RESEARCHERID
THOMSON REUTERS

[Mishra* 4(10): October, 2017] ISSN 2349-4506
Impact Factor: 2.785

Global Journal of Engineering Science and Research Management

AUTOMATED FAULT DETECTION, DIAGNOSIS AND MANAGEMENT OF WSN

D. P. Mishra*, Ramesh Kumar
* Research Scholar, CSVTU, India

DOI: 10.5281/zenodo.1007139

KEYWORDS: WSNs, NMS, Node, Cluster, Cluster head, Fault recovery; Fault management.

ABSTRACT
Sensor networks are dense wireless networks of tiny, low-cost sensors, which collect and sense parameter. Wireless sensor networks facilitate monitoring and controlling of physical environments from remote locations with better accuracy. WSN is having applications in a variety of fields such as environ-mental monitoring; military purposes and gathering sensing information in inhospitable locations. Fault recovery and Network management for Wireless Sensor Network Infrastructure is a challenging area where the management operation is to run on minimal or zero cost. The network data packets routing costs more, hence managing this unstructured network improves the network efficiency and extend the network lifetime. The deployed sensor nodes have a fixed battery life and there are some attempts made to manage this WSN network efficiently to improve the lifetime. In this paper, we focus on different networking parameters and proposed a technique that can be used efficiently for fault recovery and management.

INTRODUCTION
Sensor network came in existence based on idea coined in 1980 (DARPA initiated the Distributed Sensor Networks program), there is significant growth in the field of wireless sensor networks (WSNs) in past 10 years. Failure of WSN seems mandate due to the adverse environment and unattended deployment of WSN nodes. Apart from this energy constraint, storage capacity and computational capability make the situation worse. A node is fragile and has limited resources, which makes it easy to become faulty. In any cases, WSN uses multi-hop communication between nodes, which means when a node senses parameters, it also transmits others nodes' data at the same time and then broadcast the data through their antenna. The other nodes within the antenna range will receive the data and again broadcast the data through its antenna. In this way, the sense data moves forward and finally reaches to the base station from where the fixed network structure starts and the data will be send through the fixed networks, Mishra D. P. and Kumar Ramesh[6]. Management of this individual discrete network based structure is highly sensitive and the mismanagement may lead to the collapse of whole network.

Management of WSNs is a new research area, which recently got the attention of researchers and most of the challenges specific to management is highlighted. The operation of a WSN is highly influenced by different factors such as network traffic flows, network topologies, and communication protocols. NMS designed specifically for WSNs must provide a set of managerial and administrative functionality to integrate configuration, operation, administration, security, and maintenance of all elements and services of a sensor network. We are mainly focusing on the application that enable management system to allow the network self-formation, self-organize, and ideally to self-configure itself in the event of failures.

BACKGROUND
It is very important to point out the difference between faults, and failures. A fault is any kind of defect that leads to an error whereas failure is a state, it occurs when the system deviates from its specification and unable to deliever desired results and its intended functionality. Liu et al. [3], classify fault tolerance into four levels from the system point of view such as hardware layer, software layer, network communication layer, and applications layer. Faults at hardware layer are caused due to malfunctioning of hardware component of a sensor node, such as processing unit, memory, battery, sensing unit, and network transceiver [3, 4].

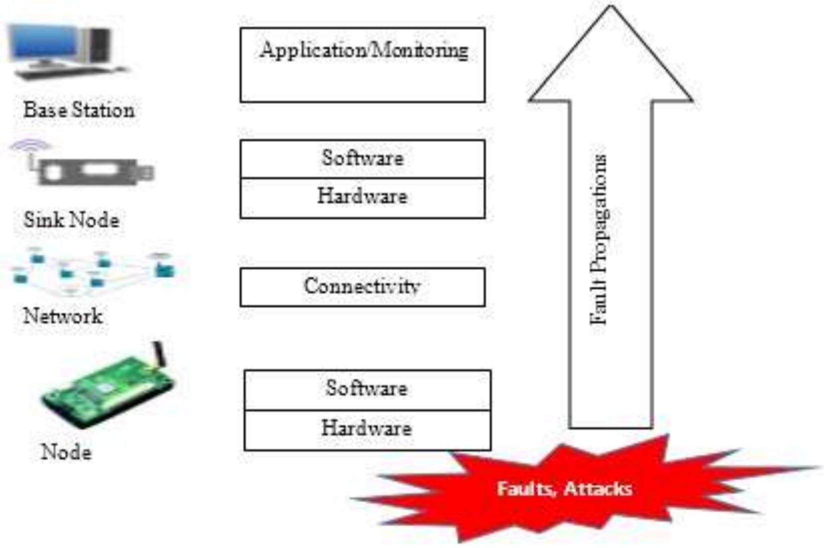


Figure -1: Fault Propagation and Classification

Based on fault management literature survey [5, 6,7], node hardware fault has been categorized into four types such as permanent faults, Intermittent faults, Temporary faults and Potential faults.

