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Load Balancing Algorithms in Wireless Sensor Network : A Survey

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Abstract— **In this paper, we examine the proposed load balancing algorithms for wireless sensor networks. Load balancing can be used to extend the lifetime of a sensor network by reducing energy consumption. Load balancing using clustering can also increase network scalability. Wireless sensor network with the nodes with different energy levels can prolong the network lifetime of the network and also its reliability. We discuss the improvement to be made for future proposed load balancing schemes. This paper should provide the reader with the basis for research in load balancing schemes for wireless sensor networks.**

Keywords- load balancing, reliability, scalabiity

I. INTRODUCTION

Information gathering is a fast growing and challenging field in today's world of computing. Sensors provide a cheap and easy solution to these applications especially in the inhospitable and low-maintenance areas where conventional approaches prove to be very costly. Sensors are tiny devices that are capable of gathering physical information like heat, light or motion of an object or environment. Sensors are deployed in an ad-hoc manner in the area of interest to monitor events and gather data about the environment. Networking of these unattended sensors is expected to have significant impact on the efficiency of many military and civil applications, such as combat field surveillance, security and disaster management. Sensors in such systems are typically disposable and expected to last until their energy drains. Therefore, energy is a very scarce resource for such sensor systems and has to be managed wisely in order to extend the life of the sensors for the duration of a particular mission. Typically sensor networks follow the model of a base station or Command node, where sensors relay streams of data to the command node either periodically or based on events. The command node can be statically located in the vicinity of the sensors or it can be mobile so that it can move around the sensors and collect data. In either case, the command node cannot be reached efficiently by all the sensors in the system. The nodes that are located far away from the command node will consume more energy to transmit data then other nodes and therefore will die sooner[4].

A wireless sensor network is typically consisting of a potentially large number of resource constrained sensor nodes and few relatively powerful control nodes. Each sensor node has a battery and a low-end processor, a limited amount of memory, and a low power communication module capable of short range wireless communication [2].

As sensor nodes have very limited battery power and they are randomly deployed it is impossible to recharge the dead battery. So the battery power in WSN is considered as scarce resource and should be efficiently used. Sensor node consumes battery in sensing data, receiving data, sending data and processing data [1].

Generally a sensor node does not have sufficient power to send the data or message directly to the base station. Hence, along with sensing the data the sensor node act as a router to propagate the data of its neighbor.

In large sensor network, the sensor nodes can be grouped into small clusters. Each cluster has a cluster head to coordinate the nodes in the cluster. Cluster structure can prolong the lifetime of the sensor network by making the cluster head aggregate data from the nodes in the cluster and send it to the base station. A randomly deployed sensor network requires a cluster formation protocol to partition the network into clusters. The cluster heads should also be selected. There are two approaches used in this process the leader first and the cluster first approach. In the leader first approach the cluster head is selected first and then cluster is formed. In the cluster first approach the cluster is formed first and then the cluster head is selected [2].

Clustering has numerous advantages like it reduces the size of the routing table , conserve communication bandwidth, prolong network lifetime, decrease the redundancy of data packets, reduces the rate of energy consumption etc[3].

Generally it is assumed that the nodes in wireless sensor networks are homogeneous, but in reality, homogeneous sensor networks hardly exist. Even homogeneous sensors have different capabilities like different levels of initial energy, depletion rate, etc. In heterogeneous sensor networks, typically, a large number of inexpensive nodes perform sensing, while a few nodes having comparatively more energy perform data filtering, fusion and transport. This leads to the research on heterogeneous networks where two or more types of nodes are considered. Heterogeneity in wireless sensor networks can be used to prolong the life time and reliability of the network. Heterogeneous sensor networks are very popular [3].

1.1 Heterogeneous *Model for Wireless Sensor Networks*

Different Heterogeneous Model for Wireless Sensor Networks are suggested based on various resources. There are three common types of resource heterogeneity in sensor nodes: computational heterogeneity, link heterogeneity, and energy heterogeneity.

Computational heterogeneity means that the heterogeneous node has a more powerful microprocessor, and more memory, than the normal node. With the powerful computational resources, the heterogeneous nodes can provide complex data processing and longer term storage.

Link heterogeneity means that the heterogeneous node has high bandwidth and long distance network transceiver than the normal node. Link heterogeneity can provide a more reliable data transmission.

Energy heterogeneity means that the heterogeneous node is line powered, or its battery is replaceable.

Among above three types of resource heterogeneity, the most important heterogeneity is the energy heterogeneity because both computational heterogeneity and link heterogeneity consumes more energy resource.

1.2 Impact of Heterogeneity on Wireless Sensor Networks

If we place some heterogeneous nodes in sensor network it shows the following benefits:

Response time: Computational heterogeneity can decrease the processing latency and link heterogeneity can decrease the waiting time, hence response time is decreased.

Lifetime: The average energy consumption will be less in heterogeneous sensor networks for forwarding a packet from the normal nodes to the sink, hence life time is increased. Further, it is also known that if in a network, heterogeneity is used properly then the response of the network is tripled and the network's lifetime can be increased by fivefold [3].

