LOAD BALANCING IN WIRELESS SENSOR NETWORKS

Abstract

Wireless Sensor Network (WSN) finds application in many real life situations. But WSN are subjected to certain challenges. One such challenge is the problem of power failure. The nodes in WSN use batteries. This gives the nodes in a WSN limited source of energy. This may lead to power failure due to heavy load in operations. So a scheme is required to balance the load in these nodes and increase the lifespan of the WSN. Different researchers have come up with different techniques to reduce the power consumption of nodes in WSN.

Keywords: Wireless Sensor Network, VGDRA, S-MAC, Sensor Nodes.

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I. INTRODUCTION

WSN is a wireless network of sensors, called nodes. The network is deployed in an ad-hoc manner for collection of sensory data through the sensor nodes. Sensor nodes have on board processors and they manage and monitor the environment where they are deployed. Sensor nodes are connected to a sink. The sink collects data from the nodes and transmits it further. WSN has application in areas such as health, military, home, business etc. In military WSN is used for command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems. In health WSN can be deployed to monitor patient and assist disabled patients. Other commercial application include managing inventory, monitoring product quality and monitoring disaster areas [1].

But WSN faces certain challenges and problems. Some of the issues faced by WSN are Quality of Service, network throughput, performance, security issues, energy efficiency, ability to cope with node failure, cross layer optimization, scalability.

Energy consumption by the nodes is an important issue of WSN. The nodes are cheap in price, miniature in size, has low data transmission rate which result in high energy consumption [2]. The nodes in WSN consists of four main components namely, a sensing element, an analog to digital converter, a processing unit and a power unit [3]. Since the nodes are powered by battery, so the WSN heavily depends on the life span of the nodes battery. So, it is very important to conserve the power in the node's battery. Different schemes have been proposed by researchers to improve the energy efficiency of the nodes in a WSN. In this paper two such techniques for increasing energy efficiency in WSN nodes has been discussed.

II. RELATED WORK

Heinzelman et al. [4], proposed a hierarchical routing protocol for WSN known as Low Energy Adaptive Clustering Hierarchy (LEACH). This protocol implements the data fusion routing mechanism to reduce the number of packets sent to the base station. The cell headers in LEACH are chosen based on a threshold. The cluster heads create TDMA schedule. The nodes transmit data during their assigned slots.

Del-Valle-Soto et al. [5] proposed an energy model for estimating the energy consumption by the nodes during its operations in WSN. The model was implemented using a Texas Instruments CC2530 based boards. The board uses multi parent hierarchical (MPH) routing protocol. The proposed method was found to have consumed low energy compared to other protocols.

Catarinucci et al. [6] proposed a cross layer based approach to minimize the energy consumption in WSN. The protocol solution is integrated with the hardware. A new wake-up system was proposed to reduce power consumption. The system consists of a sensor node and a power meter circuit

Saini et al. [7] proposes a method to optimize energy consumption in WSN. The technique proposed is based on Virtual Grid based Dynamic Route Adjustment (VGDRA) and Genetic algorithm for optimizing and balancing the load in nodes. A comparison of the proposed method was made with LEACH and was found to have a better efficiency.

III. THE VGDRA SCHEME

In traditional static node deployment, n nodes communicate their sensed data with a single static sink, which can give rise to the problem of energy hole phenomenon. So the technique of sink mobility is introduced, where the sink keeps moving within the periphery of the wireless sensory network (WSN). This technique helps to balance the node's energy dissipation and can also link isolated network segments in problematic areas.

But due to the sink's mobility the network topology becomes dynamic. The nodes need to keep track of the changing position of the sink for efficient data delivery. The nodes need to maintain fresh routes to the sink every time the sink moves. This leads to energy drain. So a data dissemination protocol called Virtual Grid based Dynamic Route Adjustment (VGDRA) is proposed by Khan et al. [8]. In this scheme a virtual infrastructure is overlaid over the physical network. Here only a set of designated nodes scattered in the sensor field are responsible to keep track of the sink's location. These designated nodes gather data from the nodes in their vicinity and report the data to the sink.

