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Shortest Reliable path for Wireless Sensor Network

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***Abstract*—Reliability is a one of the main issue faced by sensor network. A node can sense a message from the environment and send the message to sink node. There are number of intermediate nodes between them. If there is failure in intermediate node or compromised node present in the network, the message will be corrupted or the message will be lost so the information cannot be received by the sink node. But the message should be forwarded through another route and that route should be short and reliable. In this paper we propose graph theory concepts to overcome from the node failure or compromised node and find out the shortest reliable path from sender node to sink node.**

Keywords-*Sensor network; reliable; compromised node; shortest path ; graph theory.*

I. INTRODUCTION

Wireless sensor network are developed and used for monitoring the environment. Including environmental monitoring, automatic controlling, and target tracking, sensor network applications all have a data collection task. The reliability becomes one of the most important issues in WSN research. Since wireless sensor nodes are usually deployed in unattended and unfavorable environment.

Wireless sensor nodes will sense the information from the environment in two ways: 1. Event driven 2. Time driven. Event driven means if there is any event happening in the environment senor node will send the information to the sink node. Ex. Forest fire. Time driven means that sensor will sense the environment in prescribed time and send the information to the sink node. Ex. Every 10 minutes it will check the environment. In these time if the intermediate node cannot able to forward a message to sink node.

During the failure of intermediate node or may be a node is a compromised node, sender should select a alternate reliable path and that reliable path should be shortest one also. Failed node can be trace-out by distributed fault detection (DFD) scheme checks out the failed nodes by exchanging data and mutually testing among neighbor nodes in network [1]. Compromised node can be detected by trust model calculation [2].To find an alternate path and direct path between the sender node and all other nodes in the network we use contact networks concepts from graph theory.

II. RELATED WORK

Breitbart *et al.* [3] described a method for minimizing network monitoring overhead based on Shortest Path Tree (SPT) protocol. They describe two different variations of the problem: the A-Problem and the E-Problem, and show that there is a significant difference between them. They also proved that finding optimal solutions is NP-hard for both variations, and propose a theoretically best possible heuristic for the A-Problem and three different heuristics for the E-Problem.

Patrick P. C. Lee *el al.* [4] proposed a distributed secure multipath solution to route data across multiple paths so that intruders require much more resources to mount successful attack. They include a distributed routing decisions, bandwidth-constraint adaptation, and lexicographic protection, and proved their convergence to the respective optimal solutions. In his book [5], Remco van der Hofstad studied random graphs as models for real-world networks. He concluded that, these networks turn out to have rather different properties than classical random graph models, for example in the number of connections the elements in the network make. As a result, a wealth of new models was invented so as to capture these properties.

Reliability modeling for distributed system with wired network [6] proposed a connectivity-based reliability modeling from the perspective of the networks which consider node unit and link unit.[7] evaluated reliability on component based software system.

[8] Proposes task-based reliability modeling by just considering processor unit, and defines a reliability index for a task but it will not cover the system reliability perspective.[9] estimated reliability of GNU complier components. [10] Approaches the reliability modeling from the perspective of the nodes in which task involves and uses the reliability matrix with each element as the reliability of a task to evaluate reliability of a distributed system.

[11] Proposed reliability of object oriented software systems using communication variables.[12] Proposed connectivity reliability of wireless networks, but not considering the reliability modeling.[13] analyzed reliability supported protocols for transferring a message from sensor to sink.[14] proposed an integrated modeling on WSN reliability and security.

[15] Proposed a Bat algorithm to find optimized path between the source and destination and control the congestion in wireless sensor network[16].

III. CONTACT NETWORK

Contact network is a network of interconnected contacts. Every contact network can be represented by a graph, in which the edges are the contacts and the vertices are the terminals. It is an undirected, connected graph G(with no loops) in which each edge has a binary value x associated with it, which can assume only two values, 1 or 0.