- Permanent faults – Permanent faults are continuous and stable in nature e.g. hardware faults within a component.
- Intermittent faults **–** An intermittent fault is an occasional (such as a regular or irregular interval) fault that may occur due to unstable characteristics of the hardware.
- Temporary or transient faults **–** These faults are the result of some temporary or sudden environmental impact on hardware, e.g. the impact of cosmic radiation on the sensor.
- Potential faults **–** Potential faults are occurring due to depletion of node hardware resources, such as node's battery energy exhaustion.

FAULT MANAGEMENT

Fault management can be defined as a set of services and functions performed to detect, diagnose, isolate and rectify malfunctions in a network. It also takes care for the compensation for environmental changes, monitoring and examining errors logs, accepting and acting on error detection, tracing and identifying faults. Furthermore, carrying out series of diagnostics tests, correcting faults and failures, reporting error conditions and localizing and tracing faults are part of the fault management functions [8]. Important functions of fault-management include:

- Defining thresholds for potential failure conditions
- Constant monitoring of system status and usage level
- General diagnostics
- Alarm and the notification of any error or malfunctions
- Tracing the location of potential and actual malfunctions
- Auto-correction of major problem causing faulty conditions
- Should keep the probability of false alarm as minimum as possible

Fault recovery and management

Fault management for WSNs is different from traditional networks. Recent research has developed certain schemes and techniques that deal with different types of faults at different layers of the network. In order to provide feature to recover in faulty situations three main actions (fault detection, fault diagnosis and fault recovery) must be performed [1, 2, 9] and fault management phases are shown in Figure -2.

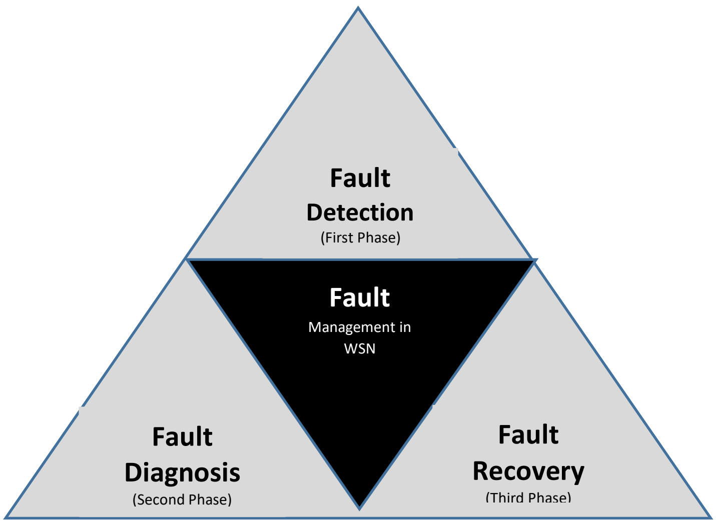
ISSN 2349-4506
Impact Factor: 2.785

Fault Detection – It is the first phase of fault management, where an unexpected failure of the network is identified by the networks system. Fault detection in WSN mainly depends on the different type of applications and failures.

Fault Diagnosis – Fault diagnosis is stage that identified the causes of faults and it can be distinguished from other irrelevant alarms.

Fault Recovery - After fault detection and diagnosis, fault recovery comes in picture and specify that how faults can be treated, L. Paradis and Q. Han[1]. The failure recovery phase is the stage in which the sensor network is restructured or reconfigured, in such a way that failures or faults nodes do not affect further on network performance, Y.Mengjie et. al [2].

Figure – 2: Fault Management Phases in Wireless Sensor Network



Classification of Fault management

WSNs fault management can be classified according to their management system network architecture [10, 11,]: Centralized Distributed, or Hierarchical.

- Centralized Architecture - In a centralized management architecture, the base station acts as a central controller or a central manager station and its responsible for controlling and collecting information from the whole network
- Distributed Architecture - Distributed management architecture employs multiple manager station throughout the network. Other managing station works in cooperation to perform management functions. Local processing and management overcomes the bandwidth and processing burden of the central controller.
- Hierarchical Architecture - Hierarchical management architecture is a hybrid between the centralized and distributed approach. Sub managers or controllers are distributed throughout the network in hierarchical manner, having lower and higher level of hierarchy. These managers are referred to as the Intermediate mangers, and they are responsible for managing subsection of network.

NETWORK MANAGEMENT SYSTEM DESIGN CRITERIA

A network management system designed for WSNs must take into account the unique properties of WSNs. The following criteria are generally used to evaluate the sensor network management systems.

Lightweight operation: The application and network operation should have simple application feature, which does not consume too much battery energy. The lightweight operations extends the network lifetime.

Fault Tolerance & Robustness: the following are the possible cause of fault tolerance.

- dropped packets
- disconnected
- nodes dying
- new nodes joining the network
- powering on or off

Responsiveness & Adaptability: The network should be able to responsive immediately inspite of multiple failures and network errors. In addition, the network system should be capable to adapt the dynamic network topology changes.

Minimal data storage: As WSN nodes are memory constrains, so the data models designed for WSN application for management operation should be capable to operate with less memory usage, Mishra D. P. and Kumar Ramesh [12]. The management system that intends to operate on WSN nodes especially on common nodes which are limited on power sources must respect the WSN's memory constrains.

