Graduate Research in Engineering and Technology (GRET)

Volume 1 | Issue 2 Article 2

October 2013

AN EFFICIENT FAULT TOLERANT SYSTEM USING IMPROVED CLUSTERING IN WIRELESS SENSOR NETWORKS

VENKATESH S
Student Member, IEEE-Computer Society, venkatesh_s@gmail.com

Recommended Citation

S, VENKATESH (2013) "AN EFFICIENT FAULT TOLERANT SYSTEM USING IMPROVED CLUSTERING IN WIRELESS SENSOR NETWORKS," *Graduate Research in Engineering and Technology (GRET)*: Vol. 1 : Iss. 2 , Article 2.
Available at: https://www.interscience.in/gret/vol1/iss2/2

AN EFFICIENT FAULT TOLERANT SYSTEM USING IMPROVED CLUSTERING IN WIRELESS SENSOR NETWORKS

VENKATESH S

Student Member, IEEE-Computer Society

Abstract- In Wireless Sensor Networks (WSNs), Efficient clustering is key for optimal use of available nodes. Fault tolerance to any failure on the network or node level is an essential requirement in this context. Hence, a novel approach towards clustering and multiple object tracking in WSNs is being explored. The Proposed method employs judicious mix of burdening all available nodes including GH (Group Head) to earn energy efficiency and fault tolerance. Initially, node with the maximum residual energy in a cluster becomes group head and node with the second maximum residual energy becomes altruist node, but not mandatory. Later on, selection of cluster head will be based on available residual energy. We use Matlab software as simulation platform to check energy consumption at cluster by 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 Traditional clustering in energy consumption rate.

***Keywords**: Wireless sensor network, Fault tolerant, energy efficiency, lifetime, clustering.*

I. INTRODUCTION

Recently, the rapid developments of various technologies for sensing, computing and communication have brought a lot of momentum to the research in wireless sensor networks (WSNs) [1]. Due to their low cost and capabilities for pervasive surveillance, sensor networks and their applications have tremendous potential in both commercial and military environments [2]. Since energy of the node can be spent in sensing, computation or communication, most of the existing strategies in the literature intend to reduce energy consumption in the network by switching off as many components as possible and as long as possible [3]. Moving object tracking is an active research area in WSNs due to its practical use in a wide variety of applications [4], including military [5] or environmental monitoring applications [6]. Technology advances in integrating sensing and communication capacities in a single node allow the deployment of a large number of sensor nodes in the surveillance field [7], which can form a double or a triple-sized network. The advantages of such systems are: (1) Better sensor reading quality thanks to the proximity of nodes to the detected target, (2) Fast deployment of the network via wireless technology, and (3) Better reliability due to data redundancy. However, this low-cost approach brings up new challenges: (1) necessity of collaborative communication and processing between nodes, (2) impossibility of using advanced signal-processing techniques due to the limited computing resources of the sensor, and (3) impossibility of keeping nodes on all the time due to the limited energy resources. Object tracking sensor networks have two critical operations [1]: 1) monitoring: sensor nodes are required to detect and track the moving states of the mobile object; 2) reporting: the nodes that sense the object need to report their discoveries to the applications. These two operations are interleaved during the entire object tracking process. There are some optimization methods in both of these operations [2], [8]. For monitoring, it has been tried to reduce the number of active nodes which participate in monitoring and tracking process using prediction methods, however this might lead to lose tracking accuracy. Also, a fault tolerant scheme needs to be integrated in the prediction algorithm in case of employing such methods. Any prediction or node failure in these methods must be handled quickly before target slips far away. For reporting on the other hand, optimization techniques are applicable on different clustering and data fusion methods. Upon the number of nodes participate in the tracking process, clustering phase can be the critical phase of the tracking from the energy consumption point of view. It wastes a big portion of energy, since cluster formation needs lots of communications depending on the number of activated nodes to form a cluster. Also, it has a repetitive nature due to continual mobility of the target.

The rest of the paper is organized as follows: section II discusses about the assumption and background , section III discusses overview of some of the existing strategies that have been proposed to improve the energy consumption in WSNs, section IV presents the challenges involved in monitoring multiple objects and the proposed method and Section V gives the conclusion and the future work.

II. BACKGROUND

A. Assumptions

Following assumptions are made about the sensors and the sensor network in the development of the proposed target tracking algorithm:

A set of sensors are deployed in a square terrain. The nodes possesses the following properties

The sensor nodes are stationary.

