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A review on node recovery techniques, RIM and LDMR, used in WSNs

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Abstract : *In this paper we have studied Node Recovery in Wireless Sensor Networks (WSNs) and analyzed and reviewed two very interesting node recovery techniques; Recovery through Inward Motion (RIM) and Least Distance Movement Recovery (LDMR). We have compared both the techniques based on different performance metrics and presented the results.*

Keywords:-*WSN, Node Recovery techniques, RIM, LDMR, Survey*

I.Introduction

I.I. Introduction to WSN

Wireless Sensor Networks (WSNs) or sometimes also mentioned as Wireless Sensor and Actor Networks (WSANs) are a spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location. Fault tolerance is one of the critical issues in WSNs [1].The development of Wireless Sensor Networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring etc.

WSNs are built of “nodes” or “actor nodes” ranging from a few to several hundreds or even thousands, where each node is connected to one or sometimes many sensors. Each such sensor network node has typically several parts; a radio transceiver with an internal antenna or connection to an external sensors and an energy source, usually a battery or an embedded form of energy harvesting unit.

The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

The main characteristics of a WSN are:

- Power consumption constraints for nodes using batteries or energy harvesting.
- Ability to cope with node failures
- Mobility of nodes
- Heterogeneity of nodes
- Scalability of large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use
- Cross-layer design

I.II. Node Failure and Recovery

WSNs are practically deployed in harsh environmental conditions like in areas where there are abrupt and/or very high temperature variations, very high or low pressure and/or corrosive chemical fumes, very high or low humidity etc. Initially, node with the maximum residual energy in a cluster becomes cluster heed and node with the second maximum residual energy becomes secondary cluster heed [3].These areas are extreme for humans to monitor but are required to monitor as in case of a chemical plant or some border area surveillance etc.

In such extreme conditions it is not rare for a sensor node to fail, and in fact these kinds of node failures are very common in WSNs deployed in such conditions. The failure of a node can have many reasons. A node can fail due to power loss (died battery or if energy harvesting system fails to harvest sufficient amount of energy), hardware or software failure. In any case, the loss creates an area with no surveillance which is not safe in areas with potentially high dangers like nuclear reactors or border areas.

In static network, it is directly not possible to recover a failed node. . Since Actors have to coordinate their motion in order to keep approachable to every node, a strongly connected network is needed all the time [5]. In these cases, a backup mobile node system is therethat can move and replace the position of the failed node. In most cases, this is practically not feasible. Instead, the WSNs are comprised of mobile nodes which are capable of moving and in case of a node failure, all the nodes move in a pattern to cover up for the loss.

Over the years most of the research in area of node recovery in such WSNs focused mainly on minimum movement of other nodes in order to optimize the network motion and cover maximum region covered by failed node at the same time. In all the cases, it is practically a tradeoff between the optimal network motion and maximum area covered.

II. Related Work

Yenegur et al.[1] authors are discussing about the sensors in a wireless sensor networks (WSNs) are having tendency to fail, due to the energy depletion, hardware failures, environmental conditions etc. Fault tolerance is one of the critical issues in WSNs. The existing fault tolerance mechanisms either consume significant extra energy to detect and recover from the failures or need to use additional hardware and software resources. The proposed algorithm enhances the lifetime of a sensor nodes shut down and it depends on ladder diffusion algorithm combined with the genetic algorithm. It can result in fewer replacements of sensor nodes with more reused routing paths and also increases the number of active nodes, reduce the rate of data loss with reduced energy consumption.

Sumalatha et al. [2] explain in wireless sensor-actor networks, sensors probe their surroundings and forward their data to actor nodes. Actors collect sensor data and perform certain tasks in response to various events. Since actors operate on harsh environment, they may easily get damaged or failed. Failed actor nodes may partition the network into disjoint subsets. In order to reestablish connectivity nodes may be relocated to new positions. This paper focus on review of three (LeDir, RIM, DARA) node recovery algorithms, and their performance has been analyzed in terms network overhead and path length validation metrics.

