A Survey of Fault Tolerance Methods in Wireless Sensor Networks

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Abstract - *In Wireless Sensor Networks (WSN's) fault tolerance is one of the most important critical issues. The difficulty of missing communication link, Node and data are ineluctably foreordained in WSN's and due to assorted factors such as power drain, environmental crash, radio interference, asymmetric communication links, dislocation of sensor node and collision, network experience failure quandaries. Many that are able To attain higher data reliability, precision, energy preserving, network lifetime enhancement and minimize failure of components researchers have proposed various fault tolerant mechanisms in WSN's . This paper state a significant analysis of fault tolerance mechanisms in wireless sensor networks such as Mobile Agent(MA) mechanisms, relay node mechanisms and Hand Over mechanisms to identify the strengths and importance of each one of these mechanisms. Collectively, this paper suggests some of future research directions that will be contributory for researchers who are working in Wireless sensor field.*

Key Words: **Mobile Agent, Fault Tolerance,Wireless Sensor Networks,Optimization ,Networks.**

1. INTRODUCTION

In recent times, the most active research field of networking is WSN's . There are many applications proposed, where sensor nodes are able to sense the physical environment to perform data collection and mission monitoring. A WSN's is a self-organized network and it consists of a group of small size, low powered Sensor Nodes with limited transmission range and sink node [12]. Homogeneous and Heterogeneous WSN's are two types of Wireless Sensor Network . In homogeneous WSN's, all the devices possess the common communication
range and computing capability. In heterogeneous WSN's, all Sensor Nodes have different capabilities like individual processing and computational power, various communication ranges and sensor types [13]. Threw single-hop or multi-hop wireless links sensor nodes work together with each other to accomplish data sensing, data processing and data communication [14]. Sensor nodes can be deployed in various fields like ground, air, vehicles, under water, on bodies, and inside buildings to achieve Monitoring task [15, 16]. Sensor nodes failed due to their deployment in hostile environments and unknown area[17]. Faulty nodes are likely to report arbitrary readings that do not transmit the reality of observed physical process to the Base Station (BS). Therefore, these faulty nodes should be recognized at the correct time and removed from the data collection process to assure the overall data quality. In large WSN'Ss environment, it is not possible for the BS to gather and aggregate data from each SN and detect faulty Sensor Nodes(SNs) in a centralized manner. Therefore, localized and distributed SN fault detection algorithms are highly preferred to detect faulty node in a large network. Faulty node could not sense data correctly or monitor process properly[18]. In a WSN's, it is important to have continuous and stable connectivity, when the SNs are being deployed in a part hazards area. WSN'S's are restricted by the limited battery power, constrained bandwidth, networks without fixed infrastructure and different types of harms such as node failure, link or path failure, vulnerability to attack, etc. To tackle these kind of problems, there is a need for WSN's to be self-configuring and self-organizing so as to improve performance, increase power efficiency, reduce data transmission and save network resources [19].

1.1 Fault Tolerance

A Basic aspect in the design of WSN's is to keep SNs active as long as possible. Failures are un avoidable but it is liable to be caused by situation out of the control of the designers [20]. Failure of sensor node may be caused by different reasons containing transmission link unsteadiness, environmental impact, failure of component, radio interference, disorder of SNs and battery weakening [21, 22]. In addition to sensor node, Base Station may fail due to different reasons such as hardware failure, software failure, external attacks and internal attacks [23, 24]. In heterogeneous WSN's Relay Node (RN) concepts [25] or Super Node can withal fails due to failure of hardware, software failure, etc. [26]. Hence, it is resulting that the WSN's as a whole should be able to fault tolerate. [15].For reliable data transmission, fault tolerance is a critical issue in WSN's applications. It should establish that a system is presented for use during any interruption or in fault condition. Fault tolerance improves the availability, reliability and dependability on the wireless network system.

