Fault Tolerance in Wireless Sensor Networks using Stiffed Delaunay Triangulation

Abhinandan Gupta
Department of Computer Science & Engg.
Thapar University
Patiala,Punjab, INDIA
aguptas078@gmail.com

Rinkle Aggarwal
Department of Computer Science & Engg.
Thapar University
Patiala,Punjab, INDIA
[2]raggarwal@thapar.edu

Abstract: In this chapter, we introduce fault tolerance in Wireless Sensor Networks. Firstly, we start with a short description of sensor networks, fault tolerance and its different techniques. Then we discuss the different phases of fault tolerance (fault models, fault detection and identification at five levels of abstractions (physical, hardware, middleware, system software and applications) and four scopes (components of individual nodes, individual node, network and the distributed system). The technical cores of the chapter covered various coverage strategies to make the system fault tolerant. We conclude the chapter with a brief survey of the future directions for fault tolerance in Wireless Sensor Networks.

Keywords: Fault Tolerance, Sensor networks, Coverage, Triangulation.

I. INTRODUCTION

Wireless Sensor Network is one of the active field in network research. Wireless Sensor Networks comprised of number of numerous sensors and they are interlinked or connected with each other for performing the same function mutually for the sake of checking and balancing the environmental factors. It provides a bridge between the real physical and virtual worlds. It allows the ability to observe the previously unobservable at a fine quality scale over a big temporal scales. These sensors which are used collectively for performing a function are distributed spatially, otherwise it is difficult for the sensors to perform cooperatively to play a role in monitoring. Scientists develop wireless sensor networking on the bases of inspiration from the application known as battle field surveillance which is completely a military application [4] . To reduce the cost and time of the deployment process, simulation is a preferred job before testing with real hardware. Presently, wireless sensor networks are beginning to be deployed at an accelerated pace. It is not unreasonable to expect that in 7-12 years that the whole world will be covered with wireless sensor networks. This can be considered as the web becoming a physical network. This new cutting edge technology is excited with unlimited potential for numerous applications.

II DEVELOPMENT IN WIRELESS COMMUNICATIONS

A Wireless Sensor Network is composed by a large number of sensors sensing the self-powered nodes. Development of sensor nodes with sensing, data processing and communicating abilities in the components at low cost, low memory, low power consumption, low dimension and also at low computational power.

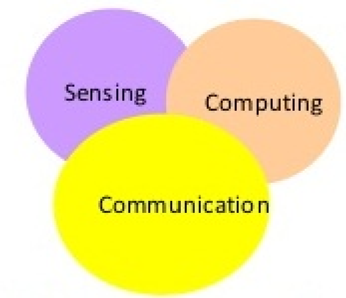


Figure 1: Major issues in WSN

A. Fault Tolerance in a Sensor Networks

Fault tolerance is an arrangement that prevent a computer or network device from failing in the event of an unexpected problem or error. Basically, it is the ability to bear on the delivery of expected services despite the presence of fault caused errors within the system itself. To make a system fault tolerant requires that the user or company to think how a computer or network device may fail and take steps that help prevent that type of failure[8].It targets at the avoidance of failures in the presence of faults. Errors are detected and rectified and permanent faults are located and removed while the system delivers its acceptable services.

1. Fault: A fault is a violation of a systems underlying assumptions.
2. Error: An error is an internal data state that reflects a fault.
3. Failure: A failure is an externally visible deviation from specific instructions.

B. Fault Models

Fault Model is a designed model of a thing that could go wrong in the development or manufacturing of a piece of product or equipment.

a. Stuck at: Where the logical value on interconnect gate is permanently set to a value stuck at one or stuck at zero.
b. Bridging: Where two or more adjacent signal lines are physically connected adding either wired AND or wired OR functions depending on the used logic family.
c. Unidirectional: When an error occurs in the same logical direction then a certain single failure occurs.
d. Short and open: They correspond to missing or additionally introduced connections respectively.

C. Fault Tolerance at various abstractions of the sensor network

i. Physical Layer: It defines the way of transmitting raw bits rather than logical data packets over a physical link connecting network nodes. The different tasks at this level are encoding-decoding and modulation- demodulation.
ii. Hardware:-Here components can be divided into two groups. First one consists of a computation engine, storage subsystem, and power supply facilities that are all reliable. Another group greatly depends on the surrounding environment i.e wireless radio.
iii. System Software:- It is a program that manages and supports the computer resources and operations of a computer system while it executes various tasks such as processing data and information, controlling hardware components, and allowing users to use application software. That is, systems software functions as a bridge between computer system hardware and the application software . A very important component of system software is the one that supports distributed and simultaneous execution of localized algorithm.
iv. Middleware:- While at the system software level, in addition to the OS of the individual nodes, communication plays the most vital role. Starting with the middleware level the emphasis is shifted toward data aggregation, data filtering and sensor fusion.
v. Application:- Fault tolerance also be addressed at application level. It may be very efficient, while addressing. Another advantage of application level fault tolerance is that it can be used to address faults in any type of resource [2].