Akbari et al .[3] shows how some WSN by a lot of immobile node and with the limited energy and without further charge of energy. Whereas extension of many sensor nodes and their operation. Hence it is normal. Inactive nodes miss their communication in network, hence split the network. For avoidance split of network, we proposed a fault recovery corrupted node and Self Healing is necessary. In this Thesis, we design techniques to maintain the cluster structure in the event of failures caused by energy-drained nodes. Initially, node with the maximum residual energy in a cluster becomes cluster heed and node with the second maximum residual energy becomes secondary cluster heed. Later on, selection of cluster heed and secondary cluster heed will be based on available residual energy. We use Matlab software as simulation platform quantities like, energy consumption at cluster and number of clusters is computed in evaluation of proposed algorithm. Eventually we evaluated and compare this proposed method against previous method and we demonstrate our model is better optimization than other method such as Venkataraman, in energy consumption rate.

Xi et al. [4**]**Authors in this paper demonstrate failure recovery in IP networks is critical to high quality service provisioning. The main challenge is how to achieve fast recovery without introducing high complexity and resource usage. The main approaches used by today's networks are route recalculation and lower layer protection. The disadvantages are: route recalculation could take as long as seconds to complete; while lower layer protection usually requires considerable bandwidth redundancy. We present two fast rerouting algorithms to achieve recovery from single-link and single-node failures, respectively. The idea is to calculate backup paths in advance. When a failure is detected, the affected packets are immediately forwarded through backup paths to shorten the service disruption. The schemes react to failures very fast because there are no calculations on the fly. They are also cost efficient because no bandwidth reservation is required. This paper answers the following questions: 1. How to find backup paths? 2. How to coordinate routers during the rerouting without explicit signaling? 3. How to realize distributed implementation? Our schemes guarantee 100% failure recovery without any assumptions on the primary paths. Simulations show that our schemes yield comparable performance to shortest path route recalculation. This work illuminates the possibility of using pure IP layer solutions to build highly survivable yet cost-efficient networks.

Kumar et al**.** [5] wireless sensor and actor networks (WSANs) refer to a group of sensors and actors linked by wireless medium to perform distributed sensing and actuation tasks. In such a network, sensors gather information about physical world, whereas actor takes decisions and perform appropriate actions upon the surroundings that allow remote and machine-controlled interaction with the surroundings. Since Actors have to coordinate their motion in order to keep approachable to every node, a strongly connected network is needed all the time. However, a failure of an associated actor might cause the network to partition into disjoint blocks and would therefore violate such a connectivity requirement. In this project, a new algorithmic rule is proposed which is localized and distributed algorithm that leverages existing route discovery activities within the network and imposes no extra pre-failure communication overhead.

III. Recovery through Inward Motion (RIM)

Recovery through Inward Motion (RIM) is an effective node recovery protocol for network of movable nodes developed by Younis et al. and published in 2008. It is a distributed algorithm to effectively restore network connectivity after a node failure. Instead of performing a network-wide analysis to assess the impact of the node failure and set a course of action, RIM triggers a local recovery process by relocating the neighbors of the lost node. RIM minimizes messaging overhead and reduces the distance that individual nodes travel during the recovery.

The idea of RIM is that when a node fails, its neighbors move inward toward its position so they can connect with each other. The rationale is that these neighbors are the ones directly impacted by the failure, and when they can reach each other again, the network connectivity is restored to its pre-failure status. The relocation procedure is recursively applied to handle any nodes that get disconnected when one of their neighbors moves. RIM is simple and effective. It employs a simple procedure that recovers from both serious and non-serious breaks in connectivity, without checking to see if the failed node is a cut vertex. The entire recovery process is distributed, enabling the network to heal itself without external supervision.