1.2 Analysis of Existing Methods

Following Concepts are taken for discussion in our study

[1]BNM [2]PCO [3]DPLA [4]IFTF [5]UP TO FAIL [6]ABF [7]FTQM [8]K-Connect [9]EASR [10]LeDiR [11]NetPebbles

Bayesian Network model approach was proposed to compute the failure probability of relay nodes. From periodic updates sensor nodes learn about the probability of failure in network by relay nodes probability of relay nodes in network. An algorithm is proposed to find more than one disjoint paths for each sensor nodes in the network. The fault tolerance algorithm is utilized a Bayesian network to determine a relay node's probability of failure and used the proposed mechanism to ensure that there are at least two disjoint paths for each sensor node to reach the base station. From the results, WSN's designer understand the guideline for a starting building block, and depending upon the application, fault tolerance level and cost, a relevant result output can be considered as a starting point for designing a fault tolerant WSN's. This paper examine fault tolerance results based on different number of nodes and sensing area [1]. This paper deals with common failures of sensor nodes and use different methods to ensure the proper working of the network, and also a theoretical modeling of a probabilistic combinatorial optimization problem. It teaches the importance of use efficient, reliable and fault tolerant approaches in order to maintain the error free network connectivity and to increase the data transmission accuracy, especially in the presence of faults. To achieve successful transmission with low energy consumption a probabilistic combinatorial optimization problem is used [2]. This proposal present a novel idea of an active node model in WSN's to identify the faulty nodes using battery power model and interference model. Using hand-off mechanism Fault tolerance against low battery power is designed where in the faulty node selects the neighboring node having highest power and transfers all the services to the selected neighboring node. The hand-off mechanism involves transmitting the connectivity status of a faulty node like source node address, destination node address, previous hop address, next hop address and time stamp to selected neighboring node in a network by dynamic power level adjustment mechanism provide Fault tolerance against interference is by allocating the time slot to all the neighboring nodes. If a particular node wishes to transmit the sensed data with maximum power once it enters active status ; otherwise it enters into sleep state having minimum power that is sufficient to receive hello messages and to maintain the connectivity. This paper simulated results for packet delivery ratio and control overhead show that paper obtained improved PDR though there is increase in control overhead. It discussed with packet delivery ratio with different transmission energy[3].An integrated fault tolerance framework (IFTF) provides a complete description of the system health with possibility to evaluate the fault reasons of abnormal situation and diagnosed network failures, detects application level failures, identifies exaggerated areas of the network and identify the root causes of application malfunctioning. The above mentioned goals were achieved efficiently through combining a network diagnosis service with an application testing service. IFTF Simulation results show that the presented solution is efficient both in terms of power consumption and memory usage. IFTF incurs a 4 %, on average, increase in power consumption (communication overhead) compared to using solely network diagnosis solutions. IFTF shows the more the diagnosis process goes in depth the more the energy consumption will be increased. The reason is simple: more particulars mean more elements to monitor and more information to be gathered . However, this technique combining the application testing service to the network analysis service, allows system monitoring at different levels without significant extra overhead. Additionally it provides more valuable information to the network administrator: Which faults affect the application service? Which faults need to be recovered quickly ? And which faults can be ignored even temporarily[4].This paper propose a method to ensure fault tolerance in WSN'S's while guaranteeing both connectivity and coverage in the network. Hence after analysis the fault tolerance related works in WSN'S's and enumerating the requirements that must be fulfilled by stated fault tolerance solution and in the case of node failure different mechanisms is proposed to maintain both coverage and connectivity in the network.