Scalability: Sensor network infrastructure should capable to operate on high scalable mode as the nodes dying is a very common feature of the wireless sensor network and also occasionally node additions would happens due to the following reasons.

- New nodes deployment on to existing network area
- New nodes joins from one cluster to another clusters

EXISTING DESIGNS FOR WIRELESS SENSOR NETWORK MANAGEMENT

Layered System Structure It is now considered as an advanced architecture in most of the application field. In layered architecture the system is operate on several layers instead of operating on single layer (monolithic approach). The disadvantage of monolithic approach is that whenever any application change or configuration changes, due to global consequence it requires more analysis. On the other hand, layered based design supports the management of lightweight operations features and based on the network role such as cluster head, sensor (common) nodes etc. There is no dependency to load all the components i.e. common nodes need not to load the cluster head components and hence the energy usage in layered based system architecture is optimized.

Distribution of Management Function - It's other approach for WSN management field. In WSN field due the traffic congestion and the nodes availability, it is difficult achieve efficiency in centralized processing. If nodes are dying in regular fashion which is common in WSN environment, then centralized management operation will be likely unfeasible or delayed (as network to get reconfigured to get a path to central processing system/base station) to get executed. Thus, distributed management operations and decision-making may lead to energy exhaustion in WSNs. For example, the distribution of cluster forming and control protocol is considered by Yu[11] to every sensor as information of node status measurement (including node capability , data accessibility, or network connectivity etc.) is more efficient to handle locally by sensor nodes.

Policy-based Management – It is based on certain policies, which need to be agreed on for the network management. There is a manager and agent based structure (MANNA [13]) where the agent will work with manager cooperatively to accomplish certain management task such as group formation, control density of network, monitor and keep the network coverage etc. There are some research work attempted in this field such as reconfigurable group management service [14], Mire [15] which are setting some pre-defined behaviors for-managing service for dynamic group formation in runtime. Similarly, TinyCubus [16] approach the generic way of reconfiguring the network framework and distributed role usages for sensor nodes.

Information Model - Certain management functions in WSN largely depend on the network state information, which help in smooth execution of management operations. A network system can be of two states as it changes from time to time in real-time scenario, static and dynamic, Mishra D. P. and Kumar Ramesh [17]. In particular, the MANNA architecture describes these two kinds of management information (static and dynamic) to represent the network status. In static status, the network information does not change rapidly where as in case of dynamic criteria, the network information changed dynamically, as per change based on information model network should be able to reconfigure itself.

Service-Oriented Management - Service oriented architecture (SOA [18]) is appealing design, it diversified the applications into unit components and make the system low coupling to achieve a well build reliable system structure. This SOA design ensure the high scaling and adaptability due to the standardize inter communication protocol (soap based protocols for service messages). Application developers will only focus on the specific operation development and hence the management operation development, enhancement and maintenance will be fast. SOA can also specifically deal with the WSN features e.g. mobility, dynamic network topology, node heterogeneity etc. and offers to integrate seamlessly for various management operations.

Self-Configurable fault management approaches –We explored certain approaches for self-configuring and fault management of sensor network and it is reconfigured in such a way that the changes will not affect the whole network opera-tion and performance. Example of such approach, S. Marti et al [19] proposed that if there is a failure of a neighboring node in the WSN architecture, a new neighboring node would be selected for routing. F. Koushanfar et al [20], suggested a heterogeneous backup procedure, it takes care to overcome the hardware malfunctioning of a sensor node. According to their proposal, a single type of hardware can provide backup to different types of resources. But this solution is not directly related to fault healing in respect of M. Yu, H. Mokhtar, and M. Merabti's [21] discussion about network system level management. In G. Gupta and M. Younis [22] proposed fault-tolerant clustering, when the gateway node fails, the cluster suspended and all of its nodes are re-allocated to other healthy gateways which consumes more time because of the involvement of all the cluster nodes in the recovery process. Ruiz et al [23] proposed a malfunction detection method where a management architecture for WSNs is suggested named MANNA. In this approach, an external manager is required for performing centralized diagnosis and communication between nodes. This external manager is expensive for sensor networks. W. L. Lee et al [24] proposed a proactive fault management system, where the central manager detects areas with low residual energy i.e. weak network health by comparing the current node or network state with the historical network information model (eg energy map and topology map). It proactively instructs the nodes of that area to send data less frequently. Luo et al [25] proposed an algorithm to improve the failure event detection precision in the existence of faulty sensor nodes. Their algorithm did not unambiguously attempt to identify faulty sensor nodes. Krishnamachari and Iyengar [26] proposed localized threshold based decision schemes for detecting misbehaving sensor nodes and happening areas. Some authors suggested some routing techniques to identify the faulty or misbehaving sensor nodes [27–29].

After studying these algorithms and fault management approaches, we come up with an energy efficient self-configuring solution for WSNs. It does not consume more energy in case of the failure of a cell manager or cluster head.

