Fast and Efficient Data Collection in Wireless Sensor Networks

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Fast and Efficient Data Collection in Wireless Sensor Network

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Dedicated to my Parents

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Certificate

This is to certify that the work in the thesis entitled "***Fast and Efficient Data Collection in Wireless Sensor Networks***" by *Binod Kumar Patra*, bearing roll number *211CS1047*, is a record of an original research work carried out by him with my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Master of Technology* in *Computer Science and Engineering.* Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Prof. Manmath Narayan Sahoo

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Abstract

Wireless sensor networks utilize large numbers of wireless sensor nodes to collect information from their sensing terrain. Wireless sensor nodes are battery-powered devices. Energy saving is always crucial to the lifetime of a wireless sensor network. Recently, many algorithms have been proposed to tackle the energy saving problem in wireless sensor networks. In these algorithms, however, data collection efficiency is usually compromised in return for gaining longer network lifetime. There is a strong need to develop wireless sensor network algorithms with optimization priorities biased to aspects besides energy saving. In this paper, a fast and efficient data collection network structure for wireless sensor networks is proposed. The objective of the proposed network structure is to minimize delays in the data collection processes of wireless sensor networks. We give a logical overview of proposed model by a taking example of sensor network having many nodes and try to form a network structure in it.

***Keywords*:** Wireless sensor network(WSN), Sub cluster head(SCH),Base station, Connection request,Rejection packets,Data collection, Clustering.

Contents

List of Abbreviations

WSN	Wireless Sensor Network
BS	Base Station
CM	Cluster Member
CH	Cluster Head
SCH	Sub Cluster Head
ME	Mobile Element
MST	Minimum Spanning tree
ETX	Expected Transmission
CTP	Collection Tree Protocol
$MSRP$	Mobile Sink Routing Protocol
NGR	Neighborhood Packet
NOR	Number of Request
NGR	No Request Got
CR	Connection Request
RP	Rejection Packet
DP	Distance Packet
D_{com}	Communication Distance
N_{Total}	Total number of nodes
TCR	Threshold communication range

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Chapter 1

Introduction

Chapter 1

Introduction

1.1 Introduction to WSN

A wireless sensor network (WSN) in its simplest form can be defined as a network possibly having low-size and low-complex. The devices that are involved denoted as nodes that can sense the environment and communicate the information gathered from the monitored field through wireless links; the data is forwarded, possibly via multiple hops relaying, to a sink that can use it locally, or is connected to other networks (e.g.- the Internet) through a gateway. In other words, a sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or very close to it.

The sink node is the node which is the destination of message originated by sensor nodes, i.e.- It represents the end point of data collection in wireless sensor network. The position of sensor nodes need not be engineered or pre-determined. This allows random deployment in inaccessible terrains or disaster relief operations. This characteristic of sensor network indicates sensor network protocols and algorithms must possess self-organizing capabilities. The nodes in the sensor network work together to collect and send data to sink node or base station. Sensor nodes are fitted with an on-board processor. Every node in the sensor network, instead of sending the raw data to the other nodes, they have responsible for the fusion of data. In the process of data fusion we can reduce the amount of data transmitted between sensor nodes and the base station. It combines one or more data packets from different sensor nodes to produce a single packet. The sensor nodes use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data.

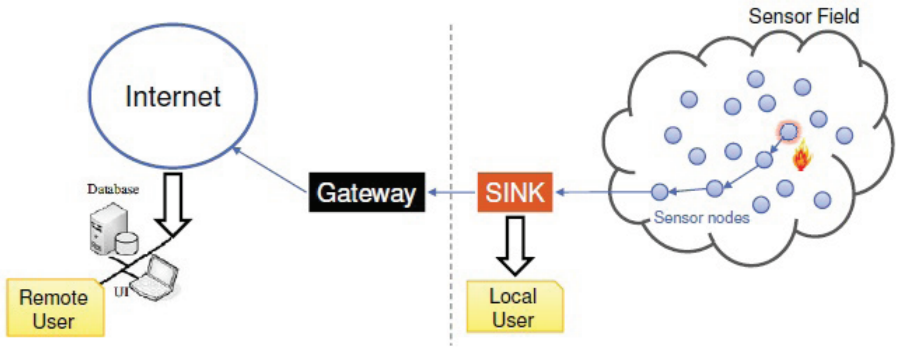

Figure 1.1: Basic network structure of WSN

The Figure 1.1 describes the basic network structure of Wireless sensor network. The sensor nodes are having limited battery power and it is totally different from conventional networks. All the processes those are executed and all the algorithms those are implanted in sensor nodes should consider the fact that energy is the most important factor in wireless sensor network. Gathering sensed information in an energy efficient manner for a long period of time, is very critical to operate the sensor network. The energy cost for transmitting a packet depends on the distance of transmission. In each round of this data collection application, all data from all nodes need to be collected and transmitted to the base station, where the end-user can access the data. A simple approach to accomplish this task is for each node to transmit its data directly to the base station. Since the base station is located far away, the cost to transmit to the base station from any node is very high and nodes will die very quickly. Therefore, an improved approach should be used for transmissions to the base station and the amount of data that must be transmitted to the base station so that entire life time of network can be improved.

Although many protocols and algorithms have been developed for traditional wireless ad hoc networks, they are not well suited for the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad hoc networks are outlined below: Sensor nodes are limited in power, memory and computational capacities. The topology of a sensor network changes very frequently. Sensor nodes mainly use broadcast communication paradigm whereas most ad hoc networks are based on point-to-point communications. Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors. Since large numbers of sensor nodes are densely deployed, neighbor nodes may be very close to each other. Sensor nodes are densely deployed. The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network. Sensor nodes are prone to failures. One of the most important constraints is the low power consumption requirement in sensor nodes.

1.2 Application Of WSN

Wireless sensor network is having many applications. We can categories the applications into military, home, environmental, health and other commercial areas. We can expand this classification with more categories like disaster relief, chemical processing, space exploration etc.

By the help of sensor nodes we can monitor wide verity of ambient conditions that includes pressure, temperature, noise level, humidity, vehicular movement, lighting condition, the presence and absence of certain kind of objects, the current characteristics such as speed, direction, and size of an object, mechanical stress levels on attached objects, and soil makeup.

In military application where it is very difficult to reach for human being, we can handle those areas and collect the valuable information by the help of sensor network. The sensor nodes can be easily deployed on those areas. The rapid deployment, self-organization and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military application. Leaders and officers can easily monitors the status of battle field, their friendly troops, the availability of the equipment and the ammunition in a battlefield by the use of sensor networks. We can collect the information about opposite troops and sensitive data by sensor nodes. We can deploy sensor nodes in the target areas to gather the battle damage assessment data before and after attacks.

In environmental case, the sensor network is very useful. We can collect data about environment in extreme condition like high temperature and cold area, low pressure area. We can monitor environmental condition like fire in the forest, flood detection, the pesticides level in the drinking water, the level of soil erosion, and the level of air pollution in real-time. We can track the movement of animals and birds.

In health application, we can use sensor network as patient monitoring, monitoring of human physiological data, drug administration in hospitals, and tracking and monitoring doctors and patients inside a hospital etc. In home applications, the sensor nodes are fitted into home devices like micro-waves ovens, refrigerator, vacuum cleaners etc. so that devices can interact with each other and with the external network via the Internet or Satellite. It allow end users to manage home devices locally and remotely more easily. Apart from that many other applications like car tracking; office building environment control etc. sensor network is very useful.

1.3 Thesis Organization

The remaining part of the thesis is organized as follows. Chapter 1 gives a brief introduction to Wireless Sensor Networks. A general overview of data collection process in WSN and some existig algorithms to transmit data faster and in energy efficient way has been discussed in Chapter 2 . Chapter 3 provides an insight into the existing work related to the thesis. The proposed scheme has been discussed in chapter 4, then followed by simulation and results in chapter 5. Finally the concluding remarks are provided in chapter 6.

Chapter 2

Overview of Data Collection in WSN

Chapter 2

Overview of Data Collection in WSN

2.1 Introduction

In recent years Wireless Sensor Networks (WSNs) have become an established technology for a large number of applications, ranging from monitoring (e.g., pollution prevention, precision agriculture, structures and buildings health), to event detection (e.g., intrusions, fire/flood emergencies) and target tracking (e.g., surveillance). WSNs usually consist of a large number of sensor nodes, which are battery-powered tiny devices. These devices perform three basic tasks:

1. Sample a physical quantity from the surrounding environment.

2. Process (and possibly store) the acquired data.

3. Transfer them through wireless communications to a data collection point called sink node or base station [1].

The traditional WSN architectures are based on the assumption that the network is dense, so that any two nodes can communicate with each other through multi-hop paths. As a consequence, in most cases the sensors are assumed to be static, and mobility is not considered as an option. More recently, similar to the research trends in Mobile Ad Hoc Networks (MANETs) [2] and Delay Tolerant Networks (DTNs) [3], mobility has also been introduced to WSNs [4–6]. In fact, mobility in WSNs is useful for several reasons [7, 8], as discussed below.

- **Connectivity**: As nodes are mobile, a dense WSN architecture may be not a requirement. In fact, mobile elements can cope with isolated regions, so that the constraints on network connectivity can be relaxed, also in terms of nodes (re)deployment. Hence, a sparse WSN architecture becomes a feasible option.