The sensor nodes have a sensing range and a transmission range. The sensing range can be related to the transmission range, Rt> 2rs.

Two nodes communicate with each other directly if they are within the transmission range

The sensor nodes are assumed to be homogeneous i.e. they have the same processing power and initial energy.

The sensor nodes are assumed to use different power levels to communicate within and across clusters.

The sensor nodes are assumed to know their location and the limits S (Number of nodes in each cluster).

III. OVERVIEW OF EXISTING SCHEMES

This paper [1] investigates prediction-based approaches for performing energy efficient reporting in object tracking sensor networks. A dual prediction-based reporting mechanism (called DPR) has been proposed, in which both sensor nodes and the base station predict the future movements of the mobile objects. Transmissions of sensor readings are avoided as long as the predictions are consistent with the real object movements. DPR achieves energy efficiency by intelligently trading off multi-hop/long-range transmissions of sensor readings between sensor nodes and the base station with one-hop/short-range communications of object movement history among neighbor sensor nodes. The impact of several system parameters and moving behavior of tracked objects on DPR performance has been explored, and also two major components of DPR are studied: prediction models and location models through simulations. The PREMON scheme [9], also a prediction-based reporting mechanism, assumes that sensors in close proximity are likely to have correlated reading and the base station is able to predict the sensor readings given certain historical and background knowledge. Therefore, the base station makes predictions about the sensor readings and transmits every prediction to the corresponding sensor node. If the predictions received from the base station are correct, the sensor nodes do not need to report their readings, otherwise, they have to update the correct readings to the base station. PREMON prevents a sensor node from unnecessarily transmitting all the readings that can be successfully predicted by the base station, thereby saving energy. In PREMON, sensor nodes do not make predictions, but only monitor the state of mobile object. In this paper, Profile-Based Algorithm (PBA) [3] has bee proposed that aims to use the information contained in the network and in the object itself to optimize energy consumption, thus extending lifetime. Here it utilizes the regularity in the object's behavior to reduce energy consumption. In this paper [10], how to efficiently use the energy of the nodes while assigning global unique ID to each node in wireless sensor networks is being explored. By analyzing the communication cost of the clustering and topological features of a sensor network, a distributed scheme of Energy Efficient Clustering with Self-organized ID Assignment (EECSIA) is presented. In the context of EECSIA, a network first selects the nodes in the high-density areas as cluster heads, and then assigns an unique ID to each node based on local information. In addition, EECSIA periodically updates cluster heads according to the nodes' residual energy and density. In this paper [11], In Target Tracking application, the sensor nodes collectively monitor and track the movement of an event or target object. The network operations have two states: the surveillance state during the absence of any event of interest, and the tracking state which is in response to any moving targets. Thus, the power saving operations, which is of critical importance for extending network lifetime, should be operative in two different modes as well. In this paper, we study the power saving operations in both states of network operations. During surveillance state, a set of novel metrics for quality of surveillance, which suggests that atleast p-sesnor nodes required to cover any location, is proposed specifically for detecting moving objects. In the tracking state, we propose a collaborative messaging scheme that wakes up and shuts down the sensor nodes with spatial and temporal preciseness. In this paper[12], a novel approach toward Base Station (BS) oriented clustering and tracking in WSNs is introduced. Proposed method overlooks ad-hoc ability of WSNs to earn energy efficiency and fault tolerance. BS is a powerful energy and computational resource, therefore, BS is burdened with major part of clustering and tracking operations. 3-D cubic antenna is used to enable our sensors to receive BS packets from long distance. Also, BS has a good knowledge of nodes energy level, as a result, BS rotates activated nodes and CH to avoid load balancing problem.

IV. PROBLEM FORMULATION AND CHALLENGES

The assumption is that a number of sensor nodes are deployed in a given area, called monitored region. The boundaries of this region are known by the applications that retrieve the information of interest about the moving objects. The sensor nodes are static, and the moving objects can also be seen as actuators, since they are active elements and exchange information with the sensor nodes. The sensors in the WSN consist of three functional parts: sensing, computation and communication. The sensing subsystem consists of a group of sensors and possibly an actuator that link the node to the physical world. The computing subsystem or Microcontroller Unit (MCU) consists of a microprocessor or microcontroller that controls the sensors and executes the communications protocols and signal processing algorithms. It also hosts the real-time operating system of the nodes. The communication unit consists of a short range radio for wireless communication. A fourth subsystem is the power supply subsystem. It houses the battery and the ac-dc converter and powers the rest of the node.

