraints Voltage changes	Omission
Lack of coordination with the receiver interface Low bit rate	Low bit rate The lack of coordination of programs and operations,	Lack of coordination between the number of nodes and data	Lack of the coincidence of the detectors	Lack of synchronization with node components	Timing
Noise	Program problem	Failure of the blocks	Offset error	×	Value

Other failures	Other failures	Memory limit Overflow Other damage	Other failures	Crossing the threshold Other damage	Arbitrary

4. Introducing the hierarchical error model for wireless sensor networks

Now, we are able to provide a mode for identifying the errors in different layers of the network. As it was mentioned in section 2, there is an increasing trend in the possibility of error propagation in wireless sensor networks.

We use a hierarchical model to analyze the reliability of a sensor network. First, based on the model, for each component, we model the element errors. Then connect all the components together to create a larger model. In this model, when we look at network from outside, there can be one of the reasons for the network failure: Failed to main canals, the failure of clusters or malfunction of the base station. In this way, we assume a network of high-level, consisting of three subsystems: the channels (channels of communication), and base station clusters (clusters). Now, we will examine each of the subsystems, how to identify, address and encrypts them.

4-1. Cluster Subsystems

Network is the number of clusters. Each cluster has an identification code that we show it by CLi meaning the cluster i. Zero node on each cluster, is the head cluster's node. Hence, the network of 10 clusters is shown in Figure 2 in the lower layer.

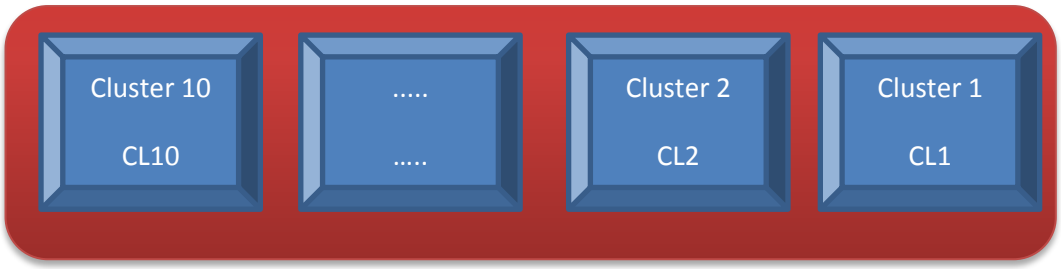

Figure 2: Clusters' subsystems of the wireless sensor network from outer look

Each cluster has a number of nodes. Nodes in the cluster k are named as N_{x-k} where x is the number of node in that cluster. On the other hands, nodes in each cluster are associated with each other or the cluster head through a channel. in the network each node, has some components including the sensor unit, feeding unit, memory unit, sending and receiving unit and the processing unit. Each of these components can work incorrectly and cause the faulty node. In the next layer, each nodes of an identified cluster can be displayed.

4-2: Subsystems of the communication path

There are some communication channel between workstations and nodes of network clusters in wireless sensor network which is essential for collecting data from sensors, software updates and configuration and cooperation between the nodes, when the routing errors in the communication path can lead to the loss of network signal and thus the network would be damaged. L is considered to be the channel ID. Channels in the clusters were reviewed in the previous section in cluster sub-systems. In this part , sub-channels is the main channel connecting the cluster head to the base station. It is assumed that each base station has a number which is *BSj* and for each link, the cluster head *i* with the base station *j* is represented by identification code L (BS_j-CL_i). This can be illustrated in the form of sub-channels in figure 3.