The input-output behavior of a contact network is usually expressed in the form of functions

F(x1,x2,x3…xk) of the binary variables. Such function f is called a switching(or Boolean function) and must assume a value of 0 or1. A Boolean algebra consists of a finite set x1,x2…..xk and two binary operation +(called Boolean addition) and .(called Boolean multiplication. Satisfying the following postulates;

1. Either xi=1 or xi=0
2. For every xi there exists another variable x_i' called complement of xi, such that if xi=0,x'i=1, and if xi=1, x'i=0.
3. (a) Sum xi+xj = $\begin{cases} 0, & if\ xi = xj = 0, \\ 1, & other\ wise \end{cases}$

   (b) Product xi.xj= $\begin{cases} 1, & if\ xi = xj = 1 \\ 0, & other\ wise \end{cases}$

With these postulates a we find out the contact between the nodes or link between the nodes. Result of theses we can get an expression then this expression will be translated into transmission matrix.

A. Transmission matrix

The transmission matrix T of an n-vertex contact network, with primitive connection matrix Q, is given by

$$T=Q^{n-1}$$

It will calculate switching function between all the vertices in graph.The transmission matrix T= [tij] of G, where n is the number of vertices, and tij is the transmission between vertices i and j in G. T is a symmetric matrix with every diagonal entry tii=1. The determination of transmission matrix involves enumeration of all paths between every vertex pair in a network.

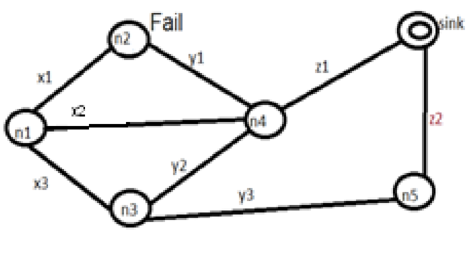

Fig-1 Compromised node in wsn

TABLE I. Transmission matrix

	n1	n2	n3	n4	n5
n1	1	x1+x2y1+x3y 2y1	x3+x2y2+x 1y1y2	x2+x1y1+x 3y2	x3y3+x 2y2y3+ x1y1y2y 3
n2	x1+x2y1 +x3y2y1	1	y1y2+x1x3 +x1x2y2	y1+x1x2+x 1x3y2	y1y2y3 +x1x3y 3+x1x2 y2y3
n3	x3+y2y1 x1+x2y2	y1y2+x1x3+y 2x2x1	1	y2+x3x2+x 3x1y1	y3
n4	x2+y1x1 +y2x3	y1+x1x2+x1x 3y2	y2+x3x2+x 3x1y1	1	y2y3
n5	y3x3+y3 y2x2+y3 y2y1x1	y3y2y1+y3x3 x1+y3y2x2x1	y3	y3y2+y3x3x 2+y3x3x1y1	1

Failure node and the link between the nodes will be detected and we have to avoid them and form primitive connection matrix. Node n2 is a failure node the transmission from other nodes to failure node n2 is through the link x1 and y1. Using transmission matrix we can easily find out the link between the nodes and number of path between the nodes. For example from node n1 to n3 there are three path between them, first one is the link x3, second path is x2y2 and the third path is x1y1y2.

A better method of determining a transmission matrix is from the primitive connection matrix, defined as follows:

The **primitive connection matrix** Q=[qij] of an n-vertex contact network G is an n by n matrix, whose elements qij are defined as

qij =1, for all i

qij =0, if vertices i and j are not directly joined by a contact and any one of the node will be failed node.

qij= Boolean sum of the variables associated with all edges directly joining vertices i and j.

In this paper we apply the concepts of contact network and transmission matrix to sensor network. In fig-1 vertices are represented as a node and edges are represented as a link. Transmission between the failure nodes should be referred as a 0 in primitive connection matrix.

TABLE II. Primitive connection matrix

	n1	n2	n3	n4	n5
n1	1	0	x3	x2	x3y3
n2	0	0	0	0	0
n3	x3	0	1	y2	y3
n4	x2	0	y2	1	y2y3
n5	y3x3	0	y3	y3y2	1

Using this matrix we can find out the reliable path and direct path between the nodes present in the network. Based on

Primitive connection matrix, fig-2 depicts the nodes and transmission between them, link between the failure nodes or compromised node is eliminated. And that path and link will be represented as 0. If there is smaller number of nodes in the network using primitive connection matrix is a enough one to find shortest and reliable path.