The objects are supposed to move within the monitored region, which includes sensor nodes, group head, BS. All the operations that are performed by a sensor network consume energy, be it transmission, reception or computation of data. Only the nodes which detect the object in their area should activate their radio components and report to the BS. The remaining nodes could have the radio off.

Requirements of the application: A network with N nodes samples the O moving objects during S seconds and has to report the information to the BS every T seconds.

Problem definition:
The clustering strategy limits the number of nodes in each cluster,S. The clustering aims to associate every node with one cluster. Every node does not violate the admissible degree constraint, D and every cluster does not violate the size constraint, S while forming the cluster. The number of clusters(C) in the network is restricted to N/S, where N is the number of nodes in the terrain.

The Proposed scheme should have fault management architecture which would consider three components: Fault detection – in which faults in sensors are detected and diagnosed, Failure Management – once faults are detected, a strategy is required to deal with it at a system level, Information integrity – related to maintenance, which would decide the quality of information available from a degraded network or in other words the “confidence rating” of that information.

The objective is to propose a fault tolerant approach in wireless sensor networks for target tracking application. The overall framework of Fault tolerant target tracking and clustering is depicted in the below figure.

PROPOSED METHOD:

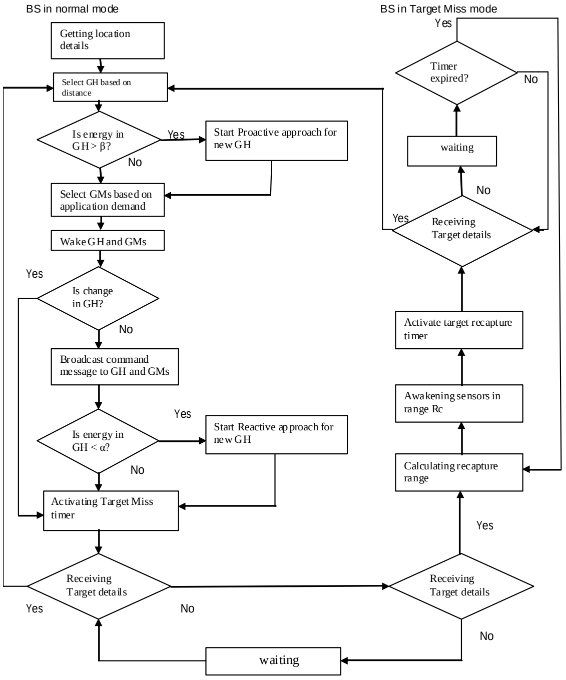

Fig.1. Working Stages For BS

Proposed Algorithm Working Stages

Fig. 1 and Fig. 2 illustrate working stages of the Fault Tolerant Base Station Based scheme. At the beginning of this algorithm, all nodes are in sleep mode except border nodes. When a border node finds a target in its sensing range it waits for a random time called back off time to avoid collision. Then, the border node sends its sensed data to the BS.

On receiving sensed data from border nodes, BS estimates target location. The nearest sensor to target’s estimated location is the candidate of being GH, however, its energy level must be upper than a predefined energy level that called β here. Also it starts the Proactive approach of selecting multiple GHs here in rotational basis. If candidate node energy level does not satisfy β, then the next nearest node to target will be candidate of being GH. This process continues until a candidate node satisfies β condition, otherwise BS decides to lower β to half of its current value but it should be $\beta > \lambda > \alpha$. Then, BS starts to examine candidates one by one to find the appropriate GH. Some nodes of the one hop communicative neighbors of the elected GH should be awakened to be GMs. Number of CMs depends on application demand which effect energy consumption and tracking accuracy. Here, we assume the number of GMs to be three. Again, energy levels of the GMs should be upper than a predefined threshold that we call it α here. BS seeks to find 3 nodes with energy level higher than α. If BS is not capable of finding such 3 nodes, then it lowers α to half of its current value.