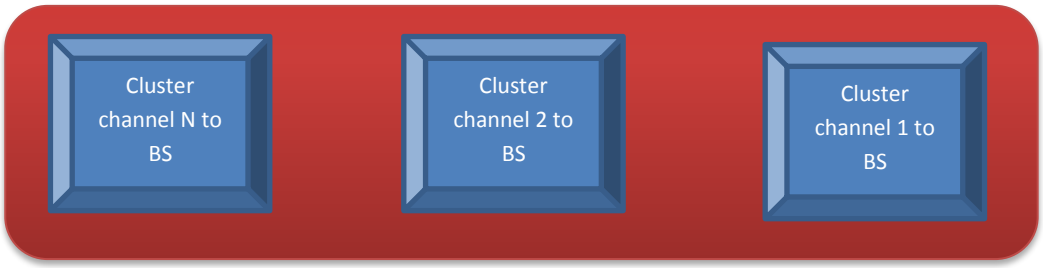

Figure 3: sub-system of the main channel from outer look

3-4: Base station subsystem

Base stations are networking tools and holes where collecting all production data on the network and transferring them to the network controller, and can be prone to error when the tool is broken, a failure of the network at large level will be occurred, So that the data is generated by the node will not be available. The wireless sensor network can have more than one base station depending on its extent in order to speed up the dissemination of information on the network and transmit each information cluster to the nearest base station. Base station identification code is shown by the *BS-i*, while *i* is the number of base stations. Therefore, for a network having two base stations, we will represent figure 4 at a lower level.

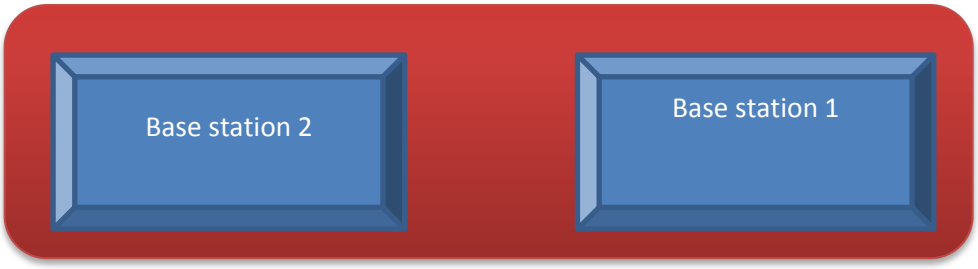

Figure4: base station subsystem from outer look

4-4: Error management model

To review the hierarchical structure we use the fault tree model. A fault tree for a network depict ways of a network failure and includes a collection of a number of gates and the number of events that the occurrence of any of these drawbacks can be found on the probability of each fault and troubleshoots the network systematically. In addition, the reliability of the system can be acquired by a fault tree, and came to the conclusion that if the reliability of the system increases; the error in the system will be reduced. When error detection is done by using a detection tree, a hierarchy is defined to identify the failed node.

5-4: Results and discussion on results

In this paper, some techniques were studied to deal with wireless sensor networks. Limited resources and features needed to take care of the network design at the time of installation and also operation of these networks have been assessed. We began with a classification of sources of error in wireless sensor networks and on the next step, various infrastructure were studied to manage the sensor network. Since the error management techniques in wireless sensor networks differ from traditional networks, scalability, mobility, and timeliness of these networks were also considered.

Also we have introduced a comprehensive and hierarchical model to analyze the reliability of the sensor nodes and wireless sensor networks. Our model can recognize the software error and sensor node hardware, clusters' error and base station and also channels errors. Error propagation in each of the hierarchy of the network is upwarding. Since the

nodes are the main components of the network and their limitations can affect other parts of the network, we have mostly focused on the nodes and detecting their fault. So that any damage to each component of the node, error management system will remove it from the network or it is replaced with other node in the network. Then, an error management system is separately created by the tree for each node, and finally to a set of nodes (clusters), as well as links and base station. Fault Tree is able to track defects and errors that caused the failure and identify them.

We have done a simulation with NS2 testing for an arbitrary topology of the network. Simulation results show that a hierarchical approach is an effective way because line management, traffic control and scheduling of packets can be controlled.

5. Conclusion

There is no priority for clusters in the model proposed in this paper, while in practice some of clusters have priority. Modeling such case with static fault tree is impossible and it must be modeled by dynamic fault tree. On the other hand, given that redundancy is one of the error recovery techniques, reservation is not considered in the proposed model. In practice, some of the links, nodes, and clusters may be supported with a reservation Hierarchical model for such a situation is a dynamic fault tree including hot and cold reservation gates.

In this paper, only a model was proposed. The solution for the entire network reliability by failure rate of the network components could be included in another study.

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