- **Cost**: Since fewer nodes can be deployed, the network cost is reduced in a mobile WSN. Although adding mobility features to the nodes might be expensive, in many cases it is possible to exploit mobile elements which are already present in the sensing area (e.g., trains, buses, shuttles or cars), and attach sensors to them.

- **Reliability**: Since traditional (static) WSNs are dense and the communication paradigm is often (ad hoc) multi-hop, reliability is compromised by interference and collisions. In addition, the message loss increases with the number of hops, which may be rather high. Mobile elements, instead, can visit nodes in the network and collect data directly through single-hop transmissions. This reduces not only contention and collisions, but also the message loss.

- **Energy efficiency**: The traffic pattern inherent to WSNs is converge cast, i.e., messages are generated from sensor nodes and are collected by the sink. As a consequence, nodes closer to the sink are more overloaded than others, and subject to premature energy depletion. This issue is known as the funneling effect [9], since the neighbors of the sink represent the bottleneck of traffic. Mobile elements can help reduce the funneling effect, as they can visit different regions in the network and spread the energy consumption more uniformly, even in the case of a dense WSN architecture [10, 11].

In this section we will discuss about the different phases of the data collection process and find out the main issues involved in it. From the Figure 2.1, we try to convince the general scenario of data collection process .Every sensor node is having its own range. Whenever a contact occurs between a mobile element and a static sensor node, they can easily reach out each through wireless communication channel or in other words we can say when both the nodes in the range of each other. The above process can be easily extended to the case where sensor nodes are also mobile. Contact time can be defined as the amount time when both the nodes in the range of each other. Contact area can also be defined as the region where that node can possibly be in contact with other nodes.

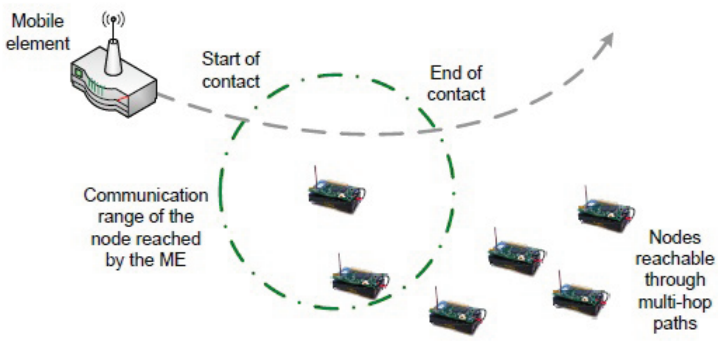

Figure 2.1: Representative scenario for data collection in WSN with mobile elements.

Before nodes are come in contact of each other, they should discover each other. Discover is processes by which nodes are detect a contact that is presence of mobile element in its communication range. After discovery process, data transfer process starts. In the data transfer process the message exchange between mobile element and sensor node. The data transfer process is single hop transmission process. Another term we are using Residual contact time. Residual contact time means the amount of time at which actual data transfer occurs. The residual time is always less than equal to the contact time. Then the final process is to routing the data to the base station. It is most the important part of data collection process. Many algorithm are proposed for find efficient root so that data can reach to base station in an energy efficient way and the integrity or originally of data cannot be lost.

2.2 Different phases of data collection

On the basis of above discussion, we can divide the data collection process into three parts.

1. Discovery
2. Data transfer
3. Routing to base station

Each phase plays very important role and have its own issues. We will discuss it more briefly.

1. **Discovery**: The main aim of the discovery process is to define the contact as soon as nodes in the communication range of each other. Discovery process should be energy efficient one. We should try to maximize the residual contact time and the number of detected contacts, while we try to minimize the energy consumption.

2. **Data transfer**: The data transfer process starts after the discovery process. The main aim of data transfer process to get most out of the residual contact time. We try to transmit maximum data with less energy consume. It is generally a single hop process.

3. **Routing to base station**: Routing to base station or transmit data to base station is a multi-hop process. Here we try to find a root to base station which is faster as well as energy efficient one. Previously many works have been done to select a path which is an efficient one but they ignore the fact how data can transmit faster. In many application data are very sensitive, they should reach to destination as soon as possible.

2.3 Impact of mobility

The mobility of sensor nodes has very high impact on data collection process. It mostly affects the discovery process. The mobility can be two types, one is deterministic and second one is random. In Deterministic mobility, the mobile element mobility pattern is known. At which time, the mobile elements will be in contact area at a particular node. For example a sensor node is placed in particular vehicle and we know its timing. So at that particular time the node will be active and in other time node will be in sleep state. In second case, when mobility pattern is random. So initially we do not idea of mobility pattern. Then we observe its mobility pattern and find its mobility pattern. After we find its pattern a node should perform discovery at that particular time. If we did not study the mobility pattern node have to discover continuously, so that it can increase the chance of detecting contacts. But it is consume more energy. However, when some knowledge on the mobility pattern of nodes can be exploited, the node can restrict discovery to the instants. So mobility of node has significant impact on data collection process.

Mobility in WSNs also introduces significant challenges which do not arise in static WSNs. These challenges are described below.

- **Contact detection**: Since communication is possible only when the nodes are in the transmission range of each other, it is necessary to detect the presence of a mobile node correctly and efficiently. This is especially true when the duration of contacts is short.
- **Mobility-aware power management**: In some cases, it is possible to exploit the knowledge on the mobility pattern to further optimize the detection of mobile elements. In fact, if visiting times are known or can be predicted with certain accuracy, sensor nodes can be awake only when they expect the mobile element to be in their transmission range.

- **Reliable data transfer**: As available contacts might be scarce and short, there is a need to maximize the number of messages correctly transferred to the sink. In addition, since nodes move during data transfer, message exchange must be mobility-aware.
- **Mobility control**: When the motion of mobile elements can be controlled, a policy for visiting nodes in the network has to be defined. To this end, the path and the speed or sojourn time of mobile nodes has to be defined in order to improve (maximize) the network performance.

2.4 Different Data-transfer algorithm

These sensor nodes are generally battery powered devices. So energy saving is most the important factor for sensor network. For the entire life time of the network can increases, if we properly distributed the work load among the node. Many algorithms are proposed to handle energy saving problem in wireless sensor network. The main aim is to save energy so that entire life time of the network can be increased. But theses algorithms ignore the efficient data collection in wireless sensor network. In below we have discussed some important algorithm for data collection in wireless sensor network. These are,

1. LEACH
2. PEGASIS
3. PEDAP
4. Top-down approach

2.4.1 LEACH

The LEACH [12] stands for Lower Energy Adaptive Clustering Hierarchy. It is a clustering protocol that minimizes energy dissipation while transmitting data to base station. The main aim of this protocol is to reduce the number of nodes communicating directly to base station. In sensor network sensor nodes are organized in $(cluster - members) \rightarrow (cluster - head) \rightarrow (base - station)$manner. The cluster head collect data from the cluster members, fuses and send the result to base station. The cluster is formed in self-organized manner. The responsibility of cluster head is rotated among the cluster members of cluster so energy can be properly distributed among the sensor network and simultaneously entire life time of the network can be increased.

2.4.2 PEGASIS

PEGASIS(Power-Efficient Gathering in Sensor Information Systems) [13] takes it further and reduces the number of nodes communicating directly with the base station to one by forming a chain passing through all nodes where each node receives from and transmits to the closest possible neighbor. The data is collected starting from each endpoint of the chain until the randomized head node is reached. The data is fused each time it moves from node to node. The designated head node is responsible for transmitting the final data to the base station.

2.4.3 PEDAP

PEDAP(Power Efficient Data Gathering and Aggregation Protocol) [14] based on idea of minimum spanning tree. It minimized the long distance transmission among the sensor node and base station as well as minimized the distance between the sensor nodes. It is also a clustering algorithm, but it is more efficient as compare to LEACH and PEGASIS in terms of energy saving in sensor nodes. Another advantage is it enhances the life time of network even if base station is inside the field where as this condition can not applicable to either LEACH or PEGASIS.Figure 2.2 shown the difference between chain based routing scheme and minimum spanning tree based routing scheme on a simple network.

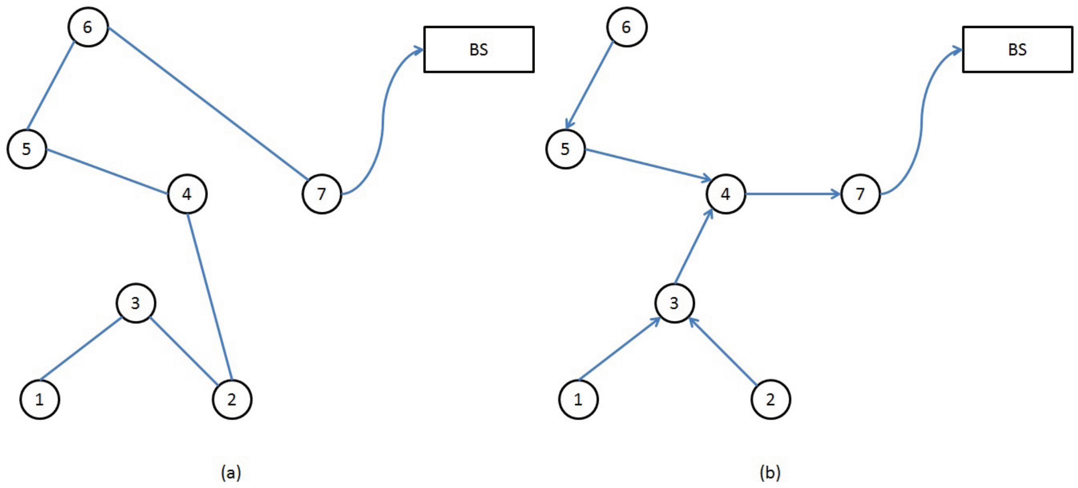

Figure 2.2: (a)Chain based routing scheme on a sample network.(b)Minimum spanning tree based routing scheme on a sample network.