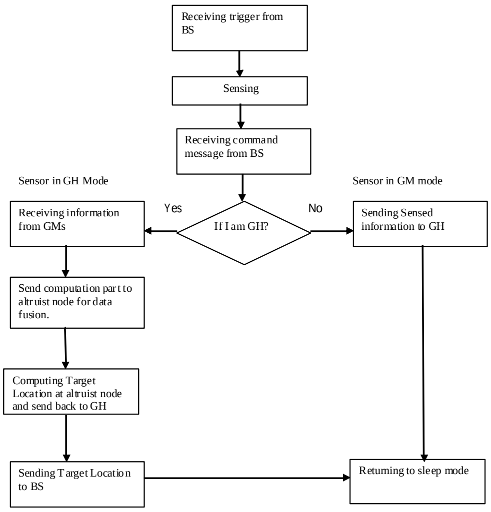

Fig.2. Working Stages for sensors

Since, all sensors autonomously return to sleep mode after a period of time, BS needs to trigger GH and GMs to awaken them and make them ready for receiving command message.

BS broadcasts Command message containing ID of the new GH, over the WSN to inform sensors about the new GH, subsequently other awakened sensors that are not GH will be CMs. Sensors work in two distinct modes shown in Fig. 1. However, if new GH and the latest GH are the same, BS won't transmit any command message indicating that everything is as the same before. Then, the very last GH again is GH for the new round and GMs just transmit their sensed data. Once a member detects the target, it ends its sensed data (its location and the time of finding the target) to the GH. GH performs data fusion to get the location of the target, and reports to the BS periodically. This data fusion is happened at the altruist node which has been declared voluntarily by some nodes to service the cluster head. The concept of altruists is a lightweight approach for exploiting differences in the node capabilities. The altruist approach can achieve significant gains in terms of network lifetime. The overall goal is to make sensor network nodes so small that they can be just thrown out somewhere, or smoothly woven into other materials such as wallpapers and extract the requested data. Sensor nodes are typically battery driven, and the batteries are too small, too cheap and too numerous to consider replacing or recharging. Hence, their energy consumption is a major concern, imposing a design constraint of utmost importance. To achieve a maximum network lifetime, it is mandatory to optimize the energy consumption in all layers of the protocol stack, from the physical layer to the application layer. Receiving tracking information from sensor field, BS starts to evaluate target location. Then, if target is not in the sense range of the current GH, BS dismisses current GH and chooses a new GH as mentioned before. So far BS leads tracking process. However, any failure needs to be handled. In this case, recovery operation is invoked and BS starts to evaluate a capture range RC and awaken all nodes within this range. After broadcasting command message, BS activate target miss timer. If BS doesn't receive report of the GH before timer expires, BS assumes it as target Loss. RC depends on the target last velocity and target maximum acceleration. If BS succeeds to capture the target, then tracking process starts from the beginning, otherwise BS doubles the capture range to its current value and keeps seeking the target until it finds the target or reach to end of the network life time. As soon as being triggered by BS, sensors change their state to sensing state and wait to receive command message. After receiving command message, they check to see if they have been announced as GH or not. If a sensor is not announced as GH, then it is GM. GM broadcast sensed information and GH receives reported information from all GMs. Finally, GH sends target location to BS. Due to energy conservation, GH and CMs return to sleep mode at this point. Due to ease of clustering in the proposed algorithm, it is more practical and energy efficient in WSNs environments. This method omits much of the communicative overhead imposed by the previous algorithms.

The proposed fault management mechanism can be divided into 2 phases:
Fault detection and diagnosis
Fault Recovery

Fault detection and diagnosis

Detection of faulty sensor nodes can be achieved by two mechanisms i.e. proactive approach
and reactive approach as shown in figure 3.[13] Once the BS selects a Group Head (GH) based on proximity of it with respect to Object being tracked, It also checks the energy level of GH and if it is very low, say below a minimum level, α, then it starts the reactive approach. The Group Members (GM) within the group start electing a new GH which would be above threshold value, λ ($\beta > \lambda > \alpha$). If none of the GMs are above λ, the value is halved and restarts the process again. At last, the lowest energy level nodes and the nodes which is not sending response due to sudden death could be updated with GH and in turn updated with other GMs and BS.

In proactive approach, once GH is selected based on proximity of it with respect to Object being tracked and since its energy level is above the threshold β ($\beta > \alpha$) and GH checks the energy level of GMs within its group. Now if more than one node is having high energy level than GH, then the node with least id get priority over others.