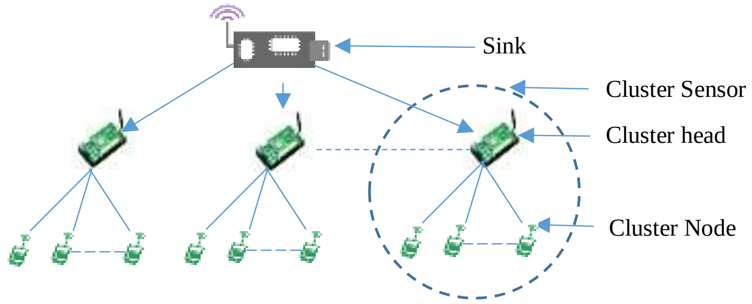
AUTONOMIC ALGORITHM

Autonomic algorithm for WSN is a three-tier hierarchical network management system as shown in Figure 3. The upper-level nodes are called headers and low-level nodes are called member nodes. The header nodes may cause the member nodes to be clustered in hostile environments. The headers nodes broadcast 'cover request' message periodically, Mishra D. P. and Kumar Ramesh [30]. If a cluster head down to low residual battery energy, the member nodes select a cluster head based on minimum hop count value by flooding the network with 'cover request' messages. If a header node die or deplete its energy then all its cluster members have to select and join a new header based on minimum hop count value.

ISSN 2349-4506
Impact Factor: 2.785

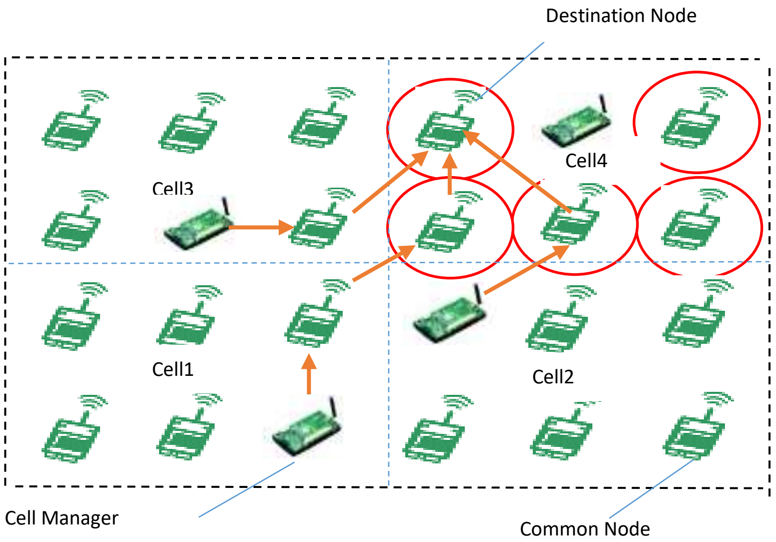
Global Journal of Engineering Science and Research Management

Figure - 3: Cluster based network for Wireless Sensor Network



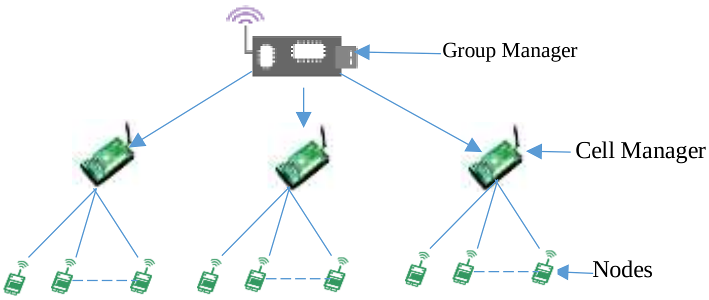
For example, consider a scenario like Figure 4, it is having 4 clusters where cluster 4 header not available to perform its regular operations. Due to no availability of header member need to join a new cluster header. Cluster 1, 2, and 3 header will send 'cover request' messages to all the members of cluster 4. Based on the minimum hop count value, cluster 4 members will select a new cluster head from neighboring clusters for themselves. Say, nodes of cluster 4 are going to join cluster 1 header due to minimum hop count. Since cluster, 1 header is low on residual energy and need to go sleep. This scenario initiates the re-configuration phase again as all the member nodes of cluster head 4 and cluster 1 required a new cluster head to perform their regular operations. For this reason, considering only hop count value is not energy efficient procedure in case of cluster head selection, [31].

Figure - 4: ***Cluster Merging Process***



Existing Self-configuring Algorithm- In WSN sensor nodes are in a virtual grid structure in which the network nodes are divided into several cells. One node in each cell is selected as cell manager. Upper level nodes of the grid are cell managers and the remaining nodes will be in lower level grid. A large virtual group can be formed by several virtual cells and these cells can have hundreds to thousands sensor nodes. A group manager is appointed for each virtual group. This group manager is responsible for managing and organizing sensor nodes in its group. Another virtual grid structure is created by the group managers from different groups. This structure is shown in Figure 5. Top level of the management hierarchy is the sink, which is above the group manager. We are referring the algorithm of M. Asim et al [31] as existing algorithm. This self-configuring algorithm follows cellular approach [31, 32]. In self-detection mechanism, sensor nodes monitor their residual battery energy periodically to identify the probable failure. M. Asim et al consider the reduction of battery energy as a main cause of sensor node's sudden death. A sensor node is marked as failing node when its energy drops below the threshold value. When a member node is failing due to low battery energy, it sends message to its cell manager about the low battery energy and goes to sleep mode. Member node failure does not require any recovery.