III HOW TO MAKE SYSTEM FAULT TOLERANT

One of the main design issues for Wireless Sensor Network is conservation of the energy available at each sensor node. To increase the life span of sensor networks we propose to employ multiple base stations. After that we split the lifetime of the sensor networks into equal intervals of time known as rounds [10].

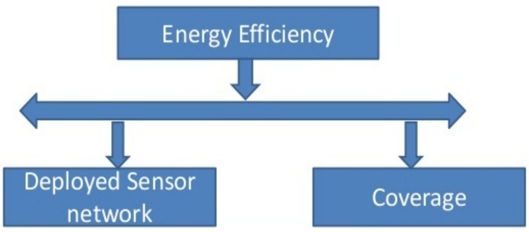


Figure 2: Research fields under WSN

A. Coverage

The most active research field in WSN,s is coverage. Coverage usually depicts as how well a sensor network will monitor a field of interest [3]. We can thought it as a measure of quality of service. It can be measured in so many ways depending on the application. It is very important for a sensor network to maintain connectivity. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. If no rote is there from sensor node to the data sink then the data collected by the given node cannot be processed.

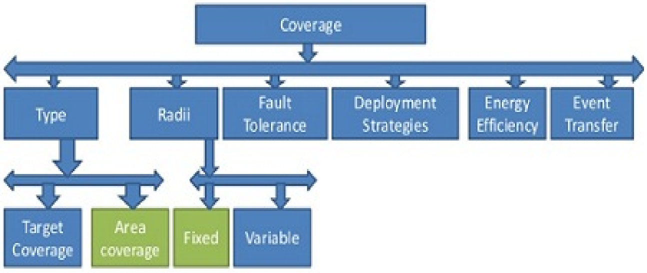


Figure 3: Different attributes of Coverage

B. Types of Coverage

A sensors main function is to sense the environment for happening of the event of interest. Therefore it is one of the main concern in WSN. It is also a key for evaluating the quality of service. It can be divided into three classes:

I. Area Coverage:- Area coverage tells that how to cover an area with the sensors.

II. Point Coverage:- Point Coverage interacts with coverage for a set of points of interest.

III. Barrier Coverage:-Lessen the prob. Of undetected penetration is the main concern in barrier coverage.

C. Coverage Strategies

This section reviews the strategies used in solving coverage problems which are implied during deployment stage. They are divided into 3 categories force based, computational geometry based and grid based [12].

I. Force Based:- These type of strategies rely on the sensors mobility. The sensors will keep running until equilibrium state is achieved.

II. Grid Based:- Grid Points are used either to measure coverage or to determine sensors positions.

III. Computational Geometry Based:- It is used in WSN coverage optimization. The most common approaches used are Voronoi diagram and Delaunay Triangulation.

D. Comparison of Various Coverage Approaches

Coverage Approach	Coverage Type	Problem Objective	Sensor Deployment	Range Sensing	Comm. Range	Algorithm Characteristics
Minimally constrained heuristic	Area	Energy efficiency, Max n/w lifetime by reducing no of working nodes	Random	Yes/No		Centralized
Disjoint dominating sets heuristic	Area	Energy efficiency, Max n/w lifetime by reducing no of working nodes	Random	Yes/NA		Centralized
Node self scheduling algorithm	Area	Energy efficiency, Max n/w lifetime by reducing no of working nodes	Random	Yes/NA		Distributed Localized
Probing based density control algo.	Area	By controlling the working of nodes density	Random	Yes/NA		Distributed Localized
Optimal Geographical Density Control Algo	Area	By reducing the no. of working node	Random	Yes/NA		Distributed Localized
Coverage Configuration Protocol	Area	By reducing the no. of working node	Random	Yes/NA		Distributed Localized
Delaunay Triangulation Coverage Strategy for WSN	Point	Energy efficiency, Connectivity provides active network & less no of ideal nodes	Random	Yes/NA		Distributed Localized
Maximal Support Path Algorithm	Barrier	Worst and Best case coverage paths	Random	Yes/NA		Distributed Localized

Figure 4: Category wise representation of Coverage strategies

E. Why Coverage Strategies?

1. Coverage strategies discussed so far do not open doors for fault tolerance and energy efficiency together.

2. Wireless Sensor Networks are energy forced as they are battery operated, but to provide fault tolerant coverage, the energy efficiency of the network must be maintained.