The RIM algorithm is based on two steps. These are:

Maintaining a One-hop Neighbor Table: When the network is setup, each node broadcasts a *HELLO* message to introduce itself to its neighbors. Then it builds a list of directly reachable nodes, i.e. 1-hop neighbors. The 1-hop neighbors table is maintained during network operation to reflect changes in the topology. Each table entry contains two parameters: {Node ID, Relative position}. Each node informs its neighbors before changing its position so they will not be wrongfully perceived as faulty.

Detecting a Failure and Initiating the Recovery Process: Nodes will periodically send heartbeat messages to their neighbors to ensure that they are functional. Missing heartbeat messages is used to detect a failed node. Let's say a failed node is S_f.

The recovery process starts with the 1-hop neighbors of S_f moving towards the position of S_f until they can reach each other and form a connected sub-network. To achieve that, they should move until they are a distance r/2 from the position ofS_f, where r is the communication range of a sensor node. This connects all neighbors ofS_f. The RIM algorithm works pretty well on any kind of network and can in theory recover n failed nodes.

IV. Least Distance Movement Recovery (LDMR)

Least Distance Movement Recovery (LDMR) is also a distributed node recovery algorithm which exploits non cut-vertices nodes in the recovery process. The idea is for a set of direct neighbors of the failed node to move toward the position of the failed node while its original position is replaced with the nearest non cut-vertex node. The recovery process starts with the search phase where each neighbor broadcasts a message containing the failed node IT, neighbor node ID and Time-To-Live (TTL). When a neighbor receives responses, it chooses the best candidate based on a certain criteria like distance etc.

In LDMR, the recovery steps are as follows:

1. If a node S_f is failed, the failure is detected by neighbors due to absence of the heartbeat messages.
2. Each neighbor is step 1 and not within r/2 distance from S_f starts a search process looking for the nearest non cut-vertex node, where r is the communication range. The non cut-vertex is called a *candidate node*C_{ij}. The neighboring node A_{Ni} broadcasts a search message containing entries like failed node ID, neighbor node ID and TTL. Then, the nearest non-cut vertex node replies to this message with its distance fromA_{Ni}. Each neighbor chooses the best candidate among received responses based on the distance.
3. Then, A_{Ni} sends a request message to C_{ij} to move to its position. Upon receiving this message, the commanded node acknowledges this message and starts moving to the specified position. The acknowledgment is necessary to avoid choosing the same non cut-vertex node by more than one neighboring node. If the node does not receive acknowledgement, it should select next nearest candidate and so on.

4. Each neighbor node A_{Ni} moves toward the position of A_F until it becomes r/2 away of it. If one of the neighbors is within this distance, no need to move further.
5. After the movements in step 3 and 4, the network connectivity is re-established.

V. Comparison and Discussion

RIM algorithm performs better with small number of nodes. With large number of nodes LDMR outperforms RIM.

In case of RIM, the number of moving nodes increases as the network becomes larger.

In contrast, in LDMR, the probability of finding a closer not cut-vertex node increases when the number of nodes increases.

In case of coverage loss again, RIM is better in small nodes but as the network grows larger with large number of nodes, more overlapping is resulted due to large number of node movement and results in more loss of coverage.

In case of LDMR, with small network with few nodes, the nodes which replace the positions of the direct neighbors of the failed node become very close to each other and therefore more overlapping is resulted and a heavy coverage loss occurs, but as the network grows very large, the total coverage for the two become comparable.

VI. Conclusion

In this paper, we have studied the node recovery techniques in WSNs, specially, mobile sensor networks or movable sensor networks. We have studied the different parameters and tradeoff factors to achieve better node recovery. We then looked at two node recovery algorithms, RIM (Recovery through Inward Motion) and LDMR (Least Distance Movement Recovery). Both the algorithms are distributed algorithms and they both have their own merits and demerits. We found out on review that RIM performs better in case of small networks but in case of large networks, LDMR is more suitable. This put both the algorithms on two different levels of network sizes on which they can be applied and thus removes any competition between the two. Both the networks on their area of operation have comparable coverage loss and average node movement.

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