1. **Virtual Structure :** The sensor field is divided into uniform size of k-cells, where k is a squared number (4, 9, 16…..). The numbers of cells are function of the total number of nodes in the sensor field. 5% of the total numbers of nodes are considered for determining the value of k. After that a set of nodes are selected as cell headers (CH). Initially the cells closest to the centre are selected as cell headers. Then the nodes using the knowledge of the sensor field's dimension and total number of nodes compute the mid points of all the cells. Nodes whose distance from the mid-point is not more than a certain threshold only takes part in the election of the CH. If no node is found within the threshold distance from the mid-point then the threshold value is gradually increased. After the CH election, each CH sends its status to the surrounding nodes in the cell as well as to nodes slightly beyond the cell boundary. Nodes may receive notification from multiple CH. These nodes associate themselves with the closest CH. Nodes receiving notification from multiple CH, share the information of secondary CH with their primary CH. The CH communicates with each other CH through gateway nodes. The cell headers (CH) along with the gateway nodes form the virtual backbone structure. After that the communication routes are setup with the sink, considering the initial position of the sink is located at the coordinates (0, 0). So, all the cell headers adjust their routes to the initial position of the mobile sink.

2. **Dynamic Route Adjustment :** When the sink changes its location, flooding the entire CH with the new location information is not efficient from energy conservation viewpoint. So the VGDRA scheme gives an optimized way of updating the routes to the sink. The mobile sink moves around the sensor field and collects data through the closest border line CH (originating CH). The VGDRA defines a set of rules for route adjustment of the CH to the sink. The rules are as follows

   - **Rule 1:** When the originating CH discovers the sink, it first verifies if its next hop is already set to the mobile sink or not. If the next hop is already set to the mobile sink then it does not propagate sink's location update. But, if the next-hop entry of the originating cell-header is other than the mobile sink, it exercises rule 2.

- **Rule 2:** The originating CH sets the mobile sink as its next hop and shares this information with the previous originating CH and its downstream adjacent CH.

- **Rule 3:** The previous originating CH then sets the current originating CH as its next hop towards the sink.

- **Rule 4:** The downstream cell-header upon receiving the sink's location update checks whether the sender cell-header is the same as its previous next-hop or different. If it is the same, the downstream cell-header drops the sink's location update packet and does not propagate it further to the next downstream cell-header. In the case when it is different, the downstream cell-header updates its next-hop entry to the new sender cell-header and further propagates the sink's location update to the next downstream cell-header. This procedure is repeated till all the downstream cell-headers adjust their data delivery routes towards the latest location of the mobile sink. This scheme reduces the routes reconstruction cost to a great extent.

3. **CH Rotation:** The CH being the local data collector is vulnerable to high energy dissipation. Therefore, the role of CH needs to be distributed among the nodes within the cell. If the residual energy of the CH gets below a certain threshold then the election for new CH is initiated by the current CH. The node that is relatively close to the centre of the cell and has a higher energy level compared to other candidates is elected as the new CH. The search zone around the cell mid-point is slightly increased and the energy threshold level is progressively decreased if no suitable nodes can be found. The current CH then shares the information of the new CH with the member nodes as well as with the adjacent CH in its neighbourhood.

IV. THE AGENT BASED APPROACH

This method proposes an expansion to the S-MAC protocol [9]. The S-MAC protocol is based on the unique feature of powering of the nodes which are not actively transmitting or receiving packets, and also turning off the radios in the process resulting in energy conservation. This method tried to minimize the energy consumption of the border nodes. The border nodes act as the shared nodes between two or more virtual clusters. Virtual clusters are formed on the basis of sleep-listen schedule.

The problem in S-MAC is that a border node (BN) receives two schedules from two virtual clusters. The BN then has to follow two schedules received, thus leading to energy drain as they have to listen for longer time compared to non-border nodes in a cluster. Shakshuki and Malik [10] addressed this problem by proposing a multi agent system in each node.

1. **Agent's Architecture:** The agents contain mainly two components namely, knowledge component and executable component. The learning component learns from the information in the knowledge component to choose energy efficient schedule. The scheduler component uses timer to start or stop certain activities. The communication component helps in communication with other agents and with events occurring in a node.

2. **Working:** Each node in the sensing field will contain a static agent (SA) and a moving agent (MA). The SA monitors and records the activities of the node and updates its energy model in its knowledge. The energy model is maintained in a table format. The table contains the list of node activities and the energy consumption for a predefined time. After the predefined time expires, the SA removes all the entries from the table and starts building a new table. MA keeps visiting the neighbour nodes periodically. MA updates its knowledge with the schedules of the neighbour nodes. The MA then reports back to the SA with the schedules of the neighbour nodes. The SA then updates its knowledge by updating the other model component. Once all the energy models have been reported by the MA, SA then makes an analytical comparison between its local and reported schedules. If the SA finds a more efficient energy schedule of a neighbouring node, then it will mark that schedule as active and will adopt the sleep time of that schedule. The adopted schedule will also be used for future SYNC packet broadcast.