2.4.4 Top-down approach

All the above algorithms those are discussed, their main aim to increases the life time of network. But they ignore the fact Data are very sensitive, it should reach to base station as soon as possible. We cannot ignore it. Top-down approach tries giving importance to both the factors. Data should reach to base station faster as well as in an energy efficient way.

In the top-down approach [15] , it is assumed that base station is having all the coordinates of all sensor nodes in the network. This algorithm will execute at the base station. It is a centralized approach to form a network structure which improves in transmitting data to base station faster. After executing the algorithm at the base station, it will instruct the sensor nodes to form appropriate network structure. The number of node are $N = 2^p$ where N=2,3,4..The algorithm will not applicable for sensor network having 1, 2, and 3 nodes. The algorithm is given below.

1. Initially all sensor nodes are connected to each other. Here connected means if two nodes are connected to each other means they have a link exist in

between them through which they can communicate each other. Sensor nodes are disconnected to each means they do not communication link in between them.

2. Degree of node indicates how many data link associated with that particular node. If there are N nodes in sensor network then initially all degree of node equal to (N-1). All the nodes will form the set $S_G = 1$. Set $k = \frac{N}{2}$

3. Select 'k' nodes from set S_G to from S_{G+1} such that the distance among these nodes are maximized. i.e-: $\sum_{i,j \in S_{G+1}} d_{i,j}^2$ is maximized.
   Here $d_{i,j}^2$ denotes distance between i and j.The other nodes will form set S_G and selected nodes will form S_{G+1}. Then the algorithm will remove all the connections among nodes within S_{G+1} set of nodes.Now set the parameters $G = G + 1$ and $k = \frac{k}{2}$.

4. Repeat the above step-3 until $k < 2$ and set parameter $t = 2$.

5. After that nodes having degree equal to $(N - t)$ form set P and the nodes having degree greater than $(N - t)$ form set Q. The set P and Q having same number of nodes.

6. The data link among nodes in the two set P and Q are removed until each node in the set P is only connection to a single node in set Q. Only one shortest link between tow set P and Q will present and other data links are removed. Then set the parameter $t = t * 2$.

7. Repeat the above step-6 until $t = N$.

Example

1. Consider a network shown in Figure 2.3 with $N = 8$. So initially all the nodes having degree=7. All the nodes are forming group $S_G = 1$ and $k = \frac{N}{2} = 4$.

2. Select $k = 4$ nodes from the group $S_G = 1$ form a new group known as $S_G = 2$. The nodes are select in such a way that the total edge weight is maximized. Nodes are select using dynamic programing.

3. So $S_G = 1$ having nodes A,B,G,H and $S_G = 2$ having nodes C,D,E,F. All the data links are removed among nodes in group $S_G = 2$. $k = \frac{k}{2} = 2$.

4. Now $k = 2$ which means $k < 2$ condition is not satisfied, so above process will be repeated. $S_{G=1} = \{A, B, G, H\}$ group will again divided into two parts. Let $S_{G=1} = \{B, G\}$ and $S_{G=3} = \{A, H\}$. So the connection between $S_{G=3}$ is removed and $k = \frac{k}{2} = 1$.

5. Now with $k = 1$ which means $k < 2$ condition is satisfied. So algorithm move the next step and set parameter $t = 2$.

6. Nodes having degree equal to $(N - t) = 6$ are set $P = \{A, H\}$. Nodes having degree greater than equal to $(N - t)$ are set $Q = \{B, G\}$.

7. Remove the connection among P and Q until each nod in set P is only connected to a single node in set U, provided that the total edge weight is minimized. Set the parameter $t = t * 2$, so now $t = 4$.

8. Now $t = 4$ which means $t < N$, so the previous step is repeated. $(N - t) = 4$. The node having degree $= 4$ are form group $P = \{C, D, E, F\}$ and the node having degree > 4 are form group $Q = \{A, B, G, H\}$.

9. Remove the connection among the nodes between groups P and Q until each node in set P is only connected to a single node in set Q, provided the total edge weight is minimized. Set the parameter $t = t * 2$, so $t = 8$.

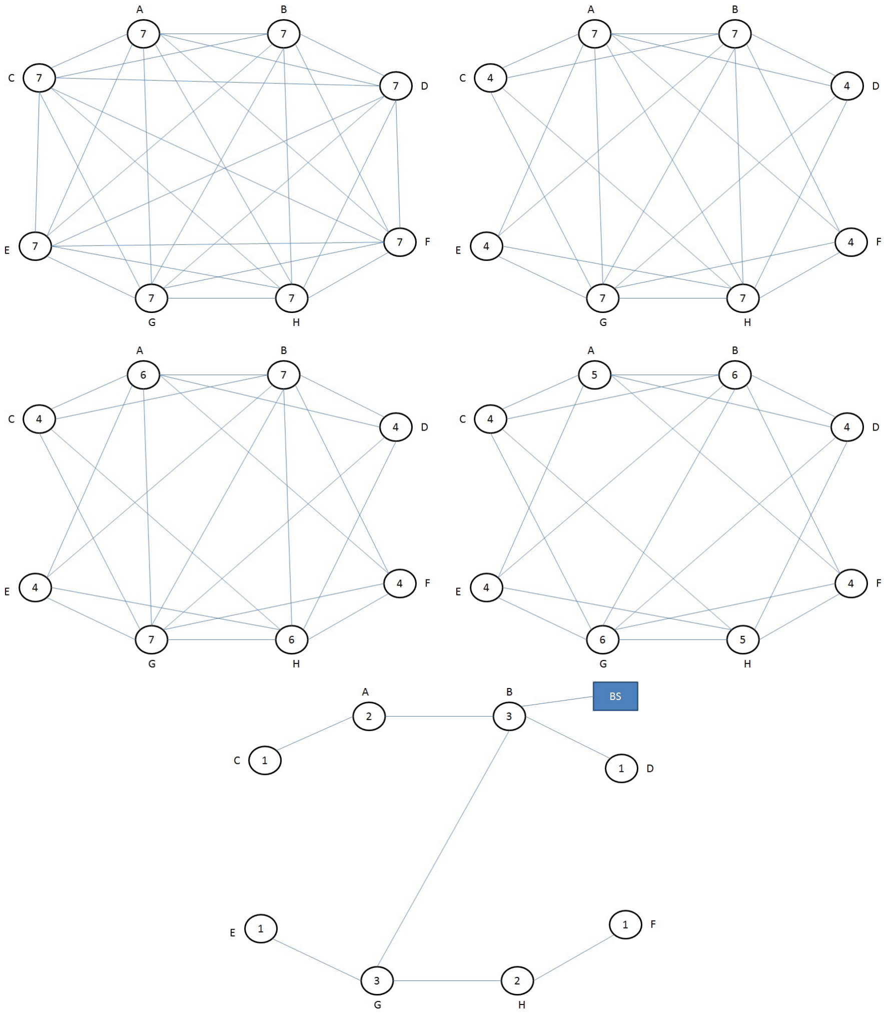

Figure 2.3: An example of the top-down approach with N=8 Sensor nodes are represented by circles and the base station (BS) is represented by a rectangle

10. Now $t = 8$ which means $t = N$, the operation is complete. The resultant network structure having two nodes degree $\log_2 N = 3$.

11. After the network structure formation, one of the two nodes which is having highest degree, will be selected as cluster head and connected directly to the base station. So the connection degree of cluster head having degree equal to $\log_2(N + 1)$

2.5 Summary

All algorithms that we have discussed above give emphasize to utilize the energy in sensor node properly. But they ignore the fact how to transmit data faster. We all know efficient energy is most important factor to sensor node so we cannot also ignore it. So in our approach we try to give importance to both factors, that is to transmit data to base station faster as well as in an energy efficient way.

Chapter 3

Literature Review

Chapter 3

Literature Review

3.1 Literature review

Due to the energy constraint of individual sensor nodes, energy conservation becomes one of the major issues in sensor networks. In wireless sensor networks, a large portion of the energy in a node is consumed in wireless communications. The amount of energy consumed in a transmission is proportional to the corresponding communication distance. Therefore, long distance communications between nodes and the base station are usually not encouraged.

One way to reduce energy consumption in sensor networks is to adopt a clustering algorithm [16]. A clustering algorithm tries to organize sensor nodes into clusters. Within each cluster, one node is elected as the cluster head. The cluster head is responsible for:

1. Collecting data from its cluster members
2. Fusing the data by means of data/decision fusion techniques
3. Reporting the fused data to the remote base station

In each cluster, the cluster head is the only node involved in long distance communications. Energy consumption of the whole network is therefore reduced. Intensive research [12–14, 17] has been conducted on reducing energy consumption by forming clusters with appropriate network structures. Heinzelmanet al. proposed a clustering algorithm called LEACH [12].

