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Energy Efficient and Efficient Data Transmission in Wireless Sensor Network

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Abstract: **For military missions and environment monitoring wireless sensor network always provide a great potential. Wireless sensor nodes need to be deployed at a distance from the base station in many applications, where the data or information are collected, stored, and analyzed. In almost all applications in wireless sensor network long distance transmissions are often required and they consumed lot of energy. Long distance achieved by Collaborative beamforming, yet low energy consuming, transmissions by means of multiple simultaneous nodes transmitting the same data to the same receiver. Collaborative transmission introduces some energy overhead due to additional steps. Several techniques are presenting in this dissertation for achieving energy-efficient collaborative transmissions in wireless sensor networks. The following questions are addressed here: (1) Energy can be saved by collaborative transmission or not, and which are the key factors that are determined, (2) how the network lifetime can be prolong by collaborative transmission , and (3) how to perform collaborative transmissions to extend the transmission distance. The first one can be addressed by achieving collaborative beamforming transmissions using different approaches. In This dissertation the factors that affect the energy savings for beamforming transmissions are analyzed. The second one is addressed using an energy-efficient transmitter scheduling algorithm that balance the energy consumption over the network, it also prolonging the network lifetime. At last, the third one is addressed by selecting a method for use beamforming in multi-hop transmissions to extend the transmission distance between hops.**

Keywords: **Wireless Sensor Network (WSNs), Data aggregation, LEACH, wireless ad hoc networks, Multi-hop communication, Natural disasters, Landslide Monitoring.**

I. INTRODUCTION

Wireless Sensor Network (WSNs) attracted lots of researchers because of its potential wide applications and also many other challenges. Studies made earlier on WSNs mainly focused on all the technologies which are based on homogeneous WSN in which all the nodes have same system resources. Nowadays heterogeneous WSN is becoming more popular because of the benefits of heterogeneous WSNs with different capabilities in order to meet the demands of various applications. In sensor networks the nodes are usually battery energy supply based. In sensor networks the large number of nodes and their work environment are incompatible to energy recharge. Therefore power consumption is an important issue in Wireless Sensor Networks. More and More attention today is being paid to energy efficiency of Wireless Sensor Networks.

In this dissertation an algorithm is proposed for saving the energy or power of cluster with data aggregation in wireless sensor networks. In this method the algorithm is divided in two phases and then the phases are divided into different steps. The very first phase have creation of cluster and selection of cluster head which is based on different parameters such as node consideration (NC), shortest distance (SD), transmission power (TP), processing speed of a node (PSN), Ram etc. In Phase second after calculation of all required parameters a table is maintained at Base Station (BS) and also only Aggregated Data is to collect and send by the Base Station (BS).

II. CONCLUSION OF LITERATURE SURVEY

Using the transmitter selection method, the energy consumption overhead on aligning the phases can be eliminated, but the energy consumption for data sharing still exist. I presented the procedures for data sharing when multiple sensing nodes and transmitters are used in each round of beamforming. I show that beamforming saves energy across the network when compared to direct transmissions, if the base station is far away. This saving even takes into account the data sharing energy overhead. Energy consumed on data sharing has negligible effect on the network lifetime of beamforming, when the transmitters are close to each other. I present a beamforming transmitter scheduling algorithm that is adaptive to the size of the deployment area. For a network within a small sensing area, I propose to schedule the transmitters based on their phase differences and remaining energy. Compared to existing work, the proposed algorithm in this dissertation prolongs the network lifetime by 60%, even in the worst case. When the size of the sensing area increases, the distance between the transmitters needs to be considered, since a huge amount of energy will be consumed by data sharing if the transmitters are far away.

III. PROBLEM STATEMENT AND METHODOLOGY

Several techniques are presenting in this dissertation for achieving energy-efficient collaborative transmissions in wireless sensor networks. The following questions are addressed here: (1) Energy can be saved by collaborative transmission or not, and which are the key factors that are determined, (2) how the network lifetime can be prolong by collaborative transmission , and (3) how to perform collaborative transmissions to extend the transmission distance. The first one can be addressed by achieving collaborative beamforming transmissions using different approaches. In This dissertation the factors that affect the energy savings for beamforming transmissions are analyzed. The second one is addressed using an energy-efficient transmitter scheduling algorithm that balance the energy consumption over the network, it also prolonging the network lifetime. At last, the third one is addressed by selecting a method for use beamforming in multi-hop transmissions to extend the transmission distance between hops.

