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Synchronized Overlapped Schedules for Clusters in Wireless Sensor Networks

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Abstract:

This paper proposes medium access control (MAC) layer protocol for wireless sensor networks. Sensor nodes are battery operated so the energy efficiency is an important aspect for the wireless sensor networks WSNs. The protocol aims for achieving energy efficiency to increases network lifetime and scalability to increase the network capacity. Clustering, synchronization and low duty cycle are some of the characteristics for utilizing energy efficiently in the network. The protocol is designed with having the schedules of the clusters to be overlapped in a low duty cycle operation. We have evaluated the performance of protocol through detailed ns- 2 simulation. The simulation results show that this protocol outperforms when compared to SMAC. It has reduced schedule updates, power consumption and data loss.

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Keywords— Wireless sensor networks, duty-cycle, clustering, schedule, synchronization, energy-efficiency

I. INTRODUCTION

A wireless sensor network is a group of specialized transducers known as sensors for monitoring and recording conditions at diverse locations. They convert physical phenomenon such as heat light sound or motion into electrical or other suitable form of signals that can be further manipulated. A sensor node is a basic unit of the sensor network with onboard sensors, processor, memory, wireless modem and power supply. Replacing or renewing energy resources after deployment becomes impossible or too difficult and costly in most cases, so the protocols and applications must make smart use of the finite energy resources. WSNs have already been used widely in many areas, including military, agriculture, environmental monitoring and so on, and have been an active research area in the recent years.

Standard MAC layer protocol concentrates on framing, reliability, flow control and error control. Their aim will be to maximize packet throughput, minimize latency and provide fairness[1]. But wireless sensor networks have some characteristics, which is why they need separate MAC layer protocols designed. Some of those attributes are that they are collaborative systems, their nodes are idle much of the time, they use in-network processing. Also energy efficiency , scalability, robustness are integral needs of the WSNs.

The main motivation of the proposed algorithm is minimizing energy usage while considering wireless sensor communication patterns and hardware limitation. Supporting low-power-listening, network clustering and maintaining the nodes synchronization are the main attributes that have been considered for designing a new medium access control protocol. The proposed MAC protocol designed where the schedules of the neighboring clusters coincides small amount of time for communication between the clusters.

Generally in a WSNs the number of nodes used will be vast. As the number of the nodes are more the data needs to be aggregated

before sending the data to the sink or to the base station. And also because there will be many number of nodes there will be need for organizing the network. Network topology must be seen that the load is balanced throughout the network. Using the concept of clustering data aggregation and network organization can be maintained efficiently. Clustering divides the nodes into groups so one group can be viewed as a single entity. This has many advantages[6]. Clustering allows the network to scale to higher level. And functionalities can be performed on local scale which will consume less energy than when performed on the global scale.

Idle listening is one of the sources of the energy wastage in the WSNs. Duty cycle is a concept where the sensor nodes time is divided into two parts. The nodes will be awake for some amount of time and they will be sleeping for the remaining amount of the time. The amount of the time nodes will be awake or sleeping depends on the application. Since in the WSN most of the time the networks are idle they will have their transreciever on and will be listening idly for messages. This will waste the sensor energy. Duty cycle is the solution for idle listening power wastage.

II. RELATED WORKS

The idea of clustering in a MAC protocol is not new, but we make the first attempt to combine this idea together with duty cycling synchronization and clustering in the context of MAC protocols. For improving energy efficiency there are many protocols designed in the MAC layer. Traditional MAC layer and the most known protocol is SMAC[2][9], it is contention-based duty-cycle MAC protocol. The main sources of the energy wastage in the WSNs are figured to be collision, idle listening, overhearing and control packet overhead. SMAC protocol uses duty cycle concept to overcome the idle listening and overhearing problem. SMAC is contention based so the collision is also avoided. Control packet overhead can be reduced by the approach SMAC uses for message passing.

The proposed paper aims to improve the SMAC protocol in reference to energy efficiency. So the proposed protocol parent is the SMAC protocol. It uses the virtual clustering, low duty cycle and synchronization algorithms which are explained in detail in the next section.