In networks using LEACH, sensor nodes are organized in multiple-cluster 2-hop (MC2H) networks (i.e., cluster members cluster head base station). Using the idea of clustering, the amount of long distance transmissions can be greatly reduced.In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster head. All non-cluster head nodes transmit their data to the cluster head, while the cluster head node receives data from all the cluster members, performs signal processing functions on the data (e.g., data aggregation), and transmits data to the remote BS. Therefore, being a cluster head node is much more energy intensive than being a noncluster head node. If the cluster heads were chosen a priori and fixed throughout the system lifetime, these nodes would quickly use up their limited energy. Once the cluster head runs out of energy, it is no longer operational, and all the nodes that belong to the cluster lose communication ability. Thus, LEACH incorporates randomized rotation of the high-energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way, the energy load of being a cluster head is evenly distributed among the nodes.

Lindsey and Raghavendra proposed another clustering algorithm called PEGASIS [13], which is a completely different idea by organizing sensor nodes into a single chain (SC) network. In such networks, a single node on the chain is selected as the cluster head. By minimizing the number of cluster heads, the energy consumed in long distance transmission is further minimized. The main idea in PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data moves from node to node, get fused, and eventually a designated node transmits to the BS. Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced

Tan and Korpeoglu developed PEDAP [14], which is based on the idea of a minimum spanning tree (MST). Besides minimizing the amount of long distance transmission, the communication distances among sensor nodes are also minimized. It is also a clustering algorithm, but it is more efficient as compare to LEACH and PEGASIS in terms of energy saving in sensor nodes. Another advantage is it enhances the life time of network even if base station is inside the field where as this condition can not applicable to either LEACH or PEGASIS.

Fonseca et al. proposed the collection tree protocol (CTP) [17]. The CTP is a kind of gradient-based routing protocol which uses expected transmissions (ETX) as its routing gradient. ETX is the number of expected transmissions of a packet necessary for it to be received without error [18]. Paths with low ETX are expected to have high throughput. Nodes in a network using CTP will always pick a route with the lowest ETX. In general, the ETX of a path is proportional to the corresponding path length [19]. Thus, CTP can greatly reduce the communication distances among sensor nodes.

All these algorithms show promising results in energy saving. However, a network formed by an energy efficient clustering algorithm may not necessarily be desirable for data collection. The focus of our research work is on investigating the data collection efficiency of networks formed by different clustering algorithms. A related work on data collection efficiency was done by Florenset al. [20]. In their work, lower bounds on data collection time are derived for various network structures. However, the effect of data fusion, which is believed as one of the major features of sensor networks, was not considered.

Wang et al. [21] proposed link scheduling algorithms for wireless sensor networks which can raise network throughput considerably. In their work, however, it is assumed that data links among wireless sensor nodes are predefined. In contrast, the objective of this paper is to form data links among wireless sensor nodes and thus to shorten the delays in the data collection processes.

Another related work was done by Solis and Obraczka [22] who studied the impact of timing in data aggregation for sensor networks. Chen et al. [23] investigated the effects of network capacity under different network structures and routing strategies. A similar work was done by Song and He. In their work, the term capacity is defined as the maximum end-to-end traffic that a network can handle.

We also studied many survey papers in wirless sensor network [1, 24].They first define WSNs with MEs and provide a comprehensive taxonomy of their architectures, based on the role of the MEs. Then, they present an overview of the data collection process in such scenario, and identify the corresponding issues and challenges. On the basis of these issues, they provide an extensive survey of the related literature.

In 2010, YoungSang Yun et al. [25] proposed a framework to maximize the lifetime of the wireless sensor networks (WSNs) by using a mobile sink when the underlying applications tolerate delayed information delivery to the sink. Within a prescribed delay tolerance level, each node does not need to send the data immediately as it becomes available. Instead, the node can store the data temporarily and transmit it when the mobile sink is at the most favorable location for achieving the longest WSN lifetime. To find the best solution within the proposed framework, we formulate optimization problems that maximize the lifetime of the WSN subject to the delay bound constraints, node energy constraints, and flow conservation constraints. They conduct extensive computational experiments on the optimization problems and find that the lifetime can be increased significantly as compared to not only the stationary sink model but also more traditional mobile sink models.

In 2010, Saeed Rasouli Heikalabad et al. [26] proposed the new cluster head selection protocol namely HEECH. This protocol selects a best sensor node in terms of energy and distance as a cluster head. They produce the Simulation Results which show that the HEECH increases the network lifetime about 56% and 9% compared to the LEACH and HEED, respectively.

In 2010, Babar Nazir et al. [27] proposed and address hotspot problem and Mobile Sink based Routing Protocol (MSRP) for Prolonging Network Lifetime in Clustered Wireless Sensor Network. In MSRP, mobile sink moves in the clustered WSN to collect sensed data from the CHs within its vicinity. During data gathering mobile sink also maintains information about the residual energy of the CHs. Mobile sink based on the residual energy of CHs move to the CHs having higher energy. Consequently, the hotspot problem is minimized as the immediate neighbor of the sink is high energy node and it changes because of regular sink movement. It results in a balanced use of WSN energy and improves network life time of network. In MSRP, mobile sink moves in the clustered WSN to collect sensed data from the CHs within its vicinity. During data gathering mobile sink also maintains information about the residual energy of the CHs. Mobile sink based on the residual energy of CHs move to the CHs having higher energy. Consequently, the hotspot problem is minimized as the immediate neighbor of the sink is high energy node and it changes because of regular sink movement. It results in a balanced use of WSN energy and improves network life time.

A Delay-aware data collection was done by Cheng et al. 2010 [15]. In their work they gave two approaches for data collection, one is Top-down and another one is bottom up approach. In bottom up approach the network structure is not that much energy efficient while transmitting the data to base station because in their network structure large numbers of nodes are involve in transmit their data to a longer distance so large amount of energy is consumed. In our research work we try to overcome this problem by reducing the transmission distance among nodes by forming a different network structure among the nodes and to transmit data as fast as possible as well.

3.2 Motivation

Wireless sensor networks (WSNs) have emerged as an effective solution for a wide range of applications. Most of the traditional WSN architectures consist of static nodes which are densely deployed over a sensing area. Recently, several WSN architectures based on mobile elements (MEs) have been proposed. Most of them exploit mobility to address the problem of data collection in WSNs. The WSN have a wide range of applications for sensor networks. Some of the application areas are health, military and home. In military, for example, the rapid deployment, self-organization, and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems. In health, sensor nodes can also be deployed to monitor patients and assist disabled patients. Some other commercial applications include managing inventory, monitoring product quality and monitoring disaster areas. This wide range of application motivates me to work on this particular area.

Chapter 4

Proposed Scheme

Chapter 4

Proposed Scheme

4.1 Introduction

Wireless sensor network is a collection of large number of sensor nodes, collecting data from sensing territory and transmitting data to the base station. These sensor nodes are generally battery powered devices so energy saving is most important factor for a sensor network. The entire life time of the network can increase, if we properly distribute the work load among the nodes. Many algorithms are proposed to handle energy saving problem in wireless sensor network. The main aim is to save energy so that entire life time of the network can be increased. But these algorithms ignore the efficient data collection in wireless sensor network. So in our work we try to develop an algorithm which will form a network structure in wireless sensor network, through which data can be transmitted faster to the base station without affecting life time of network. Performance of the proposed network structure is evaluated using computer simulations. Simulation results show that, when comparing with other common network structures in wireless sensor networks, the proposed network structure is able to shorten the delays in the data collection process significantly.

The main aim of many algorithms is to conserve energy by clustering. In clustering concept, the sensor nodes in wireless sensor network are divided into several clusters.

Within each cluster, one node behaves as cluster head and other nodes behave as cluster members. The responsibility of cluster node is to collect data from respective cluster members and transmit the data to base station in a single hop or in a multi-hop manner. The cluster head in a cluster is generally involved in long distance transmission, so its energy level decreases faster than other cluster members in a cluster. To overcome this problem we try to rotate the responsibility of cluster head among the cluster members in a cluster so that energy can be properly distributed among the nodes. By organizing sensor nodes into a cluster, very few nodes are involved in long distance transmission so it consumes less energy which increases the life time of entire network.

The energy consumption and data transmission can be further reduced by performing data fusion on nodes. Data fusion is process through which a node can collect the data packets from other nodes and combine all data packets into a single packet. Generally the data collected by the sensor nodes are highly correlated to each other so the process of data fusion does not affect original meaning of data a lot. Data fusion process is very effective as it reduces the number of data packets sent by any node in wireless sensor network.

Figure 4.1 shows a cluster having a base station, a cluster head and cluster members. In Figure 4.1 (a) all cluster member transmitting data to cluster head one by one. So it will take 3 units of time. Cluster head fuses the data packets into a single packet and transmits to the base station and it will take another one unit of time so in total Figure 4.1 (b) cluster will take 4 unit of time to transmit data to base station. But in case of Figure 4.1 (b) it will take only 3 units of time to transmit same amount of data to base station. So the network structure forms in Figure 4.1 (b) provide significant improvement in term transmitting the data faster to base station and it will not consume more than the structure form by the Figure 4.1 (a).