In this research work we use thease methodology-

Review of Clustering Algorithms:

A Clustering Algorithm in wireless sensor networks usually coordinates the activities of sensing nodes in the network for data transmission to the base station. Routing protocols in WSN can be grouped into three models as follows.

i) **One-hop model:** every node in the network transmits data directly to the base station. This is the simplest model representing direct communication from the sensor node to the base station. However, the direct communication may not be practical for routing in wireless sensor networks because each sensor node has limited transmission hop.
ii) **Muli hop model:** a sensor node transmits data to the base station by forwarding its data to one of its neighbors which are closer to the base station.
iii) **Cluster-based Hierarchical Model:** each cluster consists of a single cluster head (CH) and nodes with multiple member. A cluster head is always there in every group of nodes i.e. cluster that has the responsibility of routing data packets from one cluster to another cluster heads toward the base station. A single node can act as both the cluster head in one cluster, and also a member in another cluster which is closer to the base station.

One of the energy-efficient techniques used in wireless sensor networks is the clustering algorithm. A cluster- based routing protocol can avoids intensive message exchanges of path search update processes and overhead of storing routing table or other information that could be expensive to update.

Efficient Energy-aware Clustering Technique:

In the design of energy-aware clustering techniques for wireless sensor networks, a clustering algorithm is used for cluster head selection. A simple clustering algorithm may

Select a cluster head with minimum distance are maximum residual battery level. A minimum cost function was presented in a previous research work.The minimum cost function algorithm select a cluster head which would have a minimum cost in order to increase the lifetime of network. As a result, the selected cluster head has high residual battery level and low energy consumption.

IV. WIRELESS SENSOR NETWORK

Wireless Sensor Network is self-organizing multihop system of sensor nodes which can communicate with each other. They do not have pre-existing infrastructure therefore each node act as a router to relay packets to its neighbors. The wireless sensor network nodes are usually battery energy supply based. Basically the large numbers of nodes in these wireless networks are incompatible to energy recharge, therefore power consumption is an important issue in Wireless Sensor Networks. Today more attention is being paid to energy efficiency of Wireless Sensor Networks. To improve energy efficiency of Wireless Sensor Networks Many Cluster schemes have been proposed. An important parameter is the size of the cluster. If cluster size is decreased then consumption within each cluster is smaller, then the power consumption is hardly dependent on cluster size. These CHs will become more complicated after the number of CHs will increase, by this the resulting backbone network formed. Also a lesser number of CHs will form a simpler backbone network. Yet that will require larger cluster size, so that the RF power in each cluster becomes higher or the multihop route within the cluster becomes more complicated. There is then a tradeoff between the cluster size and the number of CHs. Therefore, optimization of the size of the cluster can improve the energy efficiency. So Many research works are mainly focused on the area of cluster-based WSNs which include energy should be efficient, network lifetime, stability and scalability of the network. In the past years, for a wide range of applications numerous clustering algorithms have been proposed. Data aggregation and hierarchical techniques are very general used in many applications of WSNs. It removes the data redundancy and data communication load. Single-hop communication model based on the first clustering protocol that is LEACH In LEACH, each node generates a random number between 0 and 1, in the setup phase. If the threshold value is greater than this random number then, T(s), then the node becomes a CH for the current round. During each round, new CHs are elected and as a result balanced load energy is distributed among the CHs and other nodes of the network. Power-Efficient Collection in Sensor Information System is a chain based on LEACH that is also based on power efficient protocol. It assumes that all of the nodes in the entire cluster must know the approximately location of all other nodes in the cluster. The chain is constructed by using a greedy algorithm and then it starts with the farthest node. The chain leader aggregates data and forwards it to the Base Station (BS). For balancing the overhead of the communication between the chain leader and the BS, each and every node in the chain takes turn to be the leader. The author described a heuristic approach to solve the data-gathering problem with aggregation in sensor network. In this scheme, the data is collected in an efficient manner from all the sensor nodes and transmitted to the BS to maximize the lifetime of the network.

