Usage of Compressive Sensing and MEMAC Protocol for Energy Efficiency in Wireless Sensor Networks

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ABSTRACT
In the Wireless sensor network, there may be possibility of failure of nodes because of the power drained or addition of new nodes or may be change in location of nodes due to physical movement. So to accommodate these types of dynamic changes in sensor nodes .MEMAC (Mobile Energy Aware Medium Access Control) protocol presents hybrid scheme of contention based and scheduled based scheme of previous MAC protocol having the purpose of overcome the drawbacks. .To avoid collision and energy consumption it must uses mobility information and acquires schedule according to mobility conditions and it also needs proper designing of mobility model for real life setting. Compressive sensing (CS) can reduce the number of data transmissions and balance the traffic load of the networks. Hence, the total number of data transmissions for collection of data by using pure CS is still large. The hybrid method of using CS to reduce the number of transmissions in sensor networks. Hence, the previous work uses the CS method on routing trees. In this paper, a clustering method that uses hybrid CS for sensor networks. The nodes are form in the clusters within that one sensor act as cluster head and other is cluster member. Within a cluster, nodes send data to cluster head (CH) without using CS. CHs use CS to transmit data to sink. In this paper Compressive sensing and MEMAC protocol is used for reducing the energy consumption of sensor nodes and also to reduce the congestion in the network.

Keywords - *Compressive sensing, clustering, data collection, MEMAC, Wireless sensor networks.*

1. INTRODUCTION

Wireless Sensor Networks (WSNs) can be defined as a self-configured and infrastructure- less wireless networks to monitor physical or environmental things and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analyzed. A sink or base station acts like an interface between users and the network. As per need one can retrieve the data from the network by injecting queries and gathering results from the sink [7].

Typically a wireless sensor network contains hundreds of thousands of sensor nodes. Radio signals are used by sensor nodes for communication. A wireless sensor node contains sensing and computing devices, radio transceivers and power components [6]. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained: they have limited speed of processing, memory capacity, and bandwidth for communication. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them. In many sensor network applications, such as environment monitoring systems, sensor nodes need to collect data and transmit them to the data sink through multi hops. According to experiments, data communication contributes majority of energy consumption of sensor nodes [1].

In a WSN, the sink node collects data from sensor nodes within the sensor field. A sink node sends queries, control packets to sensor nodes. Sensor nodes detect events in the sensor field, perform local data processing and then transmit data to the base-station. A sensor node is composed of many hardware components. Transceiver is a major energy consumer component in a sensor node because communication is one of the most energy expensive tasks; as compared to data processing. Energy cost of transmitting a single bit is approximately the same as Processing thousands of instructions in a sensor node [1],[4].MSNs are advance version of WSN. MSN have the same architecture of stationary sensor networks but only differs in the mechanism that enables devices to move in space. The structure of MSN contain highly mobile (high velocity devices), static scenario in which devices move with low velocity in shop floor like robots and hybrid which contains both classes mentioned above. There are many advantages of MSNs over the static.

WSNs. MSNs offer- i) Dynamic Network Coverage- the area where you can't reach or stay able to cover by network e.g Space, oceans, rainforests. ii) Data Routing Repair replacement of failed routing nodes and calibrating the operation of network. iii) Data Muling – Collecting data from stationary nodes which are out of range. iv) Staged Data Stream Processing- continuous processing in network to solve queries. v) User Access Points- enabling connection to devices that are out of range from communication areas.

These advantages of MSN required efficient handling of mobility in all layers of sensor network protocol. For effectiveness in both stationary and mobile network we required protocol that can work effectively in terms of energy consumption of sensor nodes in both stationary as well as mobile state. At the same time those protocol should be aware of mobility and speed of mobile sensor nodes. MAC protocol plays important role in controlling the usages of radio unit where radio transceiver unit is major power consumer unit in sensor node. Basically in MAC protocol design for WSN assume that sensor nodes are stationary in mobile environment which causes performance degradation. In this paper we present an adaptive mobility aware and energy efficient MAC protocol for wireless sensor network (briefly MEMAC). MEMAC is a hybrid mechanism based on MAC protocol which mainly combines channel access mechanism such as Time.