3. K-coverage strategies proposed are not energy efficient as several sensors reported together, leading to more energy consumption, congestion and collisions in the network [14].

4. It reduces the quality of service and network performance.

IV. Problem Definition

Things to include in Coverage Strategy

a) Event Reporting:- The reporting process is triggered by one or more sensor nodes in the neighborhood which detect an event and report it to the monitoring station[16].

b) Energy Efficiency:- It is a measure of energy used for delivering a given service . Improving it means getting more from the energy that we use. So many ways to improve energy efficiency like Innovation can leads to the equal or greater output with less energy. Ceasing out wasted energy reduces energy needed while maintaining output.

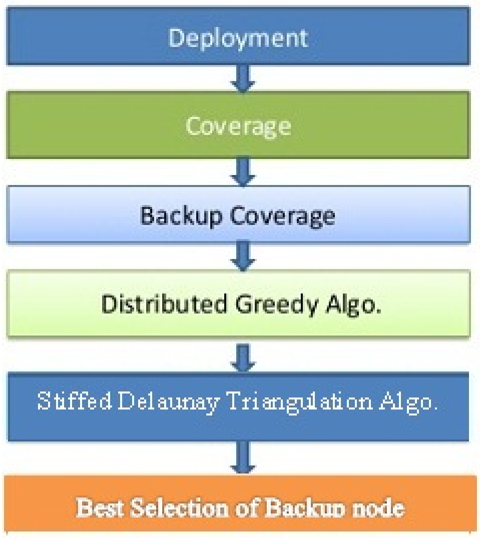
V. Objective

Our goal is to enhances a fault tolerant coverage protocol that combines:

(i) Event reporting with the help of supplementary support structure

(ii) Energy efficiency by reducing the communication between the nodes.

VI. Proposed Work



VII . How to calculate the Coverage Area

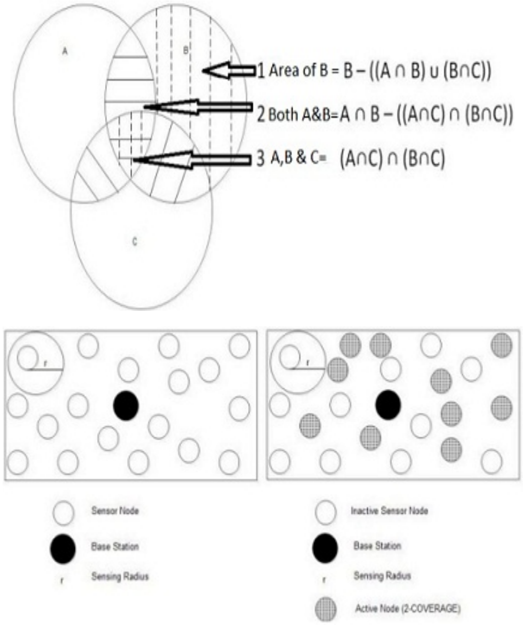


Figure 5: Coverage regions show using the Venn-diagrams

VIII. Proposed Distributed Greedy Algorithm:-

```
Func COV-2(N[])
N [] is the set of sensor nodes deployed
stc[] is the set of sensor nodes providingCOV-2
Where A is the area to be covered
snode = N[x]   : x is randomly selected node
        while (A is not covered)do
        stc[i] = snode
        snode = broadcast()
        snode = recv()
        snode = maxWeight()
        i = i+1
end while
end func
```

A. Proposed Stiffed Delaunay Triangulation Algo.

(a) Construct a triangulation, fix color of every node to white and broadcast all its 1-hop neighbor data using the Neighbour_Packet [9].

(b) Nodes having minId among its 2-hop neighbors' set their color to black.

(c) Every black node chooses a set N of nodes from its 1-hop neighbors using the following procedure.

(i) N=empty

(ii) N1 =distant neighbor

(iii) N=NUn1

(iv) For i=2,3,…..
{
    ni= select ith farthest neighbor
    if ni covers greater than 60 degree angle with n1,n2,……,ni-1
then N=NU ni
}

(d) Every black node adds the stiffed edges to the nodes in N and broadcasts these stiffed edges data using the MSG Stiffed_Packet.

(e) Every white node fix its color=Brown if it is other end of any stiffed edges rec using Stiffed_Packet.

(f) Every Brown node broadcast its stiffed edge data using the control packet Stiffed_Packet.

(g) All white and Brown nodes delete edges connected to it which crosses stiffed edges, this data is broadcasted using edge cross_Packet.

(h) Every Black node places a new edge from the White nodes, from which the edge was removed in last step to from new triangles.