It is a proactive one in the sense that before node was affected it replace the "up to fail" node .A fast rerouting mechanism was proposed to forward the traffic initially routed via the "up to fail" node, in the case of not possible replacement of the "up to fail" node. Proposed system performance evaluation of fault tolerance approach shows that the number of nodes potentially eligible for the "up to fail" node replacement depends on a threshold of node redundancy as well as density metric of the network. Experiment shows that, compared to a classical routing algorithm, proposed fast rerouting mechanism reduces the packet loss rate in the network. Indeed, paper reviewed the different works related to fault tolerance in WSN'S's and presented solution requirements. Then paper explained the different steps of our coverage-connectivity approach to support fault tolerance in WSN'Ss. Simulation results showed that depending on the redundancy threshold level, are placing node can be found or not in the locality of the "up to fail" node. For instance, the probability of finding an eligible replacing node in the "up to fail" node's neighborhood increases when as the redundancy level threshold decreases . A fast rerouting mechanism that outperforms existing routing protocol used in the network in terms of packet loss rate for the low network density scenarios .It mainly discuss about packet loss ratio and fault reparation time [5]. Fault tolerance in WSN'Ss that is based on a mobile agents that is used both for pinpointing intelligence and repair procedure, focusing on being lightweight in communication , energy and resources. Paper classified MAs as local, and global MA, providing fault tolerance at node level, network and functional levels. Paper stated Interactions between MAs are inspired by honey bee concept that builds on semantics of errors classification and their demographic distribution. Quantitative modeling of the paper substantiates that fault tolerance framework mandates inconspicuous communication through contextualized bee-inspired communications, achieved adaptive sensitivity, and hysteresis-based stability and describe the works that comprise the fault tolerance framework for WSN'Ss. The components are based on the MA technology, creates a multi-agent association that implements fault tolerance at different hierarchical levels. Paper envisioned fault tolerance system for WSN'Ss to be self- organized and self-adaptive with the MA. IT introduced a mechanism for capturing the statistics of the network elements in the form of attributes for fault detection. In order to initiate the fault repair regimen, a protocol was proposed to communicate the presence of faults to the relevant entities,. the overhead imposed by the fault tolerance architecture is need-based, leading to an attractive cost-benefit relation was proved by a mathematical expression in this paper .Simulation express with the overhead of communication in given node group [6]. Wireless sensor and actor networks (WSAN) , sensors collect the information from an event and actors perform the appropriate actions. Actor node may perform incorrect action by receiving fault sensing data. To solve this issue paper proposed fault tolerance by quartile method (FTQM). FTQM not only identify the correct data range but also sifts the correct sensors by data discreteness. As a result, actors could make the appropriate actions in FTQM. furthermore, FTQM also could be included specific with communication link fault tolerance mechanism. In the simulation results, paper demonstrates FTQM has better predicted rate of original data, the detected tolerance rate of temperature(TEMP), and the detected temperature compared with the conventional sensing fault tolerance mechanism. Comparatively, FTQM has better performance when the real original data rate and the threshold value of failure nodes are varied[7].This paper, strongly said that fault tolerance of topologies is not alike to the connectivity of multiply connected graph by illustrating two solid examples. Then the explanation of node-failure tolerance was presented. According to fault and intrusion, the two sources of malfunction nodes and define fault tolerance and intrusion tolerance as the principles to evaluate the tolerance ability of topologies, and analyze the tolerance performance of hierarchical structure of wireless sensor network. lastly, the function relation between hierarchical topology and its own tolerance abilities of fault and intrusion reading is obtained. This paper stats that, the node-failure tolerance of WSN'S, topologies is not the same to the connectivity of graphs , and defines tolerating k-failure nodes according to the ratio of existing nodes of all the sensor nodes. Then it tells the difference between fault tolerance and intrusion tolerance by using network model with Bernoulli nodes. The functions of fault and intrusion tolerance with head ratio of hierarchical topology are achieved by fault tolerance and intrusion tolerance of hierarchical topology by this Bernoulli network model, It discuss difference between flat network and cluster network fault tolerance [8]. To improve the overall performance of the network lifetime, this paper not only relieve the trouble of the hot-spot, but it can also join together the energy-aware routing mechanism. This paper proposed an energy-aware sink repositioning method (EASR), which adopts the energy-aware routing MCP as the primary routing method for message relaying. this paper demonstrate a theoretical method that EASR can prolong the network lifetime of a WSN'S additionally, the simulation shows that the EASR method well performed in terms of increasing network lifetime [9]. This paper has overcome an important problem in mission critical WSANs, that is, recreating network connectivity after node failure without extending the length of data paths and restores connectivity by careful repositioning of nodes was achieved by introducing new distributed LeDiR algorithm . LeDiR does not impose pre failure overhead[10]. In [11], fault-tolerant is based on the surveillance that choices exist in the task to execute as well as in the place where to execute . Based on choices, the code can route around failures of both the places and the networks. Fault tolerance is achieved by the following system. The previous node keeps a clone of the agent. When it detects a malfunction of the agent on the processing stage, this copy is sent to a different place. Monitoring the current agent implementation by the place of the previous stage allows the system to abide any number of sequentially happening failures. However, a coincident failure of the processing stage and the monitor place results loss of the agent and thus in a jamming execution. Proposed system overcomes this trouble by setting up a monitoring scheme where places of earlier stages monitor their descendant places.

