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Wireless sensor network failure recovery algorithms: a review

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ABSTRACT

This paper performs literature study on various failure recovery algorithms in wireless sensor networks. Studied algorithm includes DARA, RIM, LeDiR, extended LeDiR, ALeDiR, hybrid algorithm, and DDBA. Merits, limitations of the algorithms are discussed and scope for further research is identified.

KEY WORDS: Wireless sensor networks, Node failure recovery, LeDiR, DARA, RIM, RNs, ALeDiR, and DDBA.

1. INTRODUCTION

Wireless sensor networks (WSNs) refer to a group of sensor nodes linked by wireless medium to perform distributed sensing tasks. Sensor nodes communicate wirelessly and self-organize after being deployed in an ad-hoc fashion. In WSNs, each sensor node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), memory (program, data and flash memories), RF transceiver (usually with a single Omni-directional antenna), and power source. The advancement in integrated, low-power, wireless communication devices and sensors makes it possible to deploy sensor nodes in remote distributed are to gather information about physical world and provides promising solutions in military surveillance, industrial process control, home automation, supply chain management, environmental sensing, health monitoring, etc.

WSNs operated in harsh environment are subjected to node failures and may cause disjoint block in networks. Data aggregation in WSNs will be effective only when the sensor nodes are connected with each other. Therefore node failure recovery in WSNs is important to avoid network connectivity problem. We have done literature study on various methods that are used to recover failure nodes to avoid connectivity problem in WSNs. Methods in literature study includes: Distributed Actor Recovery Algorithm (DARA), Recovery through Inward Motion (RIM), Relay Nodes (RNs) placement method, Least Disruptive Topology Repair (LeDiR) Algorithm, Extended LeDiR Algorithm, Aggrandized LeDiR (ALeDiR) Algorithm, hybrid algorithm, and Distributed Dynamic Diffusion Based Algorithm (DDBA). We have discussed the merits and limitations of the existing algorithms. Open research problems and future directions are discussed.

Literature review: This section reviews node failure recovery algorithms.

Dara: Ameer Abbasi (2009), proposed DARA algorithm to restore network connectivity in WSNs. DARA algorithm is similar to LeDiR algorithm. DARA differs from LeDiR algorithm in selection of BC for replacement. BC is selected based on following three criteria's: least node degree, closest proximity of the failed actor/node, and highest actor/node ID. In DARA algorithm, the child node will not move with the parent node during replacement. When failed node is replaced by neighbor node, the child nodes of the neighbor node will check whether the parent node is the reachable radio range. If yes than the child node will continue the connectivity with parent node else another BC is selected among the available nodes in the block. Advantage of the DARA algorithm is that preventing the movement of child node will avoid wastage of energy used in the relocation of nodes. Limitation of LeDiR algorithm applies to DARA algorithm (i.e, recovering network connectivity will not be effective when multiple nodes fails at same time).

Rim: Younis (2010), proposed RIM algorithm to restore connectivity problem in WSNs by triggering local recovery process by relocating neighbors of lost node "Hello" message is broadcasted by every node to maintain 1-hop neighbor table. When connectivity problem occurs, RIM triggers recovery process by replacing failure node by 1-hop neighbor node. Neighbor node is selected for replacement based on shortest distance. RIM reduces travel distance of sensor nodes during recovery process but fails to recover network connectivity problem when multiple sensor nodes fail at same time.

RNs placement method: Fatih Senel (2011), proposed relay nodes (RNs) for establishing connectivity among the disjoint sets of WSNs. Deployment area of WSNs is divided to segments and the relay nodes are placed at the inner and outer edges of the segment to avoid network connectivity problem. RNs are placed based on Spider-web heuristic approach. RNs method imposes additional hardware cost which is the major limitation of this method. Determining boundary of the segment and the location of the RNs is a challenging work. Balanced traffic load and better coverage is the merit of the proposed method.