B. Algo. for Choosing Best Backup Nodes

```
Func: BK Select(stc[])
        stc[] is the set of sensor nodes providingCOV-2
Neighbours[] is the set of triangle neighbours of each node
i=0;
while i!stc.end()do
if stc[i].A()= Neighbours[].A() then
backup[j]= stc[i]
PriPot[]= nearest(Neighbours[],backup[j])
PriPot[]= median(Neighbours[], backup[j])
i=i+1
end if
end while
while i!PriPot.end() do
if PriPot.A()= Neighbours[].A() then
backup[]= PriPot[i]
delete(PriPot[i])
end if
end while
end func
```

IX. Selection of Backup Nodes

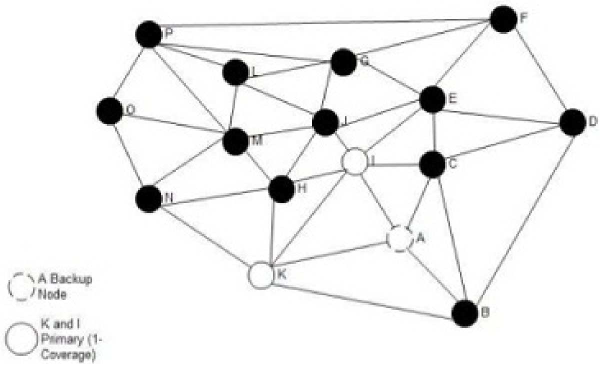


Figure 6: Graph representation of Backup & Primary Nodes

A. Functions of Backup Node

(a) Backup reporting is also done by this node.

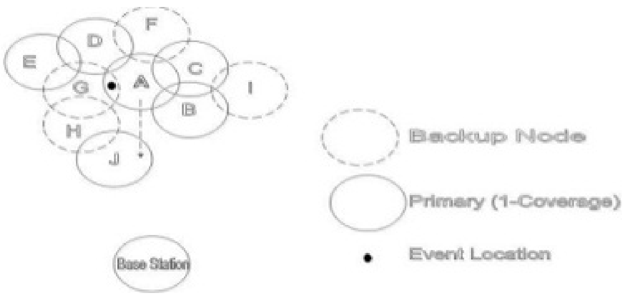
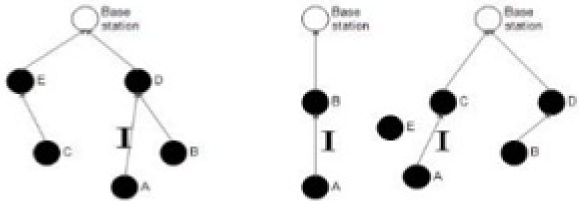
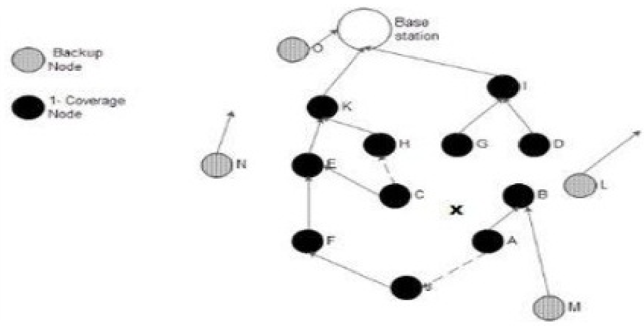


Figure 7:Graph shows F,I,G & H nodes acting as a Backup nodes

(b) Event detection is done by the backup node itself. Many nodes detecting and reporting events to common sender. A node and its sender detecting the event. Channel access issues will also be there during event reporting[7].



A. Handling of all three major concerns backup reporting,detection and access of channels



X. Simulation Results

Parameter	MinPowerValue	MaxPowerValue
No. of nodes	50	50
Area(m*m)	1000	1000
TransmissionRange(m)	175	175
Packet size	512	512
Bandwidth(kbps)	2.4	100
TransmitPower(mW)	14.68	560
ReceivePower(mW)	12.50	395
Sleep Power(mW)	1.2	300
Idle Power(mW)	12.36	350

XI. Future Research Directions

Even though there are quite a number of researches done on the fault tolerance coverage problem of WSN, but still more works need to be done so that a mutual global solution can be achieved. Following is the list of potential research areas:

(a) Better mechanism is required in selecting the minimal number of nodes for our coverage strategy.

(b) How to decrease the latency rate.

(c) By what ways we can lower the contention in the network.

XII. Conclusion

This paper reviews the researches done in maximizing the coverage of wireless sensor networks by sensor positioning. The various strategies are divided into different approaches i.e force based, grid based and computational geometry based. To accommodate a huge WSN with less no. of resources and a dynamic topology, coverage control algo. & protocols perform best if they are distributed and localized. But there is still a need to develop the protocols which provide fault tolerance, event reporting & energy efficiency, so that the network will provide the quality services by using various coverage strategies.

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