Table-1 : Parameter Analysis for Fault Tolerance

Para/ Papers		1	2	3	4	5	6	7	8	9	10	11	STT
FP	BD		*	*	*	*				*			5
	CL	*	*		*			*				*	5
	CKT	*											1
	LC				*	*							2
	CD				*								1
	CLU						*		*				2
	ED							*					1

	D												
	RESN	*			*	*			*		*		5
	EMD	*											1
STT		4	2	1	5	3	1	2	2	1	1	1	23/18
RM	IM			*									1
	LeDiR										*		1
	NRN										*		1
	SR									*			1
	QM							*					1
	IFTF				*								1
	CM						*		*				2
	CC					*			*				2
	RNP	*	*			*					*		4
	DJP	*	*						*				3
	PBT		*						*				2
	BTP			*									1
	NPC											*	1
	MA						*					*	2
Sub Total		2	3	3	1	2	2	1	4	1	3	2	24/23
NCP		*		*		*		*		*	*		6
	NRT					*							1
	NFE								*				1
RP	SA	*								*			2
EP	ECN		*							*			2
TP	NL									*			1
	RPT					*						*	2
	D		*										1
	RST											*	1
RLP	RL		*	*									2
DP	TPT			*									1
	TD							*					1
	PL					*							1
	PDR			*									1
OP	MO				*								1
	EO				*								1
	CO			*									1
	COR						*				*		2
	TPR			*						*			2
Sub Total		2	3	6	2	4	1	2	1	5	2	2	30

FP-Failure Parameters, RM-Recovery methods, NCP-Node count parameter, RP- Region as Parameter, EP-Energy parameter, TP-Time Parameter , RLP-Reliability parameter, DP-Data Parameter, OP-Overhead Parameter, BD-Battery depletion, CL-Communication link, CKT-Circuit, LC- Location Crash, CD-Clock drift,TPR-Transmission Power/range, COR-Communication overhead /range, CO-Control Overhead, EO-Energy overhead, MO- Memory Overhead, PL-Packet loss, TD-Trusted Data, TPT-Throughput, RL- Reliability, RST- Response Time,D-Delay,RPT- Repair time,NL- Network Lifetime,ECN- Energy Consumption,SA- Sensing Area,NFE- Node failure,NRT- Node replacement,NNC- Number of nodes Changes,NPC-NetPebbles Code,BTP- Battery power,PBT- Probabilistic,DJP-Disjoined path,RNP- Relay node placement/node replacement,CC- Coverage / connectivity,CM- Cluster model,QM- Quartile method,SR- Sink Relocation,NRN- Node Relocation,IM- Interference model,EMD- Environmental Damage,RESN- Relay/Sensor Node,EDD- Error Data,CLU-Cluster,STT-Sub Total.

In Table 1.1 some of the major factors seems to be influencing parameters regarding fault tolerance in Wireless Sensor Networks, these parameters were perceived over a detailed study of relevant papers. We believe that discussing the tabulated three major factors have a greater impact in analyzing fault tolerance papers taken for discussion. Part I analysis fault occurrence strategies. Part II analysis the proposed technique to recover from fault situation. Part III discuss the parameters which are taken by authors to prove their novelty. Chart-1 Shows failure reasons ,Recovery methods, Analysis parameters stated by Authors .[1] discussed about 4 kind of faults, 2 methods are introduced to ensure fault tolerance and 2 different parameters are analyzed in the paper.

In this comparison [4] discussed with maximum of 5 fault reason , [8] proposed 4 methods for fault tolerance implementation and [3] discussed 6 different parameter after implementation of algorithm and got better comparison scenario .