1.3 Cluster properties

Quite often, clustering schemes strive to achieve some characteristics for the generated clusters. Such characteristics can be related to the internal structure of the cluster or how it relates to others. The following are the relevant attributes:

1.3.1 Cluster Count: cluster heads are predetermined thus, the number of clusters is preset. Cluster head selection algorithms generally pick randomly cluster heads from the deployed sensors hence yields variable number of clusters.

1.3.2 Intra-cluster Topology: Some clustering schemes are based on direct communication between a sensor and its designated cluster head, but sometimes multi hop sensor to CH connectivity is required.

1.3.3 Connectivity of cluster head to base station: Cluster heads send the aggregated data to the base station directly or indirectly with help of other cluster head nodes. It means, there exists a direct link or a multi hop link.

1.4 Cluster head Capabilities

The following attributes of the CH node are differentiating factors among clustering schemes

1.4.1 Mobility: cluster head may be stationary or mobile. In most cases, they are stationary. But sometimes, cluster head can move within a limited region to reposition themselves for better network performance.

1.4.2 Node Types: Generally sensor nodes among the deployed sensors are designated as CHs, but sometimes sensor nodes equipped with significantly more computation and communication resources are selected as CHs.

1.4.3 Role: Some of the main roles of the CHs are simply relaying the traffic, aggregation or fusion of the sensed data.

1.5 Cluster head selection criteria

Following are some of the parameter used for selecting the cluster head

1.5.1 Initial Energy: This is an important parameter to select the CH. When any algorithm starts it generally considers the initial energy.

1.5.2 Residual Energy: After some of the rounds are completed, the cluster head selection should be based on the energy remaining in the sensors.

1.5.3 Energy Consumption Rate: This is another important parameter that considers the energy consumption rate

1.5.4 Average Energy of the Network: The average energy is used as the reference energy for each node. It is the ideal energy that each node should own in current round to keep the network alive.

II. LITERATURE REVIEW

In a cluster based load balancing [4], the maximum transmission power of the nodes is used to become the cluster member. Cluster membership depends on the communication cost. The proposed approach does not consider the backup recovery.

A load balanced clustering approach [5], uses comprehensive weight value composed of distance between the head and the member and the residual energy to improve cluster member choice. It also uses optimization threshold value to avoid load imbalance. The algorithm considers load equalization for creating balanced cluster.

A multi-hop clustering algorithm for load balancing in wireless sensor networks [6], uses layered approach for intra cluster and inter cluster communication. The algorithm consider homogeneous network.

Reconfiguration of cluster head for load balancing in wireless sensor networks [7], increases the network lifetime by fairly distributing the cluster heads. Reconfiguration of the cluster is done based of the number of general nodes in the

cluster & the number of cluster heads within the cluster head's transmission range. The algorithm provides effective data aggregation.

A novel load balancing scheduling algorithm for wireless sensor networks [8], uses optimal scheduling algorithm for packet forwarding which determines the time slot for sending the packets for the nodes. The algorithm provides uniform packet loss probability for all the nodes. The algorithm uses balanced cost objective function for optimum scheduling.

Secure load balancing via hierarchical data aggregation in heterogeneous wireless sensor networks (SLB) [9], protocol introduces pseudo sink in order to improve data accuracy and bandwidth utilization of WSN to increase network lifetime.

A load balanced algorithm in wireless sensor networks based on pruning mechanism [10], handles the hot point problems which uses pruning mechanism in the cluster to balance the load in the network. Evaluation function in the algorithm is based on pruning mechanism and uses nodes location, residual energy and count of cluster nodes as its parameter to find its cost.

In load balancing in energy efficient connected coverage wireless sensor networks (LBEECC)[11], the algorithm consider sensing coverage & network connectivity by dividing the sensor network nodes into subsets. It turns on some extra nodes in each subset to ensure network connectivity. The problem with this approach is to find the existence of critical nodes. These nodes may be on all the time and the network will be partitioned if these nodes die.

A Threshold Based algorithm for Power aware Load Balancing in Sensor Networks [12], provides possible in-network method for adaptive distributed control of energy consumption. Other methodologies like market based algorithm or game theoretic algorithm can be used. The algorithm assumes complete connectivity.

A Load Balanced Clustering Algorithm For Wireless Sensor Networks (LBCA) [13], has proposed the load balancing algorithm for cluster heads in wireless sensor networks by considering the traffic load as the key parameter. It is assumed that the traffic load contributed by all the sensor nodes is same, which is the special case of this algorithm. In general case the algorithm is NP hard. It uses centralized approach and assumes that each node is aware of the network.

Clustering and Load Balancing in Hybrid Sensor Network with mobile Cluster Nodes[14], has proposed an algorithm that consider the problem of positioning mobile cluster heads and balancing traffic load in hybrid sensor network which consists of static and mobile nodes. It is stated that the location of the cluster head can affect network lifetime significantly. Network load can be balanced and lifetime can be prolonged by moving cluster head to better location.