Division Multiple Access (TDMA) and Carrier Sense Multiple Access (CSMA). In MEMAC we use TDMA and CSMA for differentiates between data and control messages. TDMA slot assign for the long data messages while CSMA slot for the short control messages. By using radio transceiver

it reduce total energy consumption and limits message collision. As the MEMAC have advantage such as dynamic frame size which is use to enable the protocol effectively adapt itself to changes in mobility condition.

2. RELATED WORK

A WSN is an ad hoc network of autonomous low powered sensors that are spatially distributed and communicate wirelessly to cooperatively achieve a task. The improvements in stationary WSNs in along with the continues advances in distributed robotics and low power embedded systems have led to a new class of Mobile

Wireless Sensor Networks (MSNs) that can be used for air , exploration and monitoring, automobile applications and a wide range of other applications. MSNs have a same architecture to their stationary counterparts, thus MSNs are constrained by the same energy and processing limitations, but they are supplemented with implicit or explicit mechanisms that enable these devices to move in space (e.g. motor or sea/air current) over time

Compressive sensing (CS) can reduce the number of data transmissions and balance the traffic load throughout networks [4]. However, the total number of transmissions for data collection by using pure CS is still large. The hybrid method of using CS was proposed to reduce the number of transmissions in sensor networks. However, the previous works use the CS method on routing trees. The Proposed clustering method that uses hybrid CS for sensor networks. The sensor nodes are organized into clusters. Within a cluster, nodes transmit data to cluster head (CH) without using CS [14]. CHs use CS to transmit data to sink. In this first an analytical model that studies the relationship between the size of clusters and number of transmissions in the hybrid CS method, aiming at finding the optimal size of clusters that can lead to minimum number of transmissions. Then, propose a centralized clustering algorithm based on the results obtained from the analytical model. Finally, we present a distributed implementation of the clustering method [1]. Extensive simulations confirm that our method can reduce the number of transmissions significantly. In many sensor network applications, such as environment monitoring systems, sensor nodes need to collect data periodically and transmit them to the data sink through multi hops[12][13]. According to field experiments, data communication contributes majority of energy consumption of sensor nodes It has become an important issue to reduce the amount of data transmissions in sensor networks. The emerging technology of compressive sensing (CS) opens new frontiers for data collection in sensor networks and target localization in sensor [4].

To estimate the level or direction of node mobility, we need a mobility prediction algorithm. The accuracy of the mobility prediction model depends on the accuracy of the underlying localization mechanism. Mobility in sensor networks brings some challenges in designing MAC protocols, which are mainly responsible for packet scheduling, transmission, collision avoidance, and resolution. Handling mobility at MAC layer involves careful trade-off in energy efficiency, throughput, and robustness under mobility. There are some mobility issues relevant to the MAC protocol design.

3. WORKING OF COMPRESSIVE SENSING TECHNIQUE

The basic idea of CS works is as follows, as shown in Fig. 1. Suppose the system consists of one sink node and N sensor nodes for collecting data from the field. Let x denote a vector of original data collected from sensors. Vector x has N elements, one for each sensor. x can be represented by Ψs, i.e. x =Ψs, where Ψis an N X N transform basis, And s is a vector of coefficients. If there are at most k (k<< N) nonzero elements in s, x is called k-sparse in the domain. When k is small, instead of transmitting N data to the sink, we can send a small number of projections of x to the sink, that is, y=Φx, where Φ is an M X N (M <<N) random matrix (called the measurement matrix) and y is a vector of M projections. At the sink node, after collecting y, the original data x can be recovered by using l-norm minimization [2],[3] or other heuristic algorithms, such as orthogonal matching pursuit [4].