In the development of the usage of wireless sensor networks applications, how to implement and use the sensors into a wireless communication network and how to route the sensed data from the field sensors to a remote base station is a challenging problem. When the cluster is initialized, the sensed zone in a particular cluster, cluster is divided into several virtual hexagons which avoids the overlapping of circular cluster of the node. Furthermore, some sub-circle can be converted in the formatted virtual hexagon base on the average distance between the cluster's center and common nodes . Each node will form a cluster heads order list depending upon the special factor's value. A new method is adopted by the clustering technique for cluster head selection, which can avoid the frequent selection of cluster head. Simulation results demonstrate that our proposed algorithm is effective in prolonging the lifetime of networks. [2]

Wireless Sensor Networks (WSNs) are generally self-organized wireless ad hoc networks comprising of a large number of resources confined sensor nodes. One of the most important tasks of these sensor nodes is systematic collection of data and transmission of gathered data to a distant base station (BS). Hence network life- time becomes an important parameter for efficient design of data gathering schemes for sensor networks. In this dissertation, we benefit both cluster and tree structures for data gathering. In our proposed mechanism, the most appropriate hops for data forwarding will be selected and the lifetime of the whole network will be maximized. The simulation results show that the lifetime and the throughput of the network will be increased by using the proposed approach.

WSN requires the interaction of elements or members that perform different tasks. The common elements in the WSN are:

- **Sensor Node or Source Node:** is responsible for physical sensing of environmental phenomena and reporting measurements through wireless communication to the sink.

- **A Sink or Base Station**: is a node that interfaces the sensor field and the networks via the internet. In other words, it acts as a gateway between the WSN and the outside world.

- **Task Manager Node:** displays data for user analysis and enables the network manager to query for sensor nodes.

In WSN, sensor nodes are densely deployed either inside the phenomenon or very close to it. The deployment can be done in two ways, in one way position of the sensors and communication topologies are predetermined and in the other way the position of sensor nodes need not be engineered or pre-determined. Due to the capability of deployment in an undetermined manner sensor nodes can be randomly deployed at any inhospitable place or it can be used for disaster relief operation. Sensor nodes do not communicate with high power base station i.e. sink. They only communicate with their local peer by broadcasting. Sensor network dynamically adapt to topology changes due to node failure or attachment on new nodes. For these reasons by attaching new nodes a sensor network can cover a large area and if the node density is enough then it can also automatically reconfigure itself when node failure occurs. Sensor nodes are fitted with an on-board processor. Each node can perform simple computation and then send the required and partially processed data. Since sensor nodes are densely deployed, multi-hop communication is used in WSN. Multi-hop communication requires less transmission power than traditional single hop communication and also it overcomes some problem of long distance signal propagation. Another feature of WSN is its unattended operation. The sensor may left unattended over long period of time, but they can perform their task whenever needed. Due to small size, low cost and inhospitable working places sensor nodes contain small energy sources and also it is not possible to recharge them. Sensor nodes are equipped with limited memory and a microcontroller unit or processing unit. So energy is a main constraint in WSN operation as well as it has limited storage and processing capabilities. In spite of many challenges WSN has features like unattended operation, self-configuration, scalability etc. due to which it has a large number of application areas.

V. APPLICATION AREAS OF WSN

WSN have a wide range of applications into disaster management, military, environmental monitoring, health & biomedical research, tracking and other commercial areas. Several intended applications of WSN are still under research and development.

Disaster Management Application:

Natural disasters are increasing worldwide due to the global warming and climate change and the losses due to these disasters are increasing in an alarming rate. Hence, early detection of such disaster is beneficial for generating early warning and starting relief operation which can save life and property. However, these disasters are largely unpredictable and occur within very short spans of time. Therefore it is needed to capture signal and propagate it with minimum delay. Wired networks are inappropriate in such scenario as the disaster can also damage the infrastructure of wired network. So, an infrastructure fewer networks are required which can reconfigure itself even if the disaster cause damages to the network also. Wireless Sensors can quickly capture the rapid changes of data and send the sensed data to a sink. It is infrastructure less as well as self-configurable. WSN can work in inhospitable region in an unattended manner due to which it is best suitable for real-time monitoring application like disaster management.

Landslide Monitoring: Landslides are caused mainly for heavy rainfall. So by monitoring criteria like rainfall, moisture, pore pressure, tilt, vibration WSN can easily provide pre-cursor of landslide. Even after the occurrence of landslide WSN can send the location and other information of landslide to the sink which helped the rescue operation.

