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A Survey on Partition and Recovery Methods of Node Failure in Wireless Sensor Networks

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Abstract-- The rapid growth in electronics, sensor and communication technology has made it possible to construct the WSN consists of large number of sensors. But the usage of large number of sensors in WSN increases the probability of node failure. The self recovery of the network from these large scale node failures is a challenging factor. A survey has been taken to compare different algorithm and their performance that differs in detecting node failure. The aim is to provide a better understanding of different techniques used earlier. The objective of the proposed method is to detect the sensor node failure in less span of time and to recover the connectivity.

Keywords--- Wireless sensor networks, DSSD, Partition Detection, Route Recovery, Energy efficiency.

I. INTRODUCTION

Wireless sensor network consists of large number of portable sensors placed in the field with the help of wireless communication module. The purpose is to sense, collect and process the information from all the sensor nodes and then sending it for the analysis. Earlier it was used in military surveillance and medical care. But its usage has been acknowledged and is almost used in many fields such as Biomedical, Home Security, Real-time collection of data, tracking forest fire/endangered species and so on.

The sensor node failure may occur due to many factors such as environment, communication factor or battery failure. One of the most challenging problems in WSN is maintaining network connectivity to reliably communicate between sources to a specified sink, in an energy-efficient manner. The partition in the network may lead to memory and power exhaustion in disconnected nodes and network congestion in disconnected segments, such as data loss and wasted resources. Currently many researches are engaged in developing schemes to fulfill the requirements. The aim is to provide a detailed description about the current research issues that has been proposed in this field. Cut detection algorithms attempt to recognize and locate cuts. If a node were able to detect the cut, it could simply wait for the network to be repaired and finds a way to be reconnected, which saves energy of multiple nodes and prolongs their lives. The ability to detect cuts by both the disconnected nodes and the source node will lead to the increase in the operational lifetime of the network as a whole.

Previous work which considered utilizing mobility for networking, assumed mobility to be outside the control of the communication sub-layer. Mobility was either treated to be random, following partially predictable patterns or even deterministic but not controlled. Once the base station determines the network partitioning, one or more mobile nodes are sent through tunneling method. A mobile node is equipped with a radio transmitter receiver so that it can communicate with the sensor nodes. Furthermore, it maintains connectivity with the base station through the wireless sensor network which is explained in [1]. This paper covers two areas, such as Partition Detection and Route Recovery. It talks about the different methods that are proposed to detect partition and various ways to recover connection.

II. RELATED WORKS

Partition is the break in the network which makes the topology to split into two or many parts. This partition may disconnect the communication between the source and the destination. In order to establish a reliable connection, partition detection method is used. Many algorithms have been proposed to find the partition in the network. But it is tedious process.

The basic method of detecting the partition is through ACK. When node sends a message to the other nodes, it expects for its ACK. If it does not receive ACK within a certain TTL period, it is predicted to be prone to failure. Once TTL period is over, it disconnects and starts to search for the other route. This method may not provide the exact prediction of partition since it cannot distinguish whether it is partition or node failure.

Route is the path, which the nodes in the network follow in order to forward the data to the destination. If the connectivity is cut then the recovery process is applied to find the other paths to the destination. This is also a tedious process. Hence many researchers have come up with different Detection algorithms to find the partition in the network and re-establish the connectivity.

III. PARTITION DETECTION

The challenges of the network partition monitoring problem have been emphasized in many papers. The different methods proposed are suitable for different usage of networks. As of today the usage of WSN increases, hence the effective method of finding the failure is more important in order to make the communication faster and reliable.

A. Point-to-Point

This concept focuses solely on a cut that disconnects nodes from the base station. They extend the existing notion of cut detection, and propose an algorithm called Point-to-Point Cut Detection, that enables sensor nodes to autonomously monitor the connectivity to multiple target nodes. It enables each node to determine the connectivity to any destination [2]. There are two steps involved, *cut boundary abstraction* and the *cut detection phase*. The first step, as the name suggests, it collects the information about the boundary of the cut region. This phase uses the probe message in order to locate the cut in the boundary. Upon receiving the probe message if the neighboring node forms the rectangular region of width δ, then the packet is forwarded to the next node. If the rectangular region doesn't exist, then the location is noted and continues with the next phase. The second step, confirms whether the node in the boundary are reachable or not. This method consumes less energy and the lifetime of the node is greatly increased.