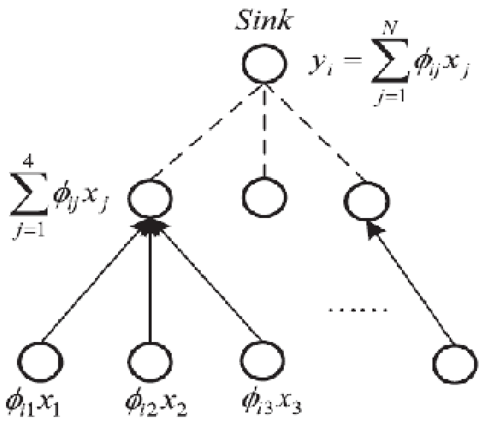


Fig.1. Data collection with the pure CS method in the tree structure

In this paper, we review a clustering method that uses the hybrid CS for sensor networks. The sensor nodes are grouped into cluster. Within a cluster, nodes transmit information to the cluster head (CH) .All cluster head will collect information from all sensor nodes and send it to sink using compressive sensing technique. One important issue for cluster method is to determine how big a cluster should be [1]. If the cluster size is large, the number of transmissions required to collect data from sensor nodes within a cluster to the CH will be very high. But if the cluster size is small, the number of clusters will be more and the information gathering tree for all CHs to transmit their collected data to the sink will be large, which would occur to a large number of transmissions by using the CS method. For this, first propose an analytical model that studies the relationship between the size of clusters and number of transmissions in the CS method, objective is to find the optimal size of clusters that can lead to small number of transmissions. Then, we propose a centralize clustering algorithm and distributed implementation of the clustering method.

4. MEMAC PROTOCOL

In the Wireless sensor network, there may be possibility of failure of nodes because of the power drained or addition of new nodes or may be change in location of nodes due to physical movement. So to accommodate these types of dynamic changes in sensor nodes MEMAC protocol presents hybrid scheme of contention based and scheduled based scheme of previous MAC protocol having the purpose of overcome the drawbacks. For the mobility handling of sensor nodes MEMAC differs from previous SEHM protocol by acquiring frame length according to mobility conditions. The issues related to designing of MAC protocols are frame errors in mobility network, probability of collision increases in contention based MAC protocol and requires retransmission, schedule inconsistency, lack of mobility information and unable to choose mobility model. So it is necessity to cope with frame errors and adjusting frame time. To avoid collision and energy consumption it must uses mobility information and acquires schedule according to mobility conditions and it also needs proper designing of mobility model for real life setting.

Now let us see what the actual difference between both systems.

In sensor networks, nodes may fail (e.g., power drained) or new nodes may be added (e.g., additional sensors deployed), or sensor nodes may physically move from their locations, either because of the motion of the medium (e.g. water, air) or by means of a special motion hardware in the mobile sensor nodes. To accommodate these topology dynamics, our MEMAC protocol uses a hybrid approach of contention-based and scheduled-based schemes as in our previous MAC protocol (SEHM protocol) presented in [11]. MEMAC differs from SEHM protocol in terms of mobility handling of sensor nodes. MEMAC adapts the frame length according to mobility conditions by incorporating a mobility prediction model.

As MEMAC is a hybrid protocol, it overcomes some of the disadvantages of MMAC through providing contention slots for short control messages and scheduled slots for data messages. Furthermore, MEMAC allows only nodes that have data to send to be included in the schedule which increases the energy efficiency of the protocol.

MEMAC is combination of contention based and scheduled based protocols to achieve significant amount of energy saving. MEMAC adjusts dynamically frame size according to mobility information of sensor nodes and number of nodes that have data to send; this avoids wasting slots by excluding the nodes which are expected to leave or join the cluster and those nodes which have no data to transmit from the TDMA schedule and to switch nodes to sleep mode when they are not included in the communication process. Through simulation experiments, we studied the performance of MEMAC protocol against MMAC protocol. Simulation results shoes that MEMAC protocol is better than MMAC in terms of energy consumption, packet delivery ratio and average packet delay.