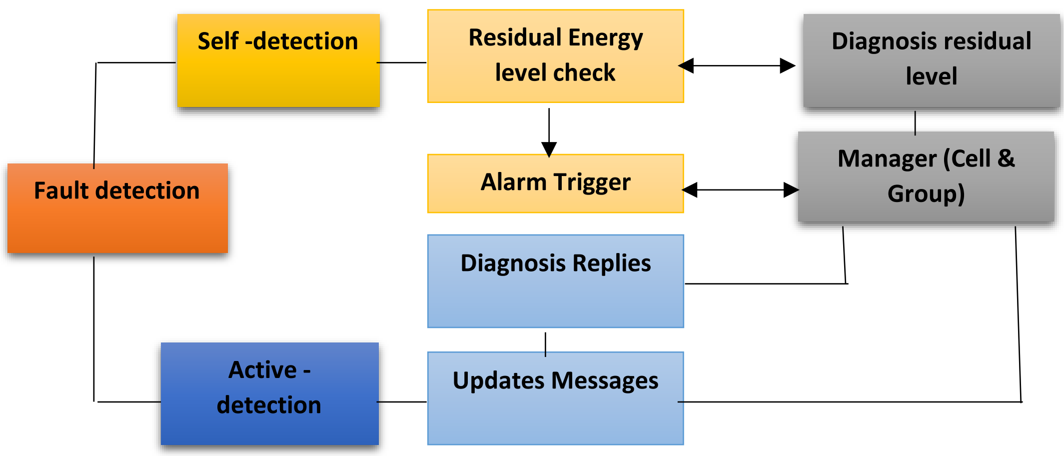
Figure - 5: ***Hierarchical Network Architecture for Wireless Sensor Network***



The self-configuring algorithm considers active detection mode for efficient detection of the sensor node's sudden death. In active-detection mechanism, cell manager asks its member nodes to send their updates regularly. To get the updated status of the member nodes, the cell manager exchange messages with its member nodes which is shown in Figure - 6. The cell manager sends "get" messages to its member nodes on regular basis. The member nodes reply with their updates. This update method is called in-cell update cycle. This update message consists of node ID, battery energy and node's location information. If such scenario happens where the cell manager is not receiving any update message from one of its member node, the cell manager sends an instant message to that node. If the cell manager does not get any as acknowledgement message in a defined time, it affirms the node as faulty. Then the cell manager sends this information to the member nodes in its cell. If the performance of the network is in a critical level only then the cell, managers inform the group manager to get further assistance.

In the existing algorithm, there is a secondary cell manager as backup of the cell manager. When a cell manager's residual battery energy becomes low, secondary cell manager takes the role of the cell manager and chooses a new secondary cell manager from the energy update messages, which are being sent periodically by the member nodes [32]. When there is no node to take the role of the cell manager in that cell, cell-merging procedure will start.

Figure - 6: Fault Detection and Diagnosis Process



RESEARCHERID
THOMSON REUTERS
[Mishra* 4(10): October, 2017] ISSN 2349-4506
Impact Factor: 2.785
Global Journal of Engineering Science and Research Management