When a Group Member (GM) is failing due to energy depletion, it sends a message to its Group Head(GH) that it is going to sleep mode due to energy below the threshold value. This requires no recovery steps. To efficiently detect the node sudden death, our fault management system employed an proactive approach. In this approach, the message of updating the node residual battery is applied to track the existence of sensor nodes. Here GH asks its GM on regular basis to send their updates. Such as; the GH sends “get” messages to the associated common nodes on regular basis and in return nodes send their updates. This is called in-group update cycle. The update_msg consists of node ID, energy and location information. As shown in figure 1, exchange of update messages takes place between GH and GMs. If the GH does not receive an update from any node then it sends an instant message to the node acquiring about its status. If GH does not receive the acknowledgement in a given time, it then declares the node faulty and passes this information to the remaining nodes in the group. GH only concentrate on its GMs and only inform the BS for further assistant if the network performance of its small region has been in a critical level.

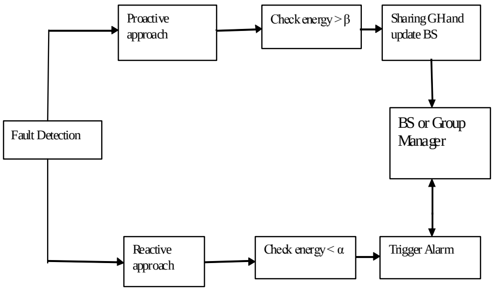

Figure 3. Fault detection and diagnosis process

Fault Recovery

After nodes failure detection (as a result of proactive or reactive approach), sleeping nodes
can be awaked to cover the required cell density or mobile nodes can be moved to fill the coverage hole. If the GM energy drops below the threshold value (i.e. less than or equal to 20% of battery life), it then sends a message and also informs its GH of its residual energy status and in turn updates BS. This is an indication that GM goes to a low computational mode. If GH energy goes below the threshold value, then new GH could be elected as done in Proactive approach if sufficient number of GMs available.

Simulation:

To study the effectiveness of the proposed method, this is simulated and compared against the existing method using MATLAB software. For that, we assume the algorithm which would consider fixed cluster head, means the cluster head wont be changed dynamically and the one which would change the cluster head based on energy left in the nodes and is used in the target based approach. For simplicity for this case, we assume the same track needs to be sensed and the same set of nodes is used for tracking purpose. After iterating for different number of sensor nodes, the energy consumption of nodes differ significantly for these 2 methods as shown in the graph below. Here 4 groups are used with 4 sensors in each group, out of these only group 3 is not participated in sensing operation since no object crossed through it.

The same approach can be extended to test for multiple object tracking and to study how it recover from fault occur on such networks.

TABLE I: PARAMETERS SETTING

Simulation Parameters	Value
Terrain dimension	100 m X 100 m
Total number of nodes in terrain, N	100 – 1000
Transmission Range	100-450m
Initial Energy level for all nodes	3J
Reception Energy	0.035J
Sensing Energy	1.75μJ

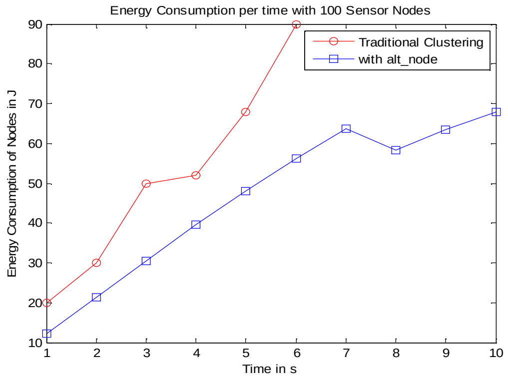

Fig.4. Energy consumption per time with 100 Sensor Nodes

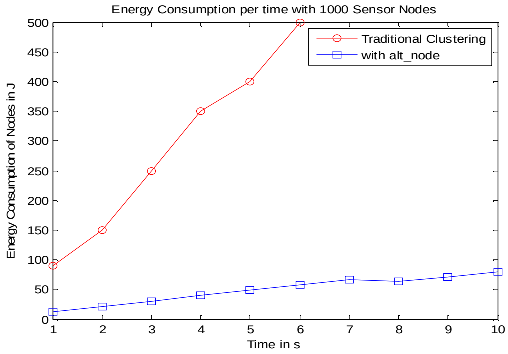

Fig.5. Energy consumption per time with 1000 Sensor Nodes

V. CONCLUSION

In this paper, the feasibility of using BS and Group Head in tracking process is being explored. Besides an idea to combine different techniques and methods to a fault tolerant based target tracking protocol with minimum energy overhead with the assistance of altruist nodes is proposed. This would be evaluated on the basis of network lifetime and transmission of data packets. There are still some problems in prediction accuracy of the target next step needs to be studied in the future. In the future, the methods should be explored for multiple targets tracking in wireless sensor networks with multiple motion models.