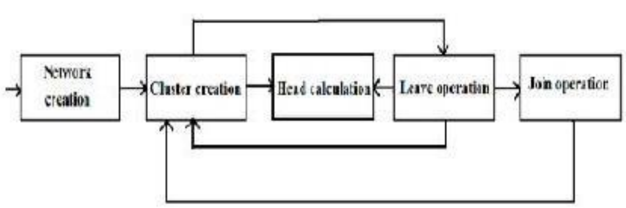


Fig2.Architecture of MEMAC Protocol

Above Fig2 shows the basic architecture of MEMAC protocol.

1. Network Creation-Creating network for connectivity. Basically in general Wi-Fi network if there are n numbers of nodes in network which are actively participated in message transfer or communication. Then if any node say node no 1 want to communicate with node no 16 then for this communication or message transfer; firstly node must connect with its neighbor nodes and so on; up to the destination node 16. Out of that it will choose shortest path to reach up to destination and then it will send message packets. This process is happen in various wireless networks. But due to some disadvantages this system is fail to acquire reliability and\proper flow control in energy efficient way. So all this disadvantages are overcome in MEMAC system

2. Cluster Creation- Clusters which are dynamically formed contain all nodes in sensor network. In MEMAC system, for eg. when node no. 1 want to communicate with node no. 16, then node 1 firstly communicate with its own cluster head (here ch1). After that ch1 communicate with ch2 which is cluster head of node no. 16 and then finally ch2 transfer message which is come from node no 1 to destination node (i.e. node no 16). In this way in MEMAC system three way communications is happen. So it is faster and energy efficient system.

3. Head Calculator-Clusters Head created with respect to cluster quantity. *Phase-In* this phase CH broadcast the calculated schedule to the other node within cluster. The schedule contains those nodes which have data to send only. The current schedule does not consider nodes that want to leave or join the cluster. If the number of request message is greater than number of join or leave messages, then frame length is increased otherwise decreased.

4. Leave/Join Operation- In case of request or leave phase the contention period should be long enough to enable all Sensor nodes. In MEMAC protocol handles the channel access through the following four phases: request\leave\join phase, schedule calculation and distribution phase and data transfer phase. In case of request or leave phase the contention period should be long enough to enable all sensor nodes that have data to transmit contain for the channel in order to acquire the access to send its request to CH as well as those nodes which are expected to leave or join the cluster should the CH by sending message of leave or join

5. MINIMUM TRANSMISSION CLUSTERING ALGORITHM

In this we have two types of clustering algorithm to reduce transmission between cluster head and its cluster member [1].

5.1 Centralized Clustering Algorithm

In this section, centralized clustering algorithm. Given the network G= {V, E} our algorithm has two major steps:
a. Select C CHs from the set V of N sensor nodes and divide the sensor nodes into C clusters and
b. construct a backbone routing tree that connects all CHs to the sink [4].

Our algorithm starts from an initial set of CHs, which is randomly selected at each iteration, the algorithm proceeds following
(a) Connect sensor nodes to their closest CHs. Ties break arbitrarily.
(b) For each cluster, choose a new CH, such that the sum of the distances .From all nodes in this cluster to the new CH is minimized.
(c)Repeat the above two steps until there is no more change of the CHs.

This algorithm converges quickly. The simulations show that it takes four or five iterations on average for the algorithm to compute the CHs of clusters .In this paper minimum spanning tree (MST)-based method to compute the backbone tree that connects all CHs and the sink. Given a set U of CHs obtained from the above algorithm, we introduce a graph GCH=VCH; ECH, where VCH consists of the sink node v0 and the set U
of CHs. There is an edge between any pair of nodes in VCH. That is, the graph GCH is a complete graph. The distance of an edge (CHi,CHj)in ECH is the length of the shortest path between CHi and CHj in G. Then, we compute the MST of GCH, which spans all nodes in VCH. From this MST, we obtain a backbone routing tree, where each edge in the MST is its corresponding shortest path in G