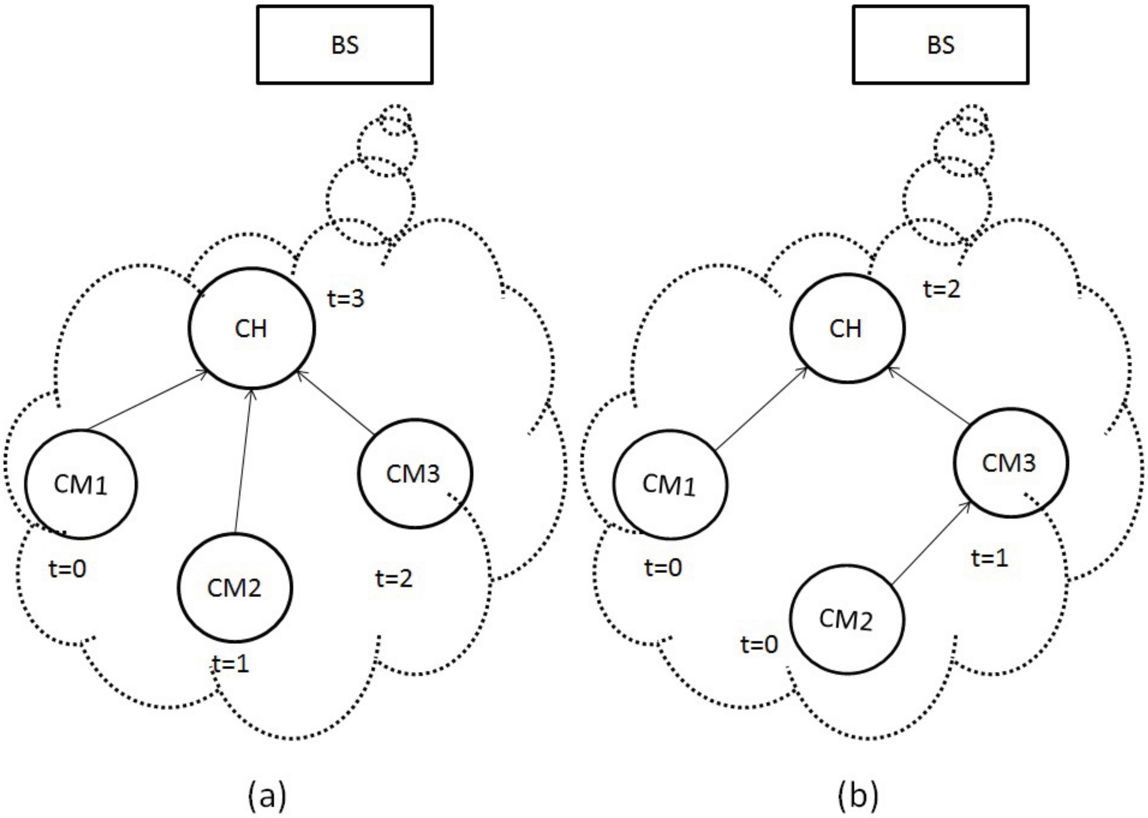

Figure 4.1: (a)Data collection in a two-hop network and (b) data collection in an improved multi-hop network.

The main aim is to form a network structure in wireless sensor network so that data will transmit to base station faster and in energy efficient way. Different phases of discussion are given below,

1. Modified Bottom-up approach
2. Algorithm
3. Steps of Modified bottom-up approach
4. Analytical study of proposed scheme

The proposed algorithms are operate between the data link layer and the network layer. The algorithm tries to transmit the data faster as well as it will try to keep the transmission distance among nodes less so that the amount of energy consumed in communications can be reduced.

4.2 Modified Bottom-up approach

Initially all the nodes have a lower transmission range which is decided by the user depending upon the type of application and its environmental operation. Each node is labeled with a unique ID and marked as a level v. $v =$ it is a function which represents the number of nodes in the cluster. All the nodes are disconnected initially and N nodes have level equal to zero. The main approach is to join clusters of same size together. There are two types of cluster formation in the proposed network structure.

- Lower level cluster formation
- Higher level cluster formation

4.2.1 Lower level cluster formation

First every node sends signal to the other nodes within their transmission range. Based on their signal strength nodes decide which node is the nearest node to it. After that all the nodes send a "nearest-neighborhood-packet" to its nearest node only. The"nearest-neighborhood-packet" contains the unique IDs of source node and destination node.

Every node counts the number of"nearest-neighborhood-packet" it has received. Let NOR=number of nearest-neighborhood-packet a node received. Initially NOR=0 for every node. The node having NOR value equal to zero means it does not get any nearest-neighborhood packet from other nodes.

If NOR value of a node is equal to 1 and received nearest-neighborhood-packet's source ID is same as its sending nearest-neighborhood-packet's destination ID, then it will form a link with its nearest node. The degree of both node increases to 1 and among them one is selected as sub-cluster-head (SCH) randomly.

Figure 4.2: Node having NOR value=1 and nearest of each other

Another packet called no-request-got (NRG) packet has a highest priority. A node can send a NRG packet to its nearest node at only one condition, that is when NOR value of a node equal to zero.

If a node got a NRG packet means it has to form a link with that node immediately, from which node it received the NRG packet. If NOR value of a node is equal to 0, then it will send a NRG (no-request-got) packet to its nearest node.

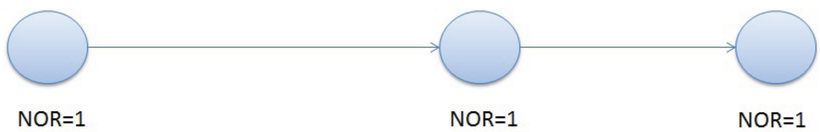

Figure 4.3: Node having NOR value=1 and not nearest of each other

A node can get more than one NRG packet from different nodes. In this case it will also form links with all the nodes by sending connection request (CR) to each node and it will form a cluster. The degree of nodes in that cluster will be equal to number of nodes connected to that node.

The node that receives all the NRG packets in the cluster becomes the sub-cluster-head (SCH) in that cluster. Once a node forms a link with another node it will send Rejection packet (RP) to rest of the nodes that sent the nearest-neighborhood-packet to it. When a node receives a Rejection packet (RP),

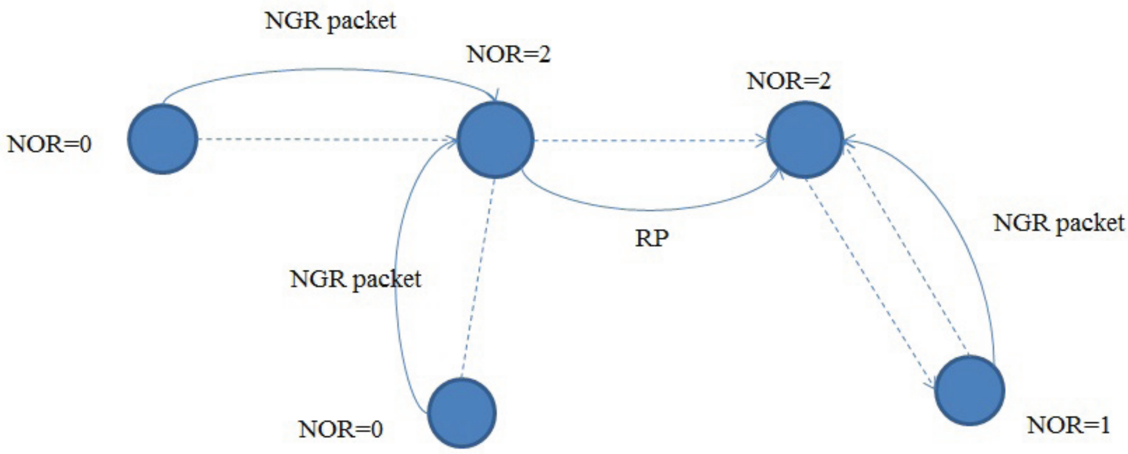

Figure 4.4: Before lower level cluster formation

then it's NOR value decreases by one. If at some point of time a node NOR value of a node may be zero or one due to receiving of RPs.

- If it is zero and it is not able to form a link with other nodes then it sends a NRG packet to its nearest node and forms a link with it.
- If it is one or more and it will not be able to form a link with other nodes then it sends connection request (CR) to the nodes from which it got the "nearest-neighborhood-packet" and it did get rejection packet (RP) from them till now and try to form a link with any of them.

4.2.2 Higher level clustering formation

After the low level clustering is over, a SCH can make connection with another SCH of the same level. Once two SCHs are connected, the two SCHs and their belonging level-w cluster will form a composite level - $(v + 1)$ cluster. One of the two SCH becomes the chief SCH randomly. The chief SCH will listen to the communication channel and replay CR from lower levels with a rejecting packet (RP).