A Load Balanced Clustering Algorithm for Heterogeneous Wireless Sensor Networks [15], has Proposed the load balanced group clustering to balance the battery power in wireless sensor network by implementing dynamic route calculation according to the condition of energy distribution in the network. It make use of heterogeneous energy to realize load balance.

Fuzzy Based Approach for Load Balanced Distributing database on Sensor Networks [16], has proposed fuzzy based approach for load balanced distributing database on sensor network that prolong the network lifetime. In this algorithm vertical partitioning algorithm for distributing database on sensors is used. In this approach, first clusters are formed and then distribute partitions on clusters.

TABLE I. SUMMARY TABLE

SNO	Title	Year & publication	Author(s)	Facts	Findings
4	Load Balanced clustering in WSN	2003 (IEEE)	G. Gupta, M. Younis	Cluster membership is depends on communication cost.	Location aware clustering with maximum transmission power is used.
5	A Load Balanced Clustering Algorithm For WSN for Data Gathering	2011 (IEEE)	H. Zhang, L. Li, X. Yan & X. Li	The algorithm consider load equalization for creating balanced cluster.	It uses comprehensive weight value. It also uses optimization threshold value to avoid load imbalance.
6	Multi-hop clustering Algorithm For Load Balancing in WSN	2006	N. Israr & I. Awan	The algorithm uses layered approach for inter and intra cluster communication.	The algorithm assumes homogeneous nodes
7	Reconfiguration ofClusterhead for Load Balancing in WSN	2008	N. Kim, J. Heo, H. S. Kim & W. H. Kwon	The proposed algorithm increases the network lifetime by fairly distributing the cluster heads.	Reconfiguration of the cluster is done based on the number of general nodes in the cluster & the number of CHs within the CH's transmission range. It provide effective data aggregation.

8	Novel Load Balancing Scheduling Algorithm For WSN	2011	E. Laszlo, K. Tornai, G. Treplan & J. Levendovszky	Optimal scheduling algorithm for packet forwarding is proposed .	Uses balanced cost objective function for optimum scheduling.
9	Secure Load Balancing via Hierarchical Data Aggregation in Heterogeneous WSN	2009	S. Ozdemir	SLB protocol introduces pseudo sink in order to improve data accuracy and bandwidth utilization.	Does not handle fault tolerance and failure recovery.
10	Load Balanced Algorithm In WSN Based on Pruning Mechanism.	2009 (IEEE)	Y. Zhang, Z. Zheng, Y. Jin, X. Wang	The Algorithm is based on pruning mechanism to tackle the hot point problems.	Evaluation function is based on pruning mechanism and uses nodes location, residual energy and count of cluster nodes.
11	Load Balancing in Energy Efficient Connected Coverage WSN	2009 (IEEE)	M. Mahdari, M. Ismail, K. Jumari	The algorithm Consider sensing coverage & network connectivity by dividing the sensor network nodes into subsets.	The problem with this approach is to find the existence of critical nodes. These nodes may be on all the time and the network will be partitioned if these nodes die.
12	Threshold Based Algorithm For Power Aware Load Balancing in Sensor Networks.	2005 (IEEE)	C. M. Canci, V. Trifa & A. Martinoli	Proposed threshold based algorithm that provide possible in-network method for adaptive distributed control of energy consumption.	It can be extended for an arbitrary number of nodes active at the same time. It assumes complete connectivity.
13	Load Balanced Clustering Algorithm For Wireless Sensor Networks.	2007 (IEEE)	C.P.Low, C. Fang, J. Mee, Ng & Y.H. Hang	Proposed the load balancing algorithm For cluster heads in wsn by considering the traffic load as the key parameter.	Distributed algorithm Can be developed which will be more scalable for the design of cluster based sensor networks.
14	Clustering & Load Balancing in Hybrid Sensor Network with mobile Cluster Nodes	2006 (ACM)	Ming Ma & Y. Yang	Proposed an algorithm that consider the problem of positioning mobile cluster heads & balancing traffic load in hybrid sensor network which consists of static and mobile nodes.	Network load can be balanced and lifetime can be prolonged by moving cluster head to better location.
15	A Load balanced Clustering Algorithm for Heterogeneous Wireless Sensor Networks	2010 (IEEE)	Y. Deng, Y. Hu	Proposed the load balanced group clustering to balance the battery power by implementing dynamic route calculation according to the condition of energy distribution in the network.	It make use of heterogeneous energy to realize load balance.
16	Fuzzy Based Approach for Load Balanced Distributing database on Sensor Networks	2010	M. Zeynali, L.M.Khanli, A. Mollanejad	Proposed fuzzy based approach for load balanced distributing database on sensor network that prolong the network lifetime. They have used vertical partitioning algorithm For distributing database on sensors.	In this approach, they first form the clusters and then distribute partitions on clusters.

III. CONCLUSION

In this paper, we have examined the proposed load balancing algorithms with respect to energy requirements. In wireless sensor network energy is the most valuable resource. The algorithms presented in this paper offer a promising improvement over conventional algorithms. However there is still much work to be done. Optimal clustering in terms of energy efficiency should eliminate all the overhead of cluster head selection process as well as cluster member selection process. Again re-clustering should be done efficiently to improve the network lifetime.

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