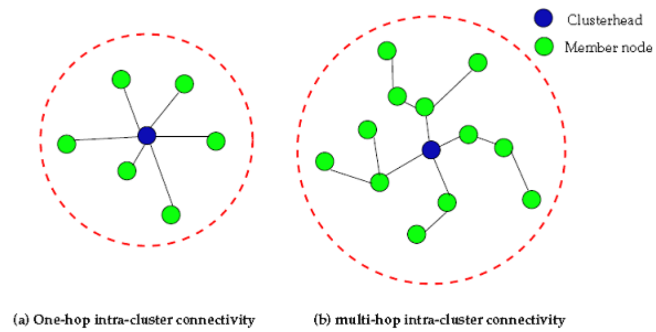


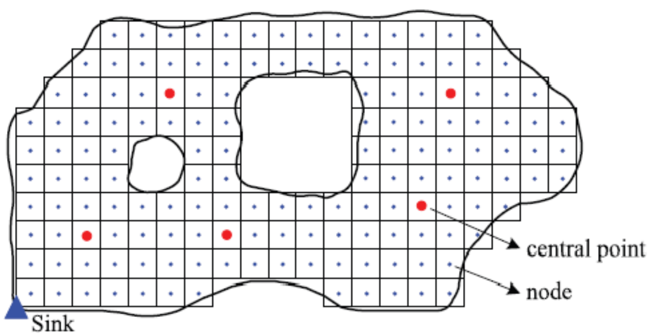
Fig.3.Cluster Head Selection

5.2 Distributed Clustering Algorithm

This section presents a distributed implementation of the clustering method. We assume that
(a) Every sensor node knows its geographic location. This location information can be obtained via attached GPS or some other sensor localization techniques
b) The sink knows the area of the whole sensor field, but does not need to know the location information of all sensor nodes [1]. This is a reasonable assumption, since in most applications of the sensor networks; the sink usually knows the area that has sensors deployed for surveillance or environmental monitoring. In our distributed algorithm, the sink divides the field into C cluster-areas, calculates the geographic central point of each cluster-area, and broadcasts the information to all sensor nodes to elect CHs. The sensor node that is the closest to the center of a cluster-area is selected to be the CH. The CHs then broadcast advertisement messages to sensor nodes to invite sensor nodes to join their respective clusters.

5.3 Calculating Central Points of Cluster-Areas

Given a sensor field and the number of cluster C to be divided to, the sink needs to find out the central points of C cluster-areas [1]. First divide the whole sensor field into small grids, as shown in Fig.4 Then, place a virtual node at the center of each grid to represent the grid. C nodes in the grids will be chosen as the approximate central points of the cluster-areas[1]. We use an auxiliary graph GA =VA; EA to help finding the central points, where VA is the set of nodes in the grids, and each node vi in VA has an edge to each of the nodes in its neighboring grids. Each grid, except those on the border of the sensor field, has eight neighboring grids (as shown in Fig. 3.4). The distance of all edges in EA is set to 1.Then compute a subset of nodes VC, VC is subset of VA and |VC|= C, such that the total distance from all nodes in VA to their nearest nodes in VC is minimized.



5.4 Cluster Head Election

Given the geographic location of the central point of a cluster-area, the sensor node that is the closest to the central point will become the CH[2][5]. Since the sensor nodes do not know who is the closest to the central point of a cluster area, and we do not know if there is a sensor node falling into the close range of the central point, let all nodes within the range of Hr from the center be the CH candidates of the cluster, where r is the transmission range of sensors. The value of H is determined such that there is at least one node within H hops from the central point of a cluster. To elect the CH, each candidate broadcasts a CH election message that contains its identifier, its location and the identifier of its cluster. The CH election message is propagated not more than 2H hops. After a timeout, the candidate that has the smallest distance to the center of the cluster among the other candidates becomes the CH of the cluster. In the extreme case that no sensor node falls within H hops from the central point so that there is no CH for this cluster-area, the nodes in this cluster-area accept the invitation from neighboring CHs and become members of other clusters[1],[6]. Thus, no node will be left out of the network.