B. *DSSD*

The only way to address the problem cuts using linear separation of the nodes from the base station explained in [4]. This algorithm relies on certain duality between straight line segment and points in 2D, which restricts the network to be diploid in 2D plane. The concept of point-to-point is applied in DSSD (Distributed Cut Detection) algorithm, but this enables every node of the wireless sensor network to detect nodes that are Disconnected frOm Source. It enables a subset of nodes that experience Connected, but Cut Occurred Somewhere (CCOS) events to detect them and estimate the approximate location of the cut in the form of a list of active nodes that lie at the boundary of the cut. The base station detects the cuts by monitoring whether it receives the messages from the sentinels. DSSD algorithm is not limited to linear cuts, instead it allows every node to detect if the cut occurs. The DSSD algorithm involves only nearest neighbor communication, which eliminates the need of routing messages to the source node. This feature makes the algorithm applicable to mobile nodes as well. Since the computation that a node has to carry out involves only averaging, it is particularly well suited to wireless sensor networks with nodes that have limited computational capability [6].

C. *ER-CD*

Recently the use of WSN increases; this creates the impact on implementing the sensors with energy efficient manner. The current, state of the art cut detection algorithm [10] suffers from relatively high energy consumption, especially in a dense wireless sensor networks. This is largely due to the cost of communications because every node must broadcast for every iteration of the algorithm. In large or dense networks, it may take much iteration to reach convergence. At the same time the lifetime is also lengthy. This means that notification of significant changes may take a long time to propagate. To solve these problems, Energy-efficient and Robust Cut Detection (ER-CD) proposed to execute a robust cut detection algorithm on a subset of nodes. The predictable topology of this subset is leveraged to provide a malicious node detection scheme and probing routes are used to detect local cuts that might otherwise be missed. The main idea is to partition the network into a grid of clusters. Each cluster elects a leader who executes the cut detection algorithm by exchanging state values with leaders in adjacent clusters. Energy efficiency is improved by the small number of nodes that directly participate in the cut detection protocol. Also, the grid topology restricts the degree of the leaders in the clustered environment to normally no larger than 4, smaller than would be typical in a network where all nodes participate. Since the number of iterations required for convergence is determined by the maximum degree of the network is explained in [7], convergence speed grows rapidly with increasing maximum degree of the network. Maintaining a small, constant degree by using a grid network allows the state to converge considerably faster. Fewer messages are sent, thereby increasing energy efficiency. Despite the additional overhead caused by the introduction of leader election module, the ER-CD algorithm shows high energy savings in dense networks. The message complexity of a typical distributed leader election algorithm is known to be O(nlogn) which is calculated in [9], where n is the total number of nodes. This method provides the faster detection of the cut in the network and is energy efficient.

D. *Distributed Partition Detection*

When there is damage in the WSN, a particular sensor is not able to send its reading to its upstream neighbor. This can be easily determined at the MAC layer when the packet is not ACKed . The node can define a certain timeout period, and when this time expires, it can decide that its upstream neighbor is failed. This technique has been used in many protocols for WSNs and mobile ad hoc networks. The search of the alternate route based on the leader selection is proposed in [1].

During the search of alternative paths, nodes with the same failed upstream nodes may respond assuming that they still have a valid path through the sink node. To overcome this problem, downstream nodes must be invalidated to restrain them to falsely send route replies. This can be achieved by invalidating downstream nodes and postpone the NEWPATH queries to allow the invalidation to be completed. Therefore, upon failing upstream node,

INVALIDATE message is sent to downstream nodes before issuing NEWPATH message for this purpose. Note that if this message is failed to be received for any reason by a downstream node, it may still assume that it has a valid path to the sink node and thus may falsely respond to any NEWPATH requests with a RREP. In this paper, they assumed that the message is safely received at MAC layer. After receiving a route reply and establishing the route to the sink node again, downstream nodes must be validated. Otherwise, the downstream nodes will continue sending periodic RREQ messages to search for new routes. In case of VALIDATE messages, each node is responsible for informing its downstream neighbors starting from the very first node which initiated the detection process.

IV. RECOVERY

The rejuvenation of the failure nodes are done in many ways such as using relay nodes, robot sensors and so on.