Many research are going on MAC layer protocols with duty cycled concepts. Some of the duty cycles have fixed amount of sleep and awake time[3]. And some of them have adaptive amount of time[4][5]. In adaptive they are further classified, where the awake time will be adaptive or else sleep time will be adaptive. TMAC and DSMAC[6] protocols are the example of fixed and adaptive duty cycle respectfully. Many protocols are designed for improving the SMAC protocol on different concepts. Some of them concentrate on the duty cycle whereas some of them concentrate on the clustering methodologies[7]. One of the SMAC protocol limitation is the border node or the cluster heads. If any node keeps track of the schedules of more than one cluster then they are bound to die sooner than other nodes for the reason of exhausting energy soon. This will lead to the holes in the network. Some of the algorithms for synchronization and scheduling are designed to overcome this limitation[8]. Schedule Unifying algorithm [10] is one of them.

III. DESIGN

A. Overview

The proposed Synchronized Overlapped schedules for Clusters in the WSNs is a protocol aiming for energy efficiency and for the protocol to scale easily to higher levels. The protocol aims to extend the network s life by using duty cycle, clustering, scheduling and synchronization. The figure represents the energy efficiency requirement diagram.

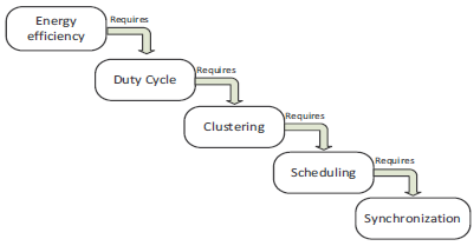

Figure 1 : Energy Efficiency Requirement Diagram

Clustering is a process where it divides all the nodes and forms groups known as clusters. The proposed algorithm is designed in such a way that all the nodes deployed are clustered. This protocol is suited for the applications where there is no need of mobility. Synchronization when done on cluster assuming the whole cluster has a single entity consumes less energy than synchronizing each node separately and thus consumes less energy.

All the nodes with the same schedules are grouped together. In the proposed protocol all the nodes in a cluster will have the same schedule. All the nodes will sleep and be awake in the same time. If all the nodes are listening for all the time it leads to idle listening and it will be the reason for the wastage of the energy. This is how duty cycle and scheduling is designed in the proposed protocol to save energy.

Synchronization methodology used in the protocol is controlled by sink or the base station. By using the synchronization algorithm the clock drifts are handled well and they support scheduled data transmission which in turn saves energy.

B. Architecture

Components of the protocol are the sink node, cluster radius and coinciding factor.

If the nodes deployed is viewed as graph G then it contains V number of nodes and L number of links between the nodes. If there is link L between U and V, it says that the node U and V are connected and at a hop distance away from each other. The number of hops between two nodes U and V can be represented with H. Since all the nodes in the network are grouped into clusters the clusters can be represented as Πi, i represnting the number of the cluster. In the proposed protocol all the nodes in the cluster have same schedule which can be represented as γi. For all the clusters there is the starter node $U^{i}_{j,0}$ where j is the index of the starter node for cluster i. If a node is represented as $U^{i}_{j,1}$, then it is a node which has one hop distance with the starter node.

The working of the protocol is designed as follows: The first step is carried out only once throughout the network and it is run only at the beginning right after the node deployment. This first step is of the sink or the starter node, at the beginning all the nodes will be in fully awake state they will be waiting for the SYNC message from the starter node. SYNC message is a small message containing the address of the sender, the next of its next sleep and counter for number of hops travelled. All the nodes around the sink will receive this SYNC message and they will update their schedules so that all the nodes in the cluster sleep and awake at the same time.

The root or the sink $U^{1}_{1,0}$ creates the first cluster Πi by choosing the schedule γi. The process caries on untill it reaches to the cluster radius. This is done to get equal sized clusters and also to balance the load throughout the network equally. The edge nodes can be identified as $U^{i}_{j,h}$ where h the number of hops is less than m the cluster radius h<m. The edge nodes create the new schedule γi+1 for the cluster Πi+1 such that γi+1=γi-k where k is the coinciding factor. The new cluster with the new schedule is created such that there is a small amount of time overlapping between the clusters at which time both the clusters will be awake, This coinciding time is used for communication between the clusters.

The process is repeated until all the nodes are formed into the clusters. The topology obtained can also be said as the connected hierarchy because the edge nodes of one cluster creates the next cluster and all the neighbouring clusters awake peiod is overlapped sufficiently to allow the communication between them.