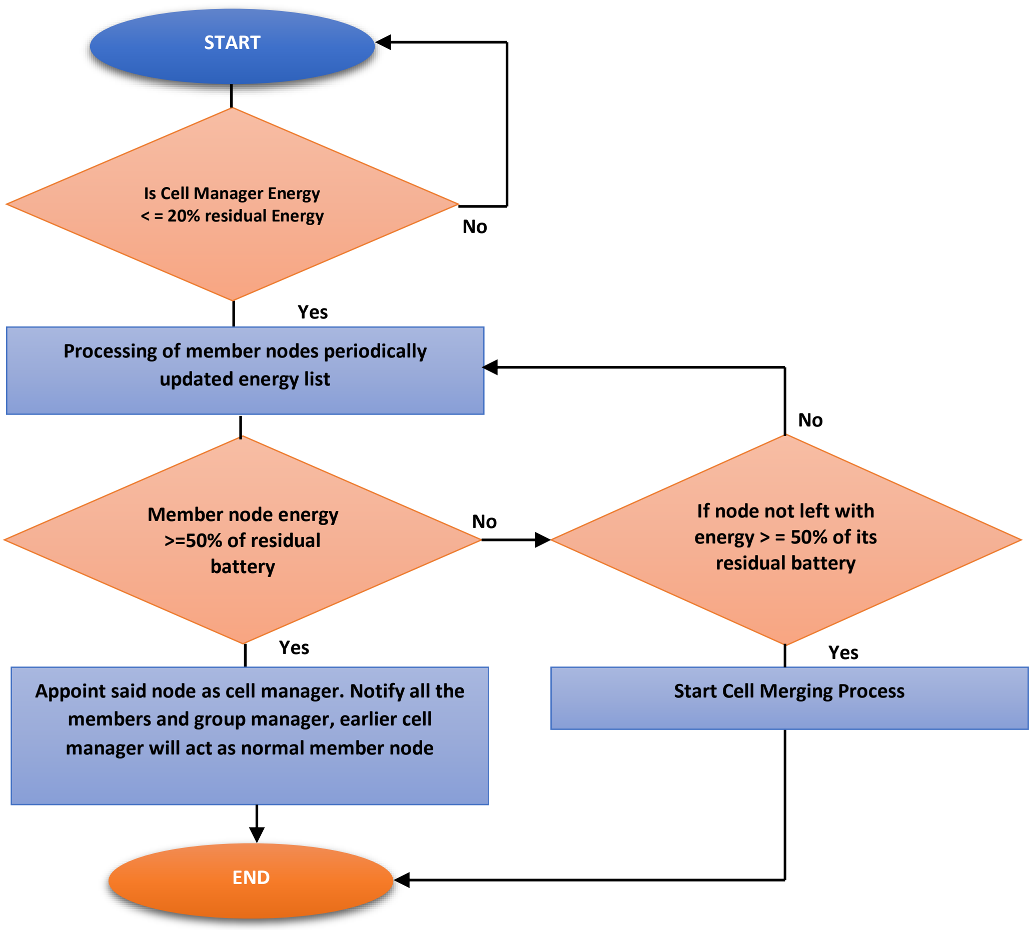
PROPOSED ALGORITHM

In the existing self-configuring algorithm, when the residual energy of both the cell manager and secondary cell manager is less than or equal to 20%, the member nodes exchange energy messages within the cell to appoint a new cell manager, which consumes high energy.

We are proposing a modification to minimize this energy consumption. In our algorithm, there is no secondary cell manager. In case of low residual energy of the cell manager, it will select the next high-energy node and appoint it as new cell manager from the energy list which is being periodically updated from the messages sent by the member nodes i.e. there will be no exchange of energy messages within the cell when the residual energy of both the cell manager and secondary cell manager are low. It will consume less energy.

A member node should have greater or equal to 50% of its residual battery energy for being appointed as cell manager. If there is no node, (residual battery energy is greater or equal to 50%) to take cell manager's responsibility in that cell, cell-merging activity will take place like the existing self-configuring algorithm. In this algorithm, we are not considering the highest energy node as new cell manager but the next higher energy node for avoiding sorting mechanism because a WSN of thousands of nodes will take higher energy and time for sorting the energy list. A flow chart of our proposed algorithm is presented in Figure. 7.

Figure - 7: Proposed algorithmic steps

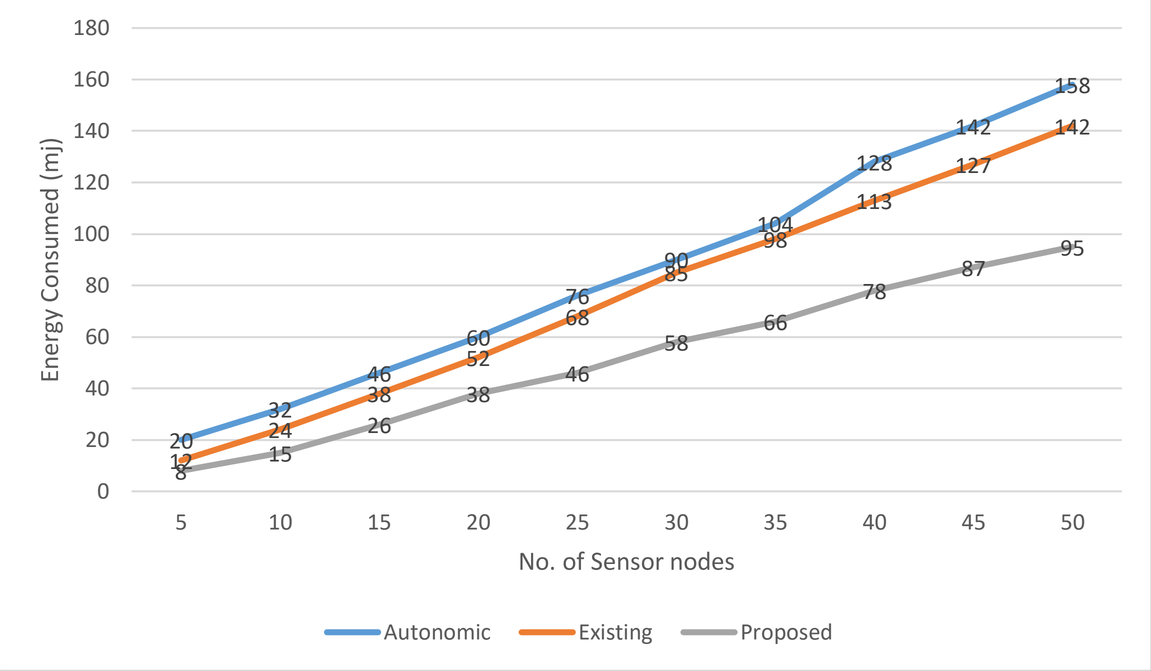


RESEARCHERID
THOMSON REUTERS
[Mishra* 4(10): October, 2017] ISSN 2349-4506
Impact Factor: 2.785
Global Journal of Engineering Science and Research Management