A. Mobile Node

The restoration of the connectivity can be done by placing the mobile nodes. By considering the degree of connectivity with neighbors, a mobile node finds the proper position where to stop in order to re-establish connectivity. A joint mobility and routing algorithm which comes close to the upper bound scenario was explained in [5]. Minimizing energy consumption is an important challenge in mobile networking. Efficient designing of a network in a way efficiently utilizes the energy of nodes to prolong the lifetime of the network. Since communication consume significant amount of battery power, sensor nodes should spend as little energy as possible when receiving and transmitting data. One form of energy saving technique is the grouping of sensor nodes into clusters. A novel algorithm is developed to efficiently communicate the intrusion information to the Cluster Head with less usage of nodes resources thus extending the life time of the network [7].

B. Robot Sensors

An actuator is a device to convert an electrical control signal to a physical action, and constitutes the mechanism by which an agent acts upon the physical environment. The term actor represents the heterogeneous devices such as robots, unmanned aerial vehicles (UAVs), and networked actuators such as water sprinklers, pan/tilt cameras, robotic arms, etc. The number of sensor nodes deployed in studying a phenomenon may over hundreds or thousands. However, such a dense deployment is not necessary for actor nodes due to the different coverage requirements and physical interaction methods of acting task. In WSANs the number of actors is much lower than the number of sensors.

C. Distributed Method

Once the partition is detected, the nodes initiate the recovery process. Considering the fact that every single node in network claims the start of the movement to fix the problem this distributed method was proposed which is explained in "Reference [1]". The goal of the approach is to limit the node movements by picking the best candidate as the leader to replace failed node and thus avoid redundant node movements. Leader node is selected by utilizing the NEWPATH messages. Upon receiving a NEWPATH message, a node learns the essential location information of the node which issued the NEWPATH message and its distance to the failed upstream node. Then the node decides whether it is closer to the failed upstream node than the node issued the NEWPATH or not. It was argued that even in the case of multiple leaders acting in different k-hop neighborhoods, the network connectivity will be restored [1]. This is because each leader will initiate a movement and this will be independent of the movement of other leaders as will be detailed in the next subsection.

When the leader is selected, it will initiate the recovery process by moving gradually towards the location of the failed node which used to be the upstream neighbor of the node that issued the NEWPATH message. While the first movement destination is obviously the position of the failed upstream node, in case of the inability of communication with the sink node, further relocations must be performed. This continues by the leader node until hitting a node which is within the transmission range of the sink node. When the leader node relocates, we need to ensure that it does not lose connectivity with its downstream neighbors.

V. COMPARISION

The different partition and detection methods have been compared and the results are postulated in the form of table 5.1 in accordance to some of the performance metrics.

1) *Recovery delay*: This metric measure the time it takes to find and establish an alternative route to the sink in case of node failure.
2) *Total message Overhead:* This is to assess the message overhead of the partition detection algorithm on sensors.
3) *Energy Efficiency:* This metric implies the conservation of the energy of the node in order to extend the lifetime of the nodes in the network.
4) *Total movement of the nodes:* This metric measures the cost of recovery process in terms of total movement performed by the nodes. Movement cost is assumed to be covered by the battery of the node.
5) *Distance Travel:* This metric is assessed to find whether this algorithm is to be applied for the shorter or longer range in the network.

TABLE I
Performance Metrics Comparison

Main Classification	Method	Recovery Delay	Message Overhead	Energy Efficiency	Total Movement	Distance Travel
Partition Detection	DSSD	Fast	Does not occur	Yes	Less	Small
	Point-to-Point	Slow	Occur	No	More	Large
	ER-CD	Fast	Does not Occur	Yes	More	Small
	Distributed Partition Detection	Fast	Occur	Yes	Less	Large
	Robot Sensors	Slow	Does not occur	No	Less	Small
	Node Replacement Algorithm	Fast	Occur	Yes	Less	Small
	Distributed Method	Fast	Occurs	No	More	Large

VI. CONCLUSIONS

By comparing the most previous studies, it shows that many algorithms restrict their working conditions. The proposed method has overcome all the restrictions which was encountered by the previous methods. Considering the possibility of network partitioning where the sensors are not able to transmit their readings to the sink, the approach first detects such a partition and then strives to fix the partition by relocating some of the mobile sensor nodes. The distributed heuristic is based on maintaining the route information at each node to the sink and then utilizing such information for the relocation of the sensors. The proposed method can achieve high accuracy, reduced overhead and less recovery delay when compared to all existing methods.

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