By using this protocol we can see that the nodes can be in the sleeping state for much of the time. If the data has to be sent to the sink node, the last cluster aggregating the data from its nodes will send it to its neighbouring cluster at the overlapped time. Now the cluster has data of its previous cluster and its own data which can be aggregated again and sent to the next cluster closer to the sink. It repeats until it reaches the base station. Once the nodes send data to its neighbouring cluster they can goto sleep and hence conserving the energy, utilizing the energy very efficiently.

The diagram shows the portion of the network model for the proposed protocol. It shows the protocol for two hops cluster. The first cluster is created by the sink node and the edge nodes creates the next clusters. The schedule of the new cluster is also determined by the edge cluster so the schedules are inter related to each other.

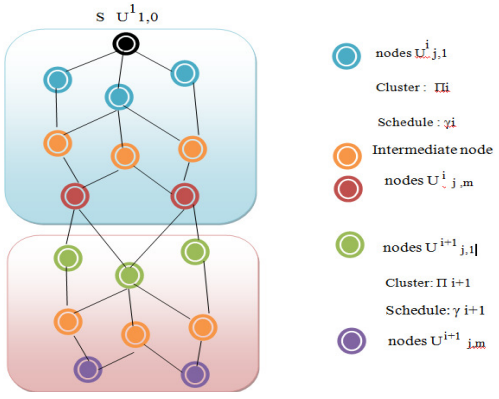

Figure 2 : Clustering Sequence for portion of the network

C. Clustering and Features

i. Virtual Clustering

Virtual clustering is a process of grouping the nodes with common schedules, there will be no strict structure to be followed. This type of clustering does not have cluster heads, nodes are grouped into flat topology where coordination between nodes is not controlled by the cluster head. It was seen in SMAC protocol that a node following more than one schedule and a node having more work than all the other nodes will exhaust its energy and die sooner. If the cluster head of the cluster dies sooner than all the other cluster members cannot contribute to the topology in spite of having energy, in this case all the nodes energy are wasted and data is also lost. By following virtual clustering the disadvantage in SMAC can be overcome and it also leads for the energy being efficiently used.

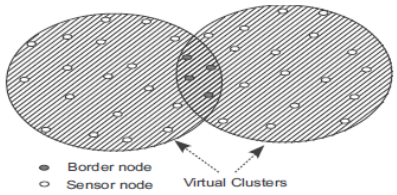

Figure 3: Virtual Clustering

ii. Scalability

Scalability is one of the performance metrics for the WSNs. Generally in a WSN the number of the nodes needed is quite large and they will usually require the data to be aggregated before sending it to the base station. By following the in-network processing there will not be need for all the nodes in the network so send the data, instead only one node send the aggregated data. This helps in saving energy to a greater extent. For any protocol in the MAC layer it is necessary to be easily scalable. The proposed protocol uses clustering process has the main attribute to conserve energy, and so scalability can be done easily. In clustering process after the nodes are grouped, they can be viewed as a single entity. When they are viewed as a single entity then the number of clusters can be

increased and still the protocol will function properly. The proposed protocol is tested if there is degradation in the process performance when the number of nodes is increased vastly, and it is found not to affect the performance.

iii. Scheduled Updated

In all the protocols there will be need to synchronize the schedule tables periodically. Since in the proposed protocol the schedules are assigned and controlled by a centralized node the need for resynchronization is very less. At the beginning of the protocol the protocol the base station or the sink will set the schedule for the first cluster and from there on the edge nodes will create the schedules for the next cluster so as to have a sufficient overlapped time between the clusters. This process will also take care of the drifts in the clock. Time of all the nodes will be synchronized. So the resynchronization time required for the proposed algorithm is quite long when compared to other protocols like SMAC and TMAC.

IV CONCLUSION

The paper proposed a MAC layer protocol synchronized overlapped schedules for clusters in WSNs for the purpose of efficient energy consumption, balance of the load among the nodes and reducing communication overhead. By clustering and low duty cycle operation the energy is efficiently utilized and the protocol can also scale easily. The resynchronization period is quite long which reduces the communication overhead and also the SYNC messages which are passed to form the clusters are very short so as to reduce the control packet overhead

As part of the future work, while sending the data from one cluster to the other cluster at the overlapped time all the edge nodes participate and they send the same data to the next cluster leading to data redundancy. So the protocol can incorporate a methodology where only one node sends the data to other cluster and all the other nodes will be monitoring the transmission. In case of loss in the packet after waiting for a certain amount of time the next node can send data to the next cluster with other nodes still monitoring.

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