Table.1. Merits and limitations of node failure recovery algorithms

Methods	Merits	Limitations
DARA	Avoids wastage of energy	Not effective in recovery when multiple nodes fail
RIM	Reduce travel distance	Not effective in recovery when multiple nodes fail
RNs placement method	Balanced distribution of traffic load	Imposes additional hardware cost
LeDiR	Reduces recovery overhead	Not effective in recovery when multiple nodes fail
Extended LeDiR	Effective in recovery when multiple nodes fail	Additional actor nodes are used
ALeDiR	Effective in recovery when multiple nodes fail, reduces travel distance	Additional actor nodes are used
Hybrid Algorithm	Fewer replacement of sensor nodes, reused routing paths, Reduces data loss rate and energy consumption	Identifying nonfunctional sensor nodes for replacement is based on complex functions
DDBA	Reduces data loss rate and energy consumption	Identifying nonfunctional sensor nodes for replacement is based on complex functions

LeDiR Algorithm: Ameer Abbasi (2013), proposed LeDiR algorithm to restore network connectivity by replacing failure node with neighbor node. Steps in LeDiR algorithm includes: failure detection, smallest block identification, replacing faulty node, and children movement. Failure nodes are detected by periodically broadcasting heart beat message to all nodes. If the failed node is critical to network connectivity then smallest block of nodes with shortest distance from failure node are identified. This is done using shortest routing path table (SRT). Faulty nodes are replaced by the Best candidate (BC) node in the identified smallest. During this replacement some direct link can be lost and may cause connectivity problem. To avoid this problem, when the parent node moves for replacement all the child nodes will moves along with the parent. Identifying smallest block for replacement will reduce recovery overhead of WSN and this is the merit of LeDiR algorithm. Recovery process will not be effective when multiple sensor node fails at same time and this is the major limitation of LeDiR algorithm.

Extended LeDiR Algorithm: Gopi raju and sumalatha (2014), proposed extended LeDiR algorithm for recovering multiple node failures in WSNs. In the proposed method extra actor nodes are deployed throughout the network. When multiple node failure is detected the nearest extra actor node will recover network connectivity by replacing the failure node. Steps in extended LeDiR algorithm includes: topology formation, failure detection, smallest block identification, replacing faulty node, and away from the failed node.

ALeDiR Algorithm: Siva kumar and santhi prabha (2010), has proposed ALeDiR algorithm to overcome multi-node failure problem in WSNs using extra actor node. Steps in ALeDiR includes: Failure detection, smallest block identification, substitution of faulty node and children movement. Missed heart beat messages are used by actor node for failure detection. Proposed method is simulated using network simulator (NS) and the performance is compared against LeDIR algorithm. Results shows ALeDiR outperform LeDiR in terms of travel distance.

Hybrid Algorithm: Ashwini Yenegur and Basawaraj. Mathpati (2014), enhanced life of sensor nodes by combining ladder diffusion algorithm with the genetic algorithm. Ladder diffusion algorithm calculates grade value, pay load value, routing table, and neighbor nodes for each sensor nodes. Genetic algorithm finds sensor nodes for replacement using following steps: initialization, evaluation, selection, cross over, and mutation. In initialization step, sensor nodes value is initialized to 0 or 1. 0 means node will not be replaced. 1 means node will be replaced. Sensor nodes are evaluated using fitness value. Fitness function is used to calculate fitness value for sensor nodes. Fitness function uses parameters generated by ladder diffusion algorithm (such as grade value, topology, etc.). During selection process, sensor nodes with lowest fitness value will be eliminated. Proposed method is simulated using network simulator and the results shows recovering of network partitioning is possible with replacement of fewer sensor nodes. Reduction in data loss rate and energy consumption is the merit of the proposed method.

Distributed Dynamic Diffusion Based Algorithm (DDBA): Mulla imroj (2015), proposed Distributed Dynamic Diffusion Based Algorithm (DDBA) using genetic algorithm and grade diffusion algorithm to enhance the life time of WSNs by reducing the rate of data loss and energy consumption. In the proposed algorithm non-functional sensor nodes are replaced by selected functional nodes based on grade value, payload value, neighboring nodes and routing tables.

Analysis: Table 1 illustrates the merits and limitations of various node failure recovery algorithms in WSNs. Most of the existing algorithms replace failure nodes based on shortest data path and minimum relocation overhead but not taken energy requirement into consideration. Sumalatha (2014), compared the performance of LeDiR, RIM, and DARA algorithm. Total distance travelled, number of relocated nodes, number of exchanged messages, shortest path length, and network overhead are used as metrics in evaluating the performance of the three algorithms. Authors claim LeDiR and RIM reported equal performance in all metrics however LeDiR outperforms RIM in network overload and

DARA in extended short path length. To the best of our knowledge, much work is not done in comparing the performance of the existing algorithms.

2. CONCLUSION

Studied the merits and limitations of the various node failure recovery algorithms in WSNs such as DARA, RIM, RNs placement method, LeDiR, extended LeDiR, ALeDiR, Hybrid algorithm, and DDBA. Scope for further research is discussed.

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