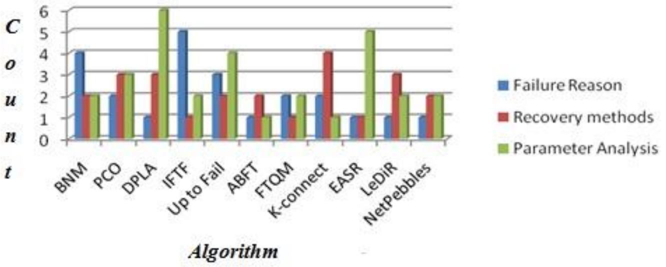

Chart-1: Failure and Recovery method parameter analysis

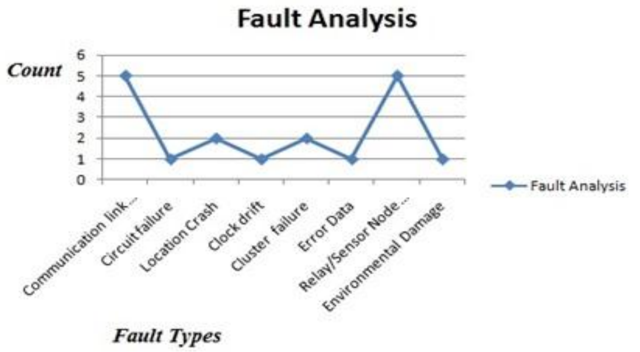

Chart-2: Fault Types analysis

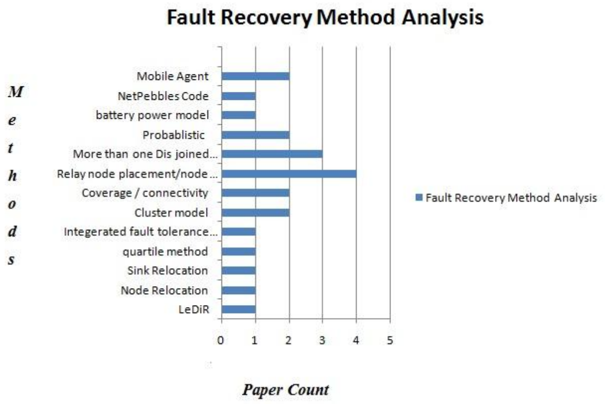

Chart-3: Analysis of Fault Recovery Methods

In Chart -2: 8 types of fault options are plotted from discussed papers, most of papers taken a single fault type ,cluster failure and location crash is considered in 2 papers and 5 paper mentioned two type of fault method namely Relay , sensor node fault and communication fault. From the analysis we came to know that more papers discussed with communication link failure and node failure. Fig:1.3 shows the fault recovery methods handled by various authors.From our study relay node placement methods is handled by most authors and produced effective results. Fig 1.4 shows 7 type of parameter can be analyzed by various authors to prove their concept's novelty. From our analysis ,Node count based analysis handled by maximum of 28% papers in our survey. We came to know scalability in the network was primary goal of authors in their proposed paper.

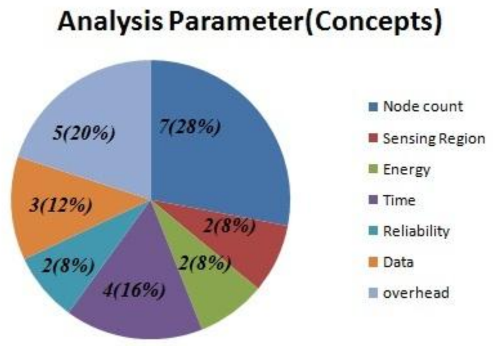

Chart-4: Output Parameter analysis

3. CONCLUSIONS

This paper presents a brief review of different fault tolerant algorithms specifically designed for WSN's. After critical analysis, it has been observed that various strategies such as Relay Node Placement, Multiple Dis-Join path, Mobile Agent and clustering model can be used in dissimilar applications with respect to the level of Fault Tolerance . Adding few Relay nodes can increase level of FT and enhance accuracy and increase lifetime of network. Selecting More than one Dis-Joined path results reduced overhead and increased the performance of the network .Most of the researchers investigated with fault node ,cluster fault, communication link, clock drift and etc for fault occurrence method .Node can be faulty when it drains battery ,physical damage, fault data reading etc. few researchers only considered malicious attack as fault in network. Malicious attack also considered to be most important fault parameter in future to attain error free data.

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