When no more connection request (CR) from lower levels can be heard, the chief SCH will start to make connection with other SCHs of same level. If a Rejection

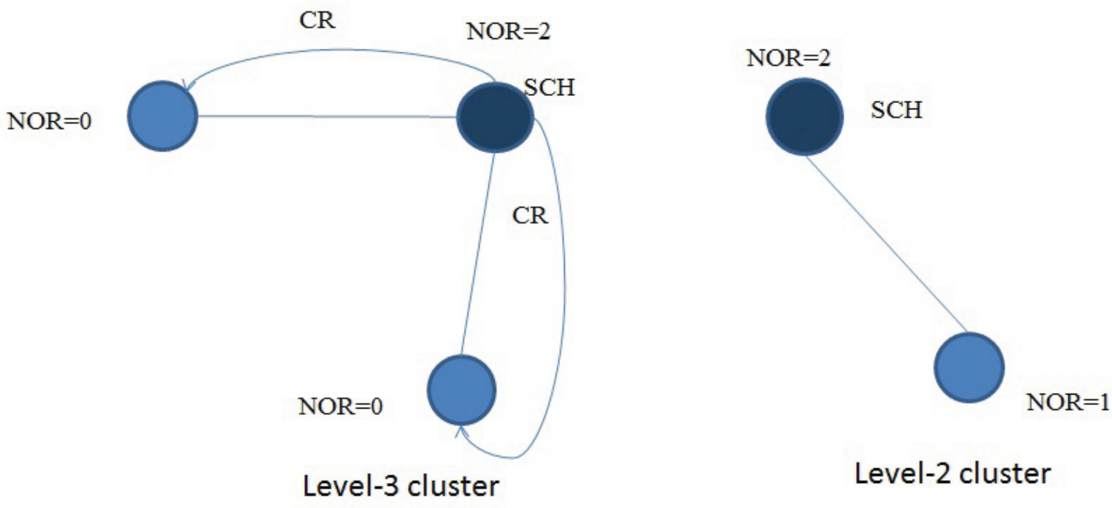

Figure 4.5: After lower level cluster formation

packet (RP) is received, a SCH will send a CR to its next nearest neighbor. If no connection can be made within a period of time either all neighbors of the same level are unavailable or all CRs have been rejected, the SCH will increase its transmission range and broadcast the CR again. The above process continues until no more connection can be formed.

4.3 Steps of Modified bottom-up approach

- Bottom-up approach is a decentralized way to form the network structure in wireless sensor network so that data can be transmitted to the base station faster. The main aim of this approach is to join the clusters of the same size together. Initially all the nodes are disconnected to each other so degree of each node is zero.

- Every node is marked with a unique id and marked as level V. Degree of a node indicates the number of nodes in a cluster to which it belongs. For a cluster of i nodes, its V value is equal to $\log_2 i$.

Algorithm 1 Modified Bottom-up Approach

$c \leftarrow 0$
$v \leftarrow 0$
$m = (\log_2 N_{total} + 1)$
for $\forall nodeN_i$ **do**
    if $\sqrt{t_x^2 + t_y^2}$ < Threshold Value **then**
        $D_{com} \leftarrow$ Threshold Value
        call function send-connection-request()
    else
        $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-c-v}$
        while $(D_{com} \neq \sqrt{t_x^2 + t_y^2})$ and $(c + v < m)$ **do**
            Node boardcast neighbourhood packet(NP) within D_{com}
            Count NP each node received
            if (NP < threshold value) or (Maximum time limit is reached) **then**
                call function send-connection-request()
            end if
            if no more connection possible **then**
                $c \leftarrow c + 1$
                $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-c-v}$
            end if
        end while
    end if
end for

Algorithm 2 send-connection-request()

for ∀ neighbour nodes **do**
    Send CR to nodes in range of D_{com}
    if (two SCH having same level v) **then**
        Make connection
        One of the two SCH will be chief SCH
        $v \leftarrow v + 1$
    else
        Send RP
    end if
end for

- In a cluster one node is selected as cluster head. One cluster head can make connection with another cluster head if both the cluster is having same degree.
- Each sensor node know its dimension (t_x, t_y) before it deployed in sensor network. Initially all node are separated to each other and all consider as sub cluster head (SCH). Each SCH broadcast distance packet (DP) to its neighboring SCHs which are within the distance $D_{com} = \sqrt{(t_x^2 + t_y^2)}$ m.
- The size of distance packet is very small as compare to data packet. So it will consume less amount of energy as compare to data packet.
- Each node count the total number of distance packets (DP) it has received in the sensor network. By the help of dimension of terrain and number of received distance packets (DP) it can estimate the total number of nodes N_{Total} in the network.
- Another important parameter communication distance (D_{com}). It is distance up to which node will send its packet to its neighbors. A cluster head adjust its communication distance (D_{com}) using N_{Total}.

- Now each SCH broadcast a neighborhood packet (NP) within range of (D_{com}). The neighborhood packet contains the level V and identify of the issuing SCH.
- A SCH will evaluate the distances of its neighboring SCHs using the received signal strength of the neighborhood packets (NP) received. A SCH will count the number of neighborhood packets (NP) received.
- Now if the number of NPs received at particular SCH has exceeded a predefined threshold value or up to certain time limit a SCH did not get any neighborhood packet then a SCH will send a connection request (CR) to its nearest neighborhood.
- If the two SCH are of same level V and nearest to each other a connection will formed between these two SCHs. Now among the two SCHs one will be selected as cluster head and their belonging level-V clusters will form a composite cluster level-($V + 1$) cluster.
- A SCH constantly listen from the SCH of the network and if any SCH got any connection request (CR) from its lower level than its own level then it will send a Rejection packet (RP) to make sure they will not connect to each other.
- When no further connection request (CR) heard from the lower level then SCH start make connection with other SCHs of same level.
- When a SCH got a rejection packet (RP), it will send a connection request to its next neighbor having same level V within its communication distance Dcom. If there will be no such SCH exist then SCH will increase its communication distance D_{com}.
- After increasing its communication distance D_{com}, the SCH will then broadcast a CR using the new D_{com}. Upon receiving the CR, a SCH having same level will accept request if it is still waiting for a CR.

- If no connection can possible within a certain period of time, it means either all neighbors of the same level do not exist or all CRs are rejected. In that case SCH will increase its D_{com} and broadcast the CR again.
- This process is repeated when $D_{com} < \sqrt{(t_x^2 + t_y^2)}$. if $D_{com} = \sqrt{(t_x^2 + t_y^2)}$, then SCH will make connection with the base station directly. The above process continued until no more connection can be formed.

if total number of node N=32 then after implementing modified bottom-up algorithm we will got a structure given below,

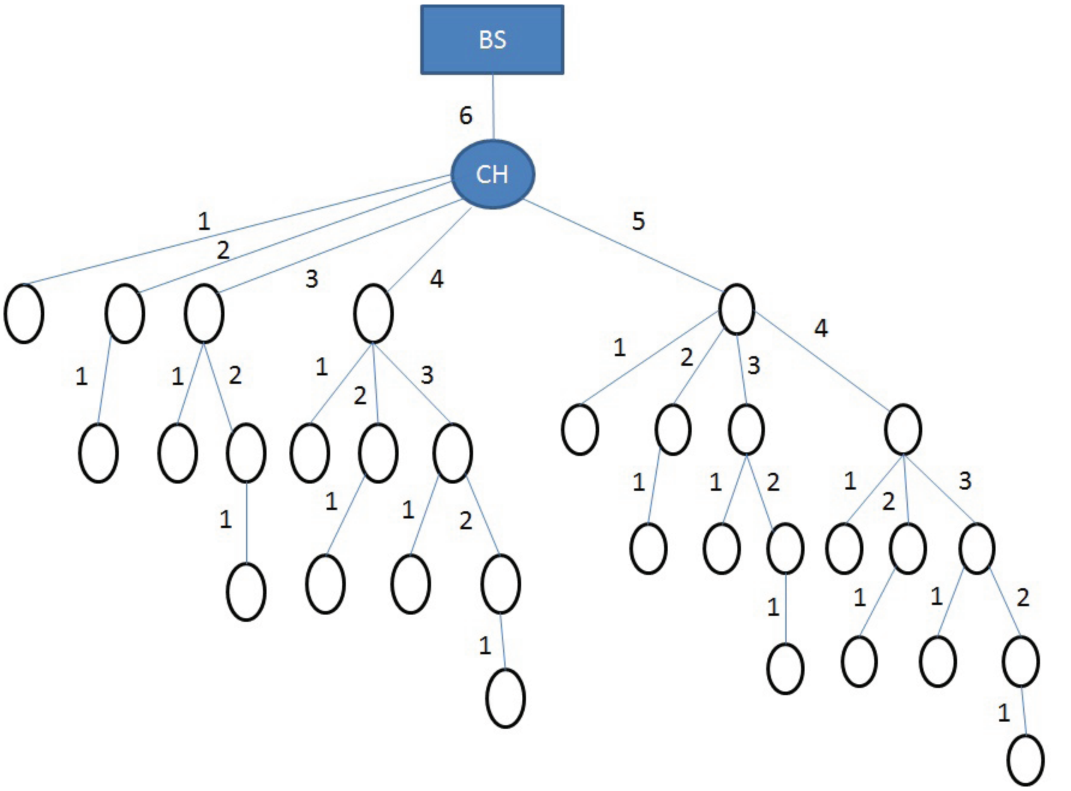

Figure 4.6: Composite cluster formation after applying modified bottom-up approach for N=32

4.4 Analytical study of proposed scheme

- In the modified bottom-up approach, the communication distance D_{com} is defined as, $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-c-v}$, $c+v<m$
  where m=maximum rank of network,It calculated as $m = \lceil \log_2 N \rceil + 1$.
  c=it is a contant set to zero initially.
  v=level of the node.