Forest fire detection: Sensor nodes are densely deployed in planned or unplanned way so they can detect the exact location of the fire and send the information to the end user through sink and by using the data the fire can be controlled before it cause fatal damages.

Flood detection: In flood detection application several types of sensors are deployed for rainfall, water level, weather. The sensors send their data to a centralized database and by analysing the data from various types of sensor the end user can easily detect flood condition of an area.

Earthquake Monitoring: The WSN can be used to monitor the damage caused by earthquake and it can also guide the rescue team.

Environmental Application:

Environmental application of WSN include tracking the movements of birds, small animals, and insects; monitoring environmental conditions that affect crops , macro instruments for large-scale Earth monitoring and planetary exploration, chemical/ biological detection, precision agriculture, biological, Earth, and environmental monitoring in marine, soil, and atmospheric contexts, meteorological or geophysical research, bio-complexity mapping of the environment and pollution study etc.

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Bio Complexity Mapping of Environment: A biocomplexity mapping of the environment integrate information across temporal and spatial scales. Although satellite and airborne sensors can observe large biodiversity (e.g., spatial complexity of dominant plant species) but they cannot be able observe small size biodiversity, which makes up most of the biodiversity in an ecosystem. So there is a need for ground level deployment of wireless sensor nodes to observe the biocomplexity.

Precision Agriculture: The WSN has the ability to monitor pesticides level etc.

Military Application:

WSN can be used in various fields of military. Its self-configuration, unattended operation, fault tolerance make it very helpful for military application.

Battlefield Surveillance: Critical terrains, approach routes, paths can be covered with sensor networks and by using its data activities of the opposing forces can be watched. As the operations progress and new plans are prepared, new sensor networks can be deployed for battlefield surveillance.

Monitoring Friendly Force Equipment and Ammunition: Commanders can monitor the latest condition of its own force by using WSN. Each vehicle, equipment and ammunitions are attached with a sensor which sends the current status to the sink node from which the commander can monitor the situation.

Nuclear Biological and Chemical Attack Detection: WSN can be deployed in friendly region and it can generate an alarm when it detects any Nuclear Biological and Chemical Attack and it decrease the casualties at a large degree.

Health Applications:

Some of the health applications for sensor networks are telemonitoring of human physical data, tracking and monitoring doctor and patient, drug administration in hospital etc.

Telemonitoring of Human Physiological Data: WSN can be used to collect physiological data for a long period of time and the data can be used by doctors to detect predefined symptoms.

Tracking and Monitoring Doctors and Patients inside a hospital:

Each patient has small and light weight sensor nodes attached to them. One sensor node may be detecting the heart rate while another is detecting the blood pressure etc. Doctors may also carry a sensor node, which allows other doctors to locate them within the hospital.

Also WSN can be used for environment control in office building, managing inventory and vehicle tracking etc.

Energy Saving and Consuming in Beamforming:

When compared with only a single transmitter, collaborative beamforming distribute the energy of long distance transmission over multiple transmitters. By this the battery energy saves and battery lifetime balances on individual nodes because lower power used by the each transmitter to transmit the data. Successful beamforming depends on the participating sensor nodes and also proper coordination should be there. In order to create constructive interference at the receiver, the signals need to be in phase. In most of the applications, sensor nodes are randomly deployed in the sensing area and each one is driven by its own crystal (i.e. clock). The signals from all nodes arrive at the receiver at different phases and therefore, phase alignment is required. Phase alignment can be achieved in two ways: (1) the location information of the transmitters and the receiver are not known a priori, and a using a random walk algorithm to adjust the transmitting phases; (2) the location information is known, on the basis of phase differences nodes are selected. No requirement for phase adjustment.

This dissertation first analyzes the parameters and conditions to answer whether beamforming saves or consumes energy.

Considering phase alignment, I show the minimum data that need to be transmitted to compensate the energy consumed for phase alignment using the random walk algorithmic suggest that by relaxing the convergence requirement, the transmitters can determine their phases an order-of-magnitude faster and save energy in pre-beamforming preparation. My analysis shows that the number of nodes and the amount of data are two critical factors for determining whether beamforming can save energy: the minimum amount of data needs to be sent using beamforming in order to compensate the energy consumed for phase alignment.