REFERENCES:

[1] Y. Xu, J.Winter, W.C Lee “Dual Prediction-based Reporting for Object Tracking Sensor Networks” In: Proceedings of the First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services (MobiQuitous’04) 0-7695-2208-4/04.

[2] Y. Xu, J.Winter, W.C Lee “Prediction-based Strategies for Energy Saving in Object Tracking Sensor Networks” In: Proceedings of the 2004 IEEE International Conference on Mobile Data Management (MDM’04) 0-7695-2070-7/04.

[3] O. Garcia, A. Quintero, and S. Pierre, “Profile-based energy minimisation strategy for Object Tracking Wireless Sensor Networks” Proc. of the IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob’06), pp 372 – 379, Montreal, June 2006.

[4] S. M. Lee, H. Cha and R. Ha, “Energy-aware location error handling for object tracking applications in wireless sensor networks,” Computer Communications, Vol. 30. No 7, pp. 1443-1450, May 2007.

[5] J. Nemeroff, L. Garcia, D. Hampel, S. DiPierro “Application of sensor network communications” In: Proceedings of MILCOM, Virginia, USA, 2001.

[6] R. Szewczyk, E. Osterweil, J. Polastre, M. Hamilton, A. Mainwaring, D. Estrin “Habitat monitoring with sensor networks” In: Communications of the ACM 47 (6) (2004) 34–40.

[7] O. Demigha, N. Badache, M. Aissani and A. Mellouk “Fault-Tolerant Prediction-Based Scheme for Target Tracking Application” In: proceedings IEEE "GLOBECOM" 2009-978-1-4244-4148-8/09.

[8] Y. Xu and W.-C. Lee. “On localized prediction for power efficient object tracking in sensor networks” In Proc. 1st International Workshop on Mobile Distributed Computing, pages 434–439, Providence RI, May 2003.

[9] S. Goel and T. Imielinski. Prediction-based monitoring in sensor networks: taking lessons from MPEG. ACM Computer Communication Review, 31(5), October 2001

[10] Qingchao Zheng, Zhixin Liu; Liang Xue, Yusong Tan, Dan Chen, and Xinping Guan
An Energy Efficient Clustering Scheme with Self-organized ID Assignment for Wireless Sensor Networks - 2010 16th International Conference on Parallel and Distributed Systems

[11] C. Gui, P. Mohapatra “Power conservation and quality of surveillance in target tracking sensor networks” The 10th Annual International Conference on Mobile Computing and Networking, Philadelphia, USA, September 2004, pp. 129–143.

[12] Rahim Pasha Khajei, Abolfazl Toroghi Haghighat, Jaber Karimpour. Fault-Tolerant Base Station Based Target Tracking in WSNs- 2011 Second International Conference on Intelligent Systems, Modelling and Simulation

[13] Muhammad Asim, Hala Mokhtar, Madjid Merabti, "A self-managing fault management mechanism for wireless sensor networks" - International Journal of Wireless & Mobile Networks (IJWMN) Vol.2, No.4, November 2010

[14] Abolfazl Akbari,Arash Dana,Ahmad Khademzadeh,Neda Beikmahdavi, "Fault Detection and Recovery in Wireless Sensor Network Using Clustering" - International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 1, February 2011

[15] Wireless Sensor Network Designs - Anna Ha´c (University of Hawaii at Manoa, Honolulu, USA)

Venkatesh S received the B.E. degree in electrical and electronics engineering from the Sri SivaSubramaniya Nadar College of Enginnering,Chennai,India, in 2005,the M.E. degree in computer science and engineering from the St.Joseph's College Of Engineering,Chennai,India,in 2007.He is currently pursuing research in Wireless Sensor Networks and working toward the PhD degree in computer science and engineering in the Department of Computer Science and Engineering, B.S.Abdur Rahman University,Chennai,India. His research interests include Fault Tolerant System in Wireless sensor networks and energy optimization including enhancing Lifetime of the networks.He is a student member of the IEEE.

◆◆◆