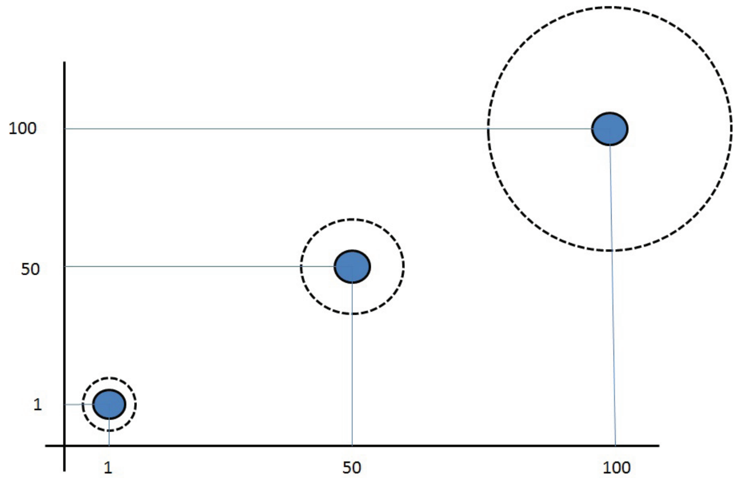

Figure 4.7: Communication range of different nodes based on formula $D_{com} = \sqrt{(t_x^2 + t_y^2)}$ m

- The sensor nodes closer to origin having smaller communication range but the nodes goes away from origin, their communication range increases. Now the problem is node are closer to origin can not able form link due to its shorter communication range. So overcome problem we have defined an threshold value known as threshold communication range(TCR).

- The node having communication range lesser than TCR then its communication range value is assigned as TCR. If it is greater than TCR then D_{com} is calculated as $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-c-v}$.

- The TCR value should choose in such way that every node should reach to its one hop neighbor. It depends on how sensor nodes are densly deployed in the network.

- Initially all the sub cluster head are with $c = 0$ and $v = 0$. Therefore the start boardcasting their neighborhood packet(NP) with $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-0-0}$.

- When one SCH make connection with another SCH then its level v will be increased by 1. so the v value will be 1.

- After that, one of the two SCH will be elected as cluster head. The new cluster head boardcast its neighborhood packet(NP) with $D_{com} = \frac{\sqrt{t_x^2+t_y^2}}{m-0-1}$

- The D_{com} is designed in such a way that when level v of a node increase D_{com} increase because SCHs are paired up to form composite cluster the average separation among composite cluster will be increased. The level v of SCH increases when one SCH combine with another SCH having same level.

- However, when no more connection is possible, the SCH will increase its c value by one.

- This will increase D_{com}. It helps in searching available SCHs and make composite cluster. A SCH can increase its Dcom by increasing c until a connection can be made.

- But the condition is $(c + v < m)$, It ensure that D_{com} is upper bounded by the diagonal of the sensing terrain.

- A SCH will send a Connection request (CR) to its neighbor node, if the number of received neighborhood packet (NP) has exceeded a threshold value.

- After implementing the algorithm, the network end of with multiple composite clusters. The composite cluster may have different sizes. The corresponding cluster head of composite cluster transmit data direct to base station.

- By considering base station as root of the network, if N is total number of nodes in the network the total time slot required to collect data form all sensor node is equal to $t(N)$. where $t(N) = \lceil \log_2(N+1) \rceil$

4.4.1 Correctness

The algorithm, we have defined for our proposed scheme is only applicable for static sensor network. It is not applicable for sensor network with mobile elements. We have defined a minimum communication range called TCR (Threshold communication range) for our sensor nodes. It is depend on how densely sensor nodes are deployed in the network. The main motive behind to define TCR is, every node should reach to its nearest one hop distance. So every node can participate in network structure formation. In our algorithm we are able to transmit data parallel in the sensor network so our approach is very effective when large numbers of sensor nodes are present in the network. In our approach we assume that every sensor node take one time slot to transmit data to other nodes irrespective of its distance.

4.5 Summary

So in our approach, we are able to transmit data faster as compare to other approaches and simultaneously we give emphasize to energy constraint of sensor network. We try to make proper balance between two factors. In case of energy saving or data transmission process (rounds) also our approach out paly other approaches expect Minimum spanning tree (PEGASIS).But In case of faster data transmission(slots) our approach is the best one as compare to all other approaches.

Chapter 5

Simulation and Results

Chapter 5

Simulation and Results

5.1 Simulation Environment

For simulation, we have selected Castalia simulator.Castalia is a simulator for Wireless Sensor Networks (WSN), Body Area Networks (BAN) and generally networks of low-power embedded devices. It is based on the OMNeT++ platform and can be used by researchers and developers who want to test their distributed algorithms and/or protocols in realistic wireless channel.

5.2 Results and Analysis

In this section the proposed network structure is compared with LEACH, PEDAP, PEGASIS and Top-down approach. Networks having N nodes and N vary from 4 to 64. The sensor nodes are distributed randomly across the sensor field of $50X50$ m_2. A node can transmit and receive at any time. In sensor network, a sensor node is always capable of fusing the all received data packets into a single packet. The size of aggregated packet is independent of number of data packets received.

For simulation, initially each node is given energy of 50 J. The network performs the data collection periodically. The lifetime of a network is defined as the number of data collection processes (in terms of rounds) that a network can accomplish before any of its nodes runs out of energy. Control packet size is very less as compare to Data packet. In the simulation, some assumption are taken,

1. All sensor nodes are static in nature.
2. All Sensor node know its location (t_x, t_y).
3. All Sensor nodes have the information about the total number of nodes in the sensor field.

In the simulation, we have two approaches,

- In the first one, we try to find how many time slots are required for the sensor nodes to transmit data to Base station. It varies the total number of nodes from 4 to 64. We compare our approach with LEACH, PEDAP, PEGASIS, Top-down approach. We plot the graph for it. In the graph X-axis indicates number of sensor nodes (N) and Y-axis indicates number of slot required to transmit data to base station.

  Form the graph it is clearly shown that our approach is best one as compare to top-down approach. In previous work it proved that top-down approach is better than LEACH, PEDAP, and PEGASIS in case of faster data transmission. For example if $N = 60$, Top-down approach was taken 12 time slots where as our approach was taken only 6 time slot. So our approach is the best one in case of transmits the data to base station faster.

- In the second one, we try to compare our approach with others on basis of life time of network (number of rounds). It means we count the number of rounds up to which sensor nodes can transmit their data to base station within their limited battery powered. Here also we plot graph to compare our approach with others. In the graph X-axis indicates number of sensor nodes (N) and Y-axis indicates number of data collection process (rounds).

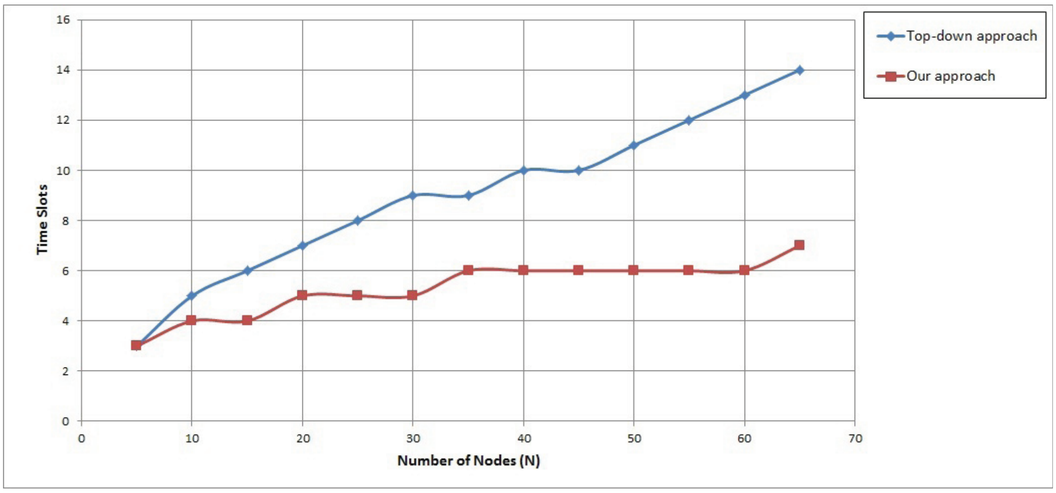

Figure 5.1: Average data collection time

From the graph it is clearly shown that our approach performs better as compared to Top-down approaches in case efficient energy utilization. Our approach is also better than PEDAP when numbers of sensor nodes are greater than 40. But in case of energy saving PEGASIS is better approach than our approach.