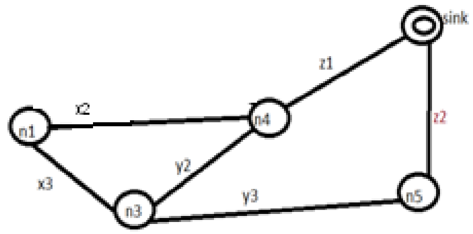

Fig-2 Elimination of Compromised node and link between the nodes.

Based on Primitive connection matrix, fig-2 depicts the nodes and transmission between them, link between the failure node or compromised node is eliminated. If there is smaller number of nodes in the network using primitive connection matrix we can find shortest and reliable path.

If the number of nodes will be a larger then shortest reliable path calculation will done by Dijkstra's algorithm. Using this algorithm we find the shortest path from specified node to another nodes in the network. Here node n1 is a sender and sink will be the receiver.

A simple weighted graph G of n vertices is described by an n by n matrix D=[dij], where

dij = length (or distance or weight) of the directed edge from vertex i to vertex j, dij ≥ 0,

dii = 0,

dij = ∞, if there is no edge from i to j.

In general dij $\neq$ dji, and the triangle inequality need not be specified. That is dij+ djk may be less than dik. The distance of a directed path P is defined to be the sum of the lengths of the edge in P. the problem is to find the shortest possible path and its length from a starting vertex s to a terminal vertex t.

Dijkstra's algorithm labels the vertices of the given graph. Some vertices have permanent labels and other temporary labels at each stage in the algorithm. The algorithm begins by assigning a permanent label 0 to the starting vertex s and a temporary label ∞ to the remaining n-1 vertices. From then on, in each iteration another vertex gets permanent label, according to the following rules:

1) Every vertex j that is not yet permanently labeled gets a new temporary label whose value is given by
   Min[old label of j, (old label of I + dij)],
   In thr previous iteration where i is the latest vertex permanently labeled, and dij is the direct distance between vertices i and j. If i and j are not joined by an edge, then dij = ∞.

2) The smallest value among all the temporary labels is found, and this becomes the permanent label of the corresponding vertex. In case of a tie, select any one of the candidates for permanent labeling.

The first vertex to be permanently labeled is at a distance of zero from s. The second vertex to get a permanent label(out of remaining n-1 vertices) is the vertex closest to s. From the remaining n-2 vertices, the next one to be permanently labeled is the second closest vertex to s

Steps 1 and 2 are repeated alternately until the destination vertex gets a permanent label.

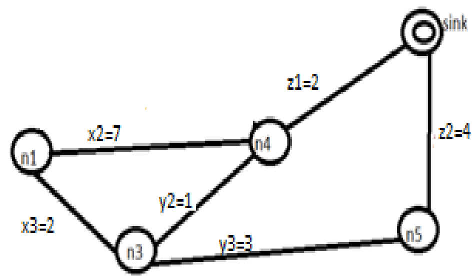

Fig-3 Distance between the nodes

Labeling proceeds as follows

n1 n3 n4 n5 sink

0√ ∞ ∞ ∞ ∞ : Starting Vertex n1 is labeled 0

0 2√ 3 5 9 : All successors of n1 get labeled

0 2 3√ - 5 : Smallest label becomes permanent

0 2 3 - 2√ : Destination vertex get permanently labeled

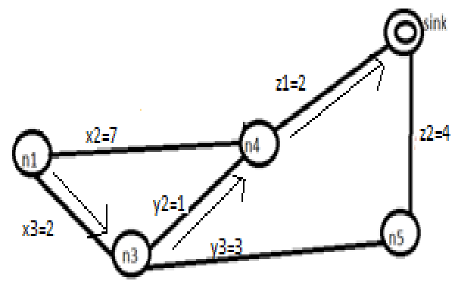

Fig-4 Shortest and reliable path from n1 to sink

Based on the algorithm Shortest reliable path is calculated. In fig-4 shortest reliable path from node n1 to sink is n3,n4.

IV. CONCLUSION

In this paper we calculate the shortest reliable path between the source and receiver. Using transmission matrix we find out the path and link between the nodes and primitive connection matrix will eliminate the link from normal node to failure or compromised node then it will find out the shortest reliable path between all other nodes in the network. For larger network, Dijkstra's algorithm will be applied to the primitive connection matrix to find out the shortest reliable path. In future we will find the reliable path and reliable node by trust mechanism.

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