5.5 Backbone Tree Construction and Network Maintenance

A backbone tree is constructed in a distributed fashion to connect all CHs and the sink. Through the broadcasting of the advertisement messages from CHs, each CH receives the advertisement messages from the other CHs that are close to it[4]. Thus, it has the knowledge about the locations of its nearby CHs and the number of hops to them. Since the sink needs to broadcast the central point's information to all sensor nodes, all sensor nodes know the location of the sink and the hop distance to it. For each CH, we define its upstream CHs as the set of CHs (including the sink) that are closer to the sink than itself in terms of Euclidean distance. We take a distributed method of an approximate MST algorithm to construct the backbone tree. For each CH, it chooses the CH that has the minimum number of hops to it from the set of its upstream CHs as its parent CH in the backbone tree. After constructing the backbone tree, each CH has the knowledge about its children CHs in the backbone tree. When M projections are generated at the CH, they are transmitted to the parent CH along the backbone tree in M rounds. When a CH fails or runs out of energy, the neighboring nodes of the CH will detect the failure of the CH. These nodes will broadcast a message to all the nodes in this cluster to start the new CH election. The new CH election algorithm and the new backbone construction follow the same methods as presented in Sections3.5.2 and 3.5.4. As there are many distributed routing algorithms that were proposed for sensor networks [31], [32], we simply use the existing method [31], [32] for route maintenance.

6. PERFORMANCE ANALYSIS

In this paper the performance of the clustering method using hybrid CS is studied. Different methods are compared with four other data collection methods. We first evaluate the performance of methods on a regular sensor field. We use two metrics to evaluate the performance of the Clustering with hybrid CS in this paper: the number of transmissions which is required to collect data from sensors to the sink and the reduction ratio of transmissions (reduction ratio for short) of our method compared with other methods. Four other data collection methods are considered that are shortest path tree with hybrid CS, shortest path tree without hybrid CS, Clustering method without CS, Clustering method with CS & Optimal tree with CS. In the clustering without CS method, the same cluster Structure to our method is used, but CS is not used. In the shortest path tree (SPT) without CS, the shortest path tree is used to collect data from sensors to the sink [1],[6]. In the SPT with hybrid CS, the shortest path tree is used to collect data from sensors to the sink, and CS is used in the nodes who has more than M descendant nodes (including itself). In the optimal tree with hybrid CS, a tree having minimum transmissions is used.

6.1 Reduction of Transmission Number

We compare methods with other methods in terms of the number of transmissions. It is obvious that the number of transmissions of method is significantly smaller than that of the clustering method without using CS. The reason is that data are compressed using the CS method at the CHs in method. Each node on the backbone tree does M transmissions for the inter cluster data gathering. It is significantly less than the number of transmissions of the method without using CS. The number of transmissions of our method is also visibly smaller than that of SPT with the hybrid CS method [1][4]. This is because in the cluster structure, sensor nodes transmit data to their cluster head, which is located nearly at the center of the cluster, while in the SPT, sensor nodes transmit data to the nodes near to the sink, which results in more transmissions than centralized and distributed method.

This method reduces the number of transmissions by about 60 percent compared with clustering without the CS method [1]. It reduces the number of transmissions by about 50 percent compared with SPT without the CS method. In addition, it reduces the number of transmissions by about 30 percent when the number of nodes is 1,200, compared with SPT with the hybrid CS method. The reduction ratio does not drop as the number of nodes increases.

7. CONCLUSION

Wireless Sensor Network used different techniques to collect data and send to cluster head. But with limited battery life, to reduce energy consumption various compressive sensing techniques were used. Sensor nodes are organized into clusters. Within a cluster, data are collected to the cluster heads by shortest path routing; at the cluster head, data are compressed to the projections using the CS technique. MEMAC protocol is used for removing network congestion and also it will improve the energy efficiency of sensor nodes.

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