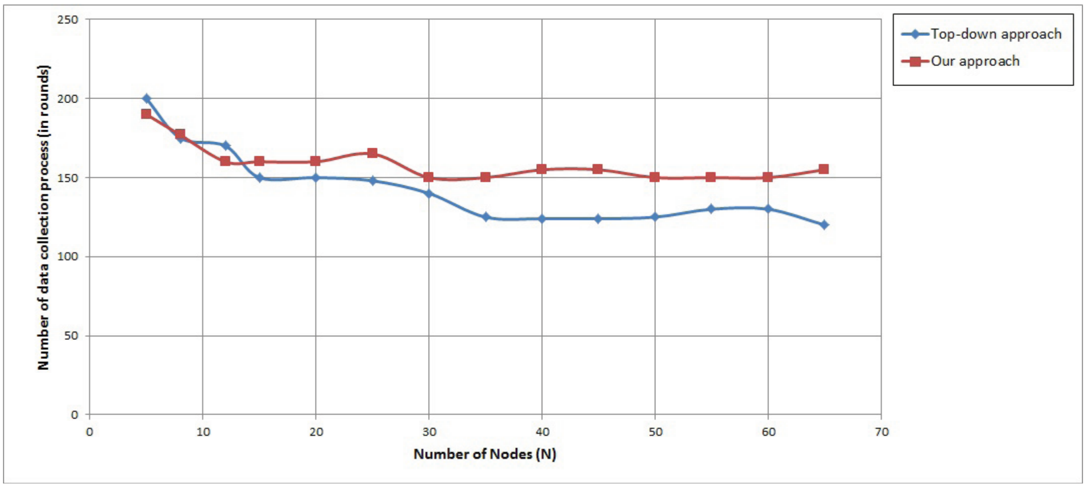

Figure 5.2: Average lifetime of sensor network

5.3 Summary

So in our approach, we are able to transmit data faster as compare to others and simultaneously we give emphasize to energy constraint of sensor network. We try to make proper balance between two factors. In case of energy saving or data transmission process (rounds) also our approach out paly other approaches expect Minimum spanning tree (PEGASIS).But In case of faster data transmission(slots) our approach is the best one as compare to all other approaches.

Chapter 6

Conclusions

Chapter 6

Conclusions

6.1 Conclusions

In recent years Wireless Sensor Networks (WSNs) have become an established technology for a large number of applications, ranging from monitoring (e.g., pollution prevention, precision agriculture, structures and buildings health), to event detection (e.g., intrusions, fire/flood emergencies) and target tracking (e.g., surveillance). WSNs usually consist of a large number of sensor nodes, which are battery-powered tiny devices. Although many protocols and algorithms have been developed for traditional wireless ad hoc networks, they are not well suited for the unique features and application requirements of sensor networks.

Many algorithms are proposed to handle energy saving problem in wireless sensor network. The main aim is to save energy so that entire life time of the network can be increased. But these algorithms ignore the efficient data collection in wireless sensor network. So in our work we have tried to develop an algorithm which will form a network structure in wireless sensor network, through which data can be transmitted faster to base station without affecting life time of network. Performances of the proposed network structure are evaluated using computer simulations. Simulation results show that, when comparing with other common network structures in wireless sensor networks, the proposed network structure is able to shorten the delays in the data collection process significantly.

In our research we tired to from a network structure so data can be collected as fast as possible and it should be in energy efficient way. In many applications of sensor network, data has high importance and it should reach to base station as fast as possible. Also we cannot ignore the fact that sensor nodes are tiny battery powered devices having limited power. So we tried to balance both the factors. The proposed network structure is shown to be efficient in terms of data collection time among all the existing network structures. The proposed network structure can greatly reduce the data collection time while keeping the total communication distance and the network lifetime at acceptable values.

6.2 Future work

The proposed model is able to collect data quickly and is also energy efficient. But there is always a room for improvement. It can be done in more energy efficient way. In our model we consider all the nodes as static in nature but in future, mobility of nodes can be considered.

Bibliography

[1] Ian F Akyildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. Wireless sensor networks: a survey. *Computer networks*, 38(4):393–422, 2002.

[2] Wenrui Zhao and Mostafa H Ammar. Message ferrying: Proactive routing in highly-partitioned wireless ad hoc networks. In *Distributed Computing Systems, 2003. FTDCS 2003. Proceedings. The Ninth IEEE Workshop on Future Trends of*, pages 308–314. IEEE, 2003.

[3] Kevin Fall. A delay-tolerant network architecture for challenged internets. In *Proceedings of the 2003 conference on Applications, technologies, architectures, and protocols for computer communications*, pages 27–34. ACM, 2003.

[4] Rahul C Shah, Sumit Roy, Sushant Jain, and Waylon Brunette. Data mules: Modeling a three-tier architecture for sparse sensor networks. In *Sensor Network Protocols and Applications, 2003. Proceedings of the First IEEE. 2003 IEEE International Workshop on*, pages 30–41. IEEE, 2003.

[5] Arnab Chakrabarti, Ashutosh Sabharwal, and Behnaam Aazhang. Using predictable observer mobility for power efficient design of sensor networks. In *Information Processing in Sensor Networks*, pages 129–145. Springer, 2003.

[6] Eylem Ekici, Yaoyao Gu, and Doruk Bozdag. Mobility-based communication in wireless sensor networks. *IEEE Communications Magazine*, 44(7):56, 2006.

[7] Mr Ravindra K Gupta, Mr Shashank Saxena, and Shailendra Singh. An efficient approach for data gathering and sharing with inter node communication in mobile-sink. 2012.

[8] Giuseppe Anastasi, Marco Conti, and Mario Di Francesco. Reliable and energy-efficient data collection in sparse sensor networks with mobile elements. *Performance Evaluation*, 66(12):791–810, 2009.

[9] Jian Li and Prasant Mohapatra. Analytical modeling and mitigation techniques for the energy hole problem in sensor networks. *Pervasive and Mobile Computing*, 3(3):233–254, 2007.

[10] Shashidhar Rao Gandham, Milind Dawande, Ravi Prakash, and Subbarayan Venkatesan. Energy efficient schemes for wireless sensor networks with multiple mobile base stations. In *Global telecommunications conference, 2003. GLOBECOM'03. IEEE*, volume 1, pages 377–381. IEEE, 2003.

[11] Guiling Wang, Guohong Cao, Tom La Porta, and Wensheng Zhang. Sensor relocation in mobile sensor networks. In *INFOCOM 2005. 24th Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings IEEE*, volume 4, pages 2302–2312. IEEE, 2005.

[12] Wendi B Heinzelman, Anantha P Chandrakasan, Hari Balakrishnan, et al. An application-specific protocol architecture for wireless microsensor networks. *IEEE Transactions on wireless communications*, 1(4):660–670, 2002.

[13] Stephanie Lindsey and Cauligi S Raghavendra. Pegasis: Power-efficient gathering in sensor information systems. In *Aerospace conference proceedings, 2002. IEEE*, volume 3, pages 3–1125. IEEE, 2002.

[14] Hüseyin Özgür Tan and Ibrahim Körpeog(lu. Power efficient data gathering and aggregation in wireless sensor networks. *ACM Sigmod Record*, 32(4):66–71, 2003.

[15] Shuai Gao, Hongke Zhang, and Sajal K Das. Efficient data collection in wireless sensor networks with path-constrained mobile sinks. *Mobile Computing, IEEE Transactions on*, 10(4):592–608, 2011.

[16] Jamal N Al-Karaki and Ahmed E Kamal. Routing techniques in wireless sensor networks: a survey. *Wireless Communications, IEEE*, 11(6):6–28, 2004.

[17] Omprakash Gnawali, Rodrigo Fonseca, Kyle Jamieson, David Moss, and Philip Levis. Collection tree protocol. In *Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems*, pages 1–14. ACM, 2009.

[18] Douglas SJ De Couto. *High-throughput routing for multi-hop wireless networks*. PhD thesis, Citeseer, 2004.

[19] Onur Tekdas, Volkan Isler, Jong Hyun Lim, and Andreas Terzis. Using mobile robots to harvest data from sensor fields. *Wireless Communications, IEEE*, 16(1):22–28, 2009.

[20] Xianwei Sun, Scott C-H Huang, and Minming Li. Lower bounds on data collection time in sensor networks. In *Wireless Algorithms, Systems, and Applications*, pages 120–131. Springer, 2012.

[21] Weizhao Wang, Yu Wang, Xiang-Yang Li, Wen-Zhan Song, and Ophir Frieder. Efficient interference-aware tdma link scheduling for static wireless networks. In *Proceedings of the 12th annual international conference on Mobile computing and networking*, pages 262–273. ACM, 2006.

[22] Ignacio Solis and Katia Obraczka. The impact of timing in data aggregation for sensor networks. In *Communications, 2004 IEEE International Conference on*, volume 6, pages 3640–3645. IEEE, 2004.

[23] Zhen Yi Chen and Xiao Fan Wang. Effects of network structure and routing strategy on network capacity. *Physical Review E*, 73(3):036107, 2006.

[24] Giuseppe Anastasi, Marco Conti, Mario Di Francesco, and Andrea Passarella. Energy conservation in wireless sensor networks: A survey. *Ad Hoc Networks*, 7(3):537–568, 2009.

[25] YoungSang Yun and Ye Xia. Maximizing the lifetime of wireless sensor networks with mobile sink in delay-tolerant applications. *Mobile Computing, IEEE Transactions on*, 9(9):1308–1318, 2010.

[26] Saeed Rasouli Heikalabad, Nasrin Firouz, Ahmad Habibizad Navin, and Mir Kamal Mirnia. Heech: Hybrid energy effective clustering hierarchical protocol for lifetime prolonging in wireless sensor networks. In *Computational Intelligence and Communication Networks (CICN), 2010 International Conference on*, pages 325–328. IEEE, 2010.

[27] Babar Nazir and Halabi Hasbullah. Mobile sink based routing protocol (msrp) for prolonging network lifetime in clustered wireless sensor network. In *Computer Applications and Industrial Electronics (ICCAIE), 2010 International Conference on*, pages 624–629. IEEE, 2010.

[28] Chi-Tsun Cheng, Chi K Tse, and Francis CM Lau. A delay-aware data collection network structure for wireless sensor networks. *Sensors Journal, IEEE*, 11(3):699–710, 2011.