RESULTS AND DISCUSSION

The performance of the proposed algorithm evaluated and analysis is done to measure node energy expenditure, which is given in Figure 8. Number of sensors is varied from 5 to 50. We have done the assumption that each sensor node is having an initial energy of 2000 mJ. In autonomic algorithm, the cluster head could be failed to operate due to insufficient residual energy and all the sensor nodes from that cluster need to join with a neighboring cluster head using cluster merging technique Cluster merging is not an energy efficient process as it takes time to reorganize the clusters as well consumes more energy which is verified through comparative analysis graph

Figure - 8: Comparative analysis of autonomic, existing and proposed algorithm



In the existing self-configuring algorithm, when a cell manager's energy becomes low, secondary cell manager takes the role of the cell manager and selects a new secondary cell manager based on the energy update messages. If the energy of primary and secondary cell manager are low, the member nodes exchange energy messages within the cell and choose new cell manager. The new cell manager again selects a new secondary cell manager with condition to have 50% residual energy. Selection of new or secondary manager consumes more energy and in case there is no node to take the role of the cell manager, cell-merging technique will happen.

In the proposed algorithm, there will be no secondary cell manager. Every cell manager has the updated list of energy status of its member nodes. If a cell manager's residual battery energy becomes low, it will designate the next high-energy node from the list as the new cell manager (having energy greater or equal to 50% of its residual energy). This process will continue until there are nodes having energy greater than or equal to 50%, overall this process requires less energy as compared to existing solutions.

CONCLUSION

Wireless sensor networks are a collection of heterogeneous or homogeneous sensor devices having limited battery energy, memory and computational power. Sensor node failure due to limited battery energy interrupts the operation of WSN. To keep the network operation uninterrupted and smooth, self-configuring techniques are imposed on WSN. In this paper, we have discussed different techniques available for automated fault detection, diagnosis and management of WSN, we have suggested an energy efficient modified algorithm for wireless sensor network, which is based on the existing self-configuring algorithm. The proposed algorithm may select appropriate sensor node to act as cell manager, reorganizes the topology more efficiently, reduces the power consumption and overcomes fault.

REFERENCES

1. L. Paradis and Q. Han, "A Survey of Fault Management in Wireless Sensor Networks," Journal of Network and System Management, Springer Science + Business Media, LLC, vol. 15, pp. 171-190, June 2007.
2. Y.Mengjie, H.Mokhtar, and M.Merabti, "Fault Management in Wireless Sensor Networks," IEEE Wireless Communications, vol. 14, pp. 13-19, 2007.
3. H.Liu, A.Nayak, and I.Stojmenovic, "Fault-Tolerant Algorithms/Protocols in Wireless Sensor Networks," in Guide to Wireless Ad Hoc Networks, ed: Springer-Verlag London, 2009, pp. 265-295.
4. B.Khelifa, H.Haffaf, M.Madjid, and D.Llewellyn-Jones, "Monitoring Connectivity in Wireless Sensor Networks," International Journal of Future Generation Communication and Networking, vol. 2, p. 10, June. 2009.
5. M.Yu, H.Mokhtar, and M.Merabti, "Self-Managed Fault Management in Wireless Sensor Networks," in Proceedings of the The Second International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies (UBICOMM '08), 2008, pp. 13-18.
6. Mishra D. P. and Kumar Ramesh ,"A Vision of Hybrid Security Framework for Wireless Sensor Network", Indian Journal of Applied Research, Volume:5 , Issue:1, Jan 2015, ISSN-2249-555X pp. 167-171
7. M.Al-Kasassbeh and M.Adda, "Network fault detection with Wiener filter-based agent," Journal of Network and Computer Applications, vol. 32, pp. 824-833, 2009.
8. L.M.d.souza, H.Vogt, and M.Beigl, "A survey on Fault Tolerance in Wireless Sensor Networks," www.digbib.ubka.uni-karlsruhe.de/volltexte/documents/11824. , n.d.
9. I.F.Akyildiz, W.Su, Y.Sankarasubramaniam, and E. Cayirci, "A Survey on Sensor Networks," IEEE Communication Magazine, pp. 102-114, 2002.
10. W.L.Lee, A. Datta, and R. Cardell-Oliver, Network Management in Wireless Sensor Networks: Handbook on Mobile Ad Hoc and Pervasive Communications American Scientific Publishers, 2006.
11. Yang Yu, B.K., Viktor K. Prasanna, Issues in Designing Middleware for Wireless Sensor Networks. IEEE Network, 2004. 18(1): p. 15-21.
12. Mishra D. P. and Kumar Ramesh, "Analysis of Wireless Sensor Networks Security Solutions and Countermeasures", Journal of Scientific and Technical Research, Volume 6 Issue 1 June 2016
13. LinnyerBeatrys Ruiz, J.M.S.N., Antonio A.F. Loureiro, MANNA: A Management Architecture for Wireless Sensor Networks. IEEE Communications Magazine, 2003. 41(2): p.116-125
14. Mardoqueu Souza Vieira, N.S.R. A Reconfigurable Group Management Middleware Service for Wireless Sensor Networks.in 3rd International Workshop on Middleware for Pervasive and AdHoc Computing. 2005. Grenoble, France.
15. Qing Li, X.L., Jian Zhai, Liu Wenyin. MIRES- an Information Exchange System for Mobile Phones.in 2004 ACM Symposium on Applied Computing. 2004. Nicosia, Cyprus: ACM Press.
16. Pedro Jose Marron, A.L., Daniel Minder, Matthias Gauger,Olga Saukh, Kurt Rothermel, Management and configuration issues for sensor networks. International Journal of Network Management, 2005. 15(4): p. 235-253.
17. Mishra D. P. and Kumar Ramesh, "Hybrid Framework for Intrusion Detection in Wireless Sensor Networks", International Journal of Advanced Research in Computer Science, Volume 8, No. 3, March – April 2017, ISSN No. 0976-5697
18. Colan, M. Service-Oriented Architecture expands the vision of Web services, Part 1. June, 2004
19. MARTI, S.—GIULI, T. J.—LAI, K.—BAKER, M. : Mitigat-ing Routing Misbehaviour in Mobile Ad Hoc Networks, ACM Mobicom (2000), 255–265.
20. KOUSHANFAR, F.—POTKONJAK, M.—SANGIOVANNI VINCENTELLI, A. : Fault Tolerance Techniques in Wireless Ad-Hoc Sensor Networks, UC Berkeley technical reports.