   So, the MA keeps visiting the neighbouring nodes and reports the energy models to SA. Whenever the SA finds a better energy model, the node switches to the new virtual cluster. So the BN keeps toggling between clusters whenever a better energy model is encountered. This method helps in efficient energy consumption by the BN.

V. COMPARATIVE ANALYSIS

The VGDRA scheme partitions the sensor field into a virtual grid, which forms the virtual backbone structure. The cell headers are responsible for adjusting the routes to the mobile sink. Using a set of predefined rules, only a limited numbers of cell headers take part in the route readjustment process. This leads to a reduction in the overall communication cost thus, reducing the energy dissipation. Also, electing a single node as a cell header among a number of nodes and entrusting the cell header with route readjustment and also electing another node as a new cell header when the energy of the current cell header falls below a certain threshold, increases the overall energy efficiency of the WSN. VGDRA when simulated showed improved performance in reducing nodes energy consumption.

Whereas the agent based system proposes a scheme to increase the energy efficiency of the border nodes in a WSN, by proposing two agents (SA and MA). These agents gather the energy model of the neighbour nodes and compare them with the active energy model of the border nodes, thus helping the border nodes to switch to a more efficient cluster. This method outperforms S-MAC protocol. Due to SA's initial time required to build the knowledge, the S-MAC performed slightly better during initial simulation time. It is seen that when the value of visit interval is decreased for MA, then there is a decrease in energy consumption. This is because MA can visit the neighbours frequently and so SA can build the others model component faster resulting in BN's early and frequent decision to adapt to better neighbour.

VI. CONCLUSION

Load balancing of nodes is a very crucial part of WSN deployment. Optimizing the operations in the nodes can increase the life span of the WSN. The two methods discussed above are effective in reducing the power consumption of the nodes. But more research needs to be performed to develop techniques for increasing the energy efficiency of the nodes. Integrating different load balancing techniques for nodes in a WSN could give us a much more effective way of optimizing the loads.

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REFERENCES

[1] Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. A survey on sensor networks. IEEE Communications magazine. 2002 Nov 7;40(8):102-14.
[2] Zhou C, Wang M, Qu W, Lu Z. A wireless sensor network model considering energy consumption balance. Mathematical Problems in Engineering. 2018 Jan 1;2018.
[3] Zaman N, Tang Jung L, Yasin MM. Enhancing energy efficiency of wireless sensor network through the design of energy efficient routing protocol. Journal of Sensors. 2016 Jun 26;2016.
[4] Heinzelman, W.R., Chandrakasan, A. and Balakrishnan, H., 2000, January. Energy-efficient communication protocol for wireless microsensor networks. In Proceedings of the 33rd annual Hawaii international conference on system sciences (pp. 10-pp). IEEE
[5] Del-Valle-Soto C, Mex-Perera C, Nolazco-Flores JA, Velázquez R, Rossa-Sierra A. Wireless sensor network energy model and its use in the optimization of routing protocols. Energies. 2020 Jan;13(3)
[6] Catarinucci L, Colella R, Del Fiore G, Mainetti L, Mighali V, Patrono L, Stefanizzi ML. A cross-layer approach to minimize the energy consumption in wireless sensor networks. International Journal of Distributed Sensor Networks. 2013 Dec 29;10(1):268284.
[7] Saini A., Kansal A., & Randhawa N. S. (2019). Minimization of energy consumption in WSN using hybrid WECRA approach. Procedia Computer Science, 155, 803-808.
[8] Khan AW, Abdullah AH, Razzaque MA, Bangash JI. VGDRA: a virtual grid-based dynamic routes adjustment scheme for mobile sink-based wireless sensor networks. IEEE sensors journal. 2014 Aug 12;15(1):526-34.
[9] W. Ye, J. Heidenmann, and D. Estrin, “An Energy-Efficient MAC Protocol for Wireless Sensor Networks”, In Proceedings of IEEE INFOCOM, New York, NY, June 2002.
[10] Shakshuki E, Malik H. Agent based approach to minimize energy consumption for border nodes in wireless sensor network. In21st International Conference on Advanced Information Networking and Applications (AINA'07) 2007 May 21 (pp. 134-141). IEEE.

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