With the transmitters selected using phase partition method, I analyze the energy consumed for data sharing by first presenting the procedures for data sharing when multiple sensing nodes and transmitters are used. The energy consumed for data sharing among different numbers of sensing nodes and transmitters were analyzed, and the impact on beamforming transmissions. (1) Showed how data can be shared among the transmitters when there are multiple sensing nodes and transmitters in each round. (2) In each round, nodes are categorized into four types of roles as: transmitter, master node, sensing node, and all other nodes that are not transmitting or sensing. Also examined the energy consumed for each type of nodes in data sharing. (3) Comparison of energy consumed by direct transmission and beamforming to achieve the same number of transmissions.

Transmitter Scheduling for Energy Balancing in Beamforming:

Knowing the conditions and key factors for beamforming to save energy, the next issue addressed in this dissertation is how to prolong the network lifetime while using beamforming. We show how this may be achieved using an efficient scheduling algorithm.

Beamforming efficiency depends on the phase differences between the electromagnetic waves. The efficiency is 100% when phase differences are zero. In these phases differences can be estimated using two-way signal exchanges. Beamforming efficiency is higher when the transmitters with smaller phase differences are chosen. To achieve better efficiency, the nodes with small phase differences are always used and these nodes will deplete their energy much faster than the others.

A beamforming transmitter scheduling algorithm has been proposed that prolongs the network lifetime by balancing the energy consumption over the network. The proposed scheduling algorithm selects the transmitters in each round from N available nodes. Based on the analysis, It is found that the transmitters should be closer to each other in order to reduce the energy overhead in pre-beamforming. Hence, an adaptive beamforming transmitter scheduling algorithm has been proposed that considers the size of the sensing area relative to the distance from the base station. I divide networks into two types: small network and large network. If network is small then all nodes can directly communicate with each other and beamforming transmitters are scheduled based on the phase differences and remaining energy of the nodes. This scheduling algorithm can be called, “energy and phase”, i.e. EP.

VI. CONCLUSION

In this Synopsis i analyze the energy consumption overhead in pre-beamforming preparations. I show that minimum amounts of data need to be sent using beamforming to compensate for the energy consumed on phase alignment that uses a random walk algorithm. The minimum transmitted data size can be decided based on the total number of nodes and the selected beamforming efficiency. Using the transmitter selection method, the energy consumption overhead on aligning the phases can be eliminated, but the energy consumption for data sharing still exist. I presented the procedures for data sharing when multiple sensing nodes and transmitters are used in each round of beamforming. I show that beamforming saves energy across the network when compared to direct transmissions, if the base station is far away. This saving even takes into account the data sharing energy overhead. Energy consumed on data sharing has negligible effect on the network lifetime of beamforming, when the transmitters are close to each other. I present a beamforming transmitter scheduling algorithm that is adaptive to the size of the deployment area. For a network within a small sensing area, I propose to schedule the transmitters based on their phase differences and remaining energy. Compared to existing work, the proposed algorithm in this dissertation prolongs the network lifetime by 60%, even in the worst case. When the size of the sensing area increases, the distance between the transmitters needs to be considered, since a huge amount of energy will be consumed by data sharing if the transmitters are far away. We show that network lifetime can be enhanced by dividing the nodes into clusters and selecting one cluster at a time to perform each round of beamforming transmission. By reducing the energy consumed for data sharing, the scheduling algorithm triples the network lifetime compared with the single-cluster scheduling algorithm. I also show beamforming achieves more transmissions than direct and multi-hop transmissions, when the receiver is far away from the sensing area. I performed outdoor experiments and show that signal strength can be enhanced by selecting the beamforming transmitters. I also present a method to apply beamforming to multi-hop transmissions. This method uses beamforming to extend the transmission range between hops. Without frequency or phase synchronizations, the frequency drifts of the nodes are used to form the transmission beam. I analyze

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the energy consumption of this proposed method and compare it with the standard single node multi-hop transmission. I find the energy consumption using sweeping beam is related to the data rate in single node transmission and the frequency difference between two beamforming transmitters. I find that when the data rate in the single node transmission is low, using sweep beam with high sweeping frequency, more energy is saved. WSN technology is widely used for mobile communication where distant users easily exchange ideas without any interference. Constant research is going on in mobile communication field and various spheres of technological era such as electrical, electronics and computer science are implementing the embedded communication chips that response to user's message exchange requests. Telecommunication field is now evoked by the node to message and vice-versa information transfer techniques.

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