21. YU, M.—MOKHTAR, H.—MERABTI, M. : A survey on Fault Management in Wireless Sensor Network, Proceedings of the 8th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting Liverpool, UK, 2007.
22. GUPTA, G.—YOUNIS, M. : Fault-Tolerant Clustering of Wire-less Sensor Networks, Proceedings of the IEEE WCNC 2003, New Orleans, Louisiana, 2003.
23. RUIZ, L. B.—SIQUEIRA, I. G.—OLIVEIRA, L. B.—WONG, H. C.—NOGUEIRA, J. M. S.—LOUREIRO, A. A. F. : Fault Management in Event-Driven Wireless Sensor Networks, Proc. 7th ACMInt. Symp. Modeling, Analysis and Simulation ofWire-less and Mobile Systems, Venice, Italy, pp. : 149–156.
24. LEE, W. L.—DATTA, A.—CARDELL-OLIVER, R. : WinMS: Wireless Sensor Network-Management System, An Adaptive Policy-Based Management for Wireless Sensor Networks, School of Computer Science and Software Engineering, The UniversityofWestern Australia, 2006,Technical Report,UWA-CSSE-06-01.
25. LUO, X.—XDONG, V—HUANG, Y. : On Distributed Fault-Tolerant Detection in Wireless Sensor Networks, Proc. IEEE Trans. Comput. 55 No. 1, 58–70.
26. KRISHNAMACHARI, B.—IYENGAR, S. : Distributed Bayes-ian Algorithms for Fault-Tolerant Event Region Detection in Wireless Sensor Network, IEEE Trans. Comput. 53 No. 3,241–250.
27. STADDON, J.—BALFANZ, D.—DURFEE, G. : Efficient Trac-ing of Failed Nodes in Sensor Networks, Proc. 1st ACM Int. Workshop on Wireless Sensor Networks and Applications, At-lanta, USA, Sep 2002, pp. 122–130.
28. TANACHAIWIWAT, S.—DAVE, P.—BHINDWALE, R.—HELMY, A. : Secure Locations: Routing on Trust and Isolat- ing Compromised Sensors in Location-Aware Sensor Networks,Proc. 1st Int. Conf. Embedded Networked Sensor Systems, Los Angeles, Nov 2003, pp. 324–325.
29. PERRIG, A.—SZEWCZYK, R.—WEN, V.—CULLER, D. E.—TYGAR, J. D. : SPINS: Security Protocols for Sensor Net- works, Proc. Wirel. Netw. 8 No. 5, 521–534.
30. Mishra D. P. and Kumar Ramesh, "Fault Tolerant Clustering Mechanism for Wireless Sensor Networks", International Journal of Electronics Engineering, Volume 9, No.1, Jan-June 2017,pp. 184-192, ,ISSN: 0973-7383.
31. ASIM, M.—MOKHTAR, H.—MERABTI, M.: A Self-Manag-ing Fault Management Mechanism forWireless Sensor Networks, International Journal of Wireless & Mobile Networks (IJWMN) 2 No. 4 (2010), 184–197.
32. ASIM, M.—YU, M.—MOKHTAR, H.—MERABTI, M.: A Self-Configurable Architecture for Wireless Sensor Networks, 2010 Developments in E-systems Engineering, pp. 76–81.