Thesis for the B.Sc. Degree in Computer Science and Engineering (CSE)

Energy Efficient Clustering in Wireless Sensor Network

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CERTIFICATE OF RESEARCH

This is to certify that the work presented in this paper is the outcome of the research carried out by the candidates under the supervision of Md. Sakhawat Hossen, Assistant Professor, Department of CSE, IUT, Gazipur and Kashif Nizam Khan, Lecturer, Department of CSE, IUT, Gazipur. It is also declared that neither of this thesis nor any part thereof has been submitted anywhere else for the award of any degree or for any publication.

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Abstract

Wireless sensor nodes are small sensing devices responsible for sensing some physical or environmental conditions, collect data based on this sensing and then send this data to a remotely located server. A common drawback of sensor nodes is the limited battery life. We need to make sure that this limited energy is utilized properly for the efficiency of the network. One popular concept of wireless sensor networking is called “clustering”, which is to break the entire network into small cells known as “clusters”. Each cluster contains a “cluster-head” node and member nodes, where the cluster-head node contains more energy than the member nodes. These cluster-heads get data from all the member nodes and aggregates them and then send to the cluster-head of another cluster; which eventually sends this data to the remote server. There has to be a way to ensure the efficient utilization of this limited energy of the cluster-heads available so that the network doesn’t get down.

In this work, we have attempted to develop and analyze an energy efficient clustering protocol. This protocol seeks to provide efficiency to the wireless sensor network in terms of energy consumption, in a way such that it reduces message transmission from one node to another significantly. This reduces the amount of energy consumed by the cluster-head. Thus it helps the wireless sensor network more energy efficient.

We have done the simulation of our proposed scheme using network simulator ns-2 v.2.34. The results demonstrate that our proposed technique achieves better output compared to BCDCP, LEACH-C and PEGASIS protocols.

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CHAPTER-1

INTRODUCTION

1.1: Introduction:

The rapid technological advances in low-power hardware design have enabled the development of tiny battery-powered sensor nodes which are able to compute, sense physical parameters and communicate with each other. A wireless sensor network (WSN) is a network of large numbers of sensors nodes, where each node is equipped with limited on-board processing, storage and radio capabilities. Sensor nodes are quasi-stationary, densely deployed and with limited capabilities. Nodes sense and send their signals towards a data center which is called the ``information sink''. The design of protocols and applications for such networks has to be energy aware in order to prolong the lifetime of the network because it is quite difficult to recharge node batteries. Additionally, it has to take into account the multi-hop communication nature. Communication in a WSN between any two nodes that are out of one another's transmission range is achieved through intermediate nodes, which relay messages to set up a communication channel between the two nodes.

The WSNs are deployed in a target area in order to facilitate many applications like habitat monitoring, disaster relief, target tracking and so on. Many of these applications require simply an aggregate value to be reported to the ``information sink'' (observer, base station, etc.). In these cases, sensors in different regions of the field can collaborate to aggregate the information that they gathered. For instance, in habitat monitoring applications the sink may require the average of temperature; in military applications the existence or not of high levels of radiation may be the target information that is being sought. Grouping nodes into clusters has been widely pursued by the research community in order to achieve the network scalability objective. Clustering not only allows aggregation, but also limits data transmission primarily within the cluster, thereby reducing both the traffic and the contention for the channel.

Wireless sensor networks consist of hundreds to thousands of low-power multifunctioning sensor nodes, operating in an unattended environment, with limited computational and sensing capabilities. Recent developments in low-power wireless integrated microsensor technologies have made these sensor nodes available in large numbers, at a low cost, to be employed in a wide range of applications in military and national security, environmental monitoring, and many other fields [1]. In contrast to traditional networks, sensor networks offer a flexible proposition in terms of the ease of deployment and multiple functionalities. In classical networks, the placement of the nodes and the network topology need to be predetermined and carefully engineered. However, in case of modern wireless sensor networks, their compact physical dimensions permit a large number of sensor nodes to be randomly deployed in inaccessible terrains. In addition, the nodes in a wireless sensor network are also capable of performing other functions such as data processing and routing, whereas in traditional sensor networks special nodes with computational capabilities have to be installed separately to achieve such functionalities. In order to take advantage of these features of wireless sensor nodes, we need to account for certain constraints associated with them. In particular, minimizing energy consumption is a key requirement in the design of sensor network protocols and algorithms. Since the sensor nodes are equipped with small, often irreplaceable, batteries with limited power capacity, it is essential that the network be energy efficient in order to maximize the life span of the network [1, 2]. In addition to this, wireless sensor network design also demands other requirements such as fault tolerance, scalability, production costs, and reliability. It is therefore critical that the designer takes these factors into account when designing protocols and algorithms for wireless sensor networks [1].

Since a large number of low-power nodes have to be networked together, conventional techniques such as direct transmissions from any specified node to a distant base station have to be avoided. In the direct transmission protocol, the base station serves as the destination node to all the other nodes in the network where the end user can access the sensed data. When a sensor node transmits data directly to the base station, the energy loss incurred can be quite extensive depending on the location of the sensor nodes relative to the base station. In such a scenario, the nodes that are farther away from the base station will have their power sources drained much faster than those nodes that are closer to the base station [3]. On the other hand, utilizing a conventional multihop routing scheme such as the Minimum Transmission Energy (MTE) routing protocol will also result in an equally undesirable effect. In MTE, the nodes closest to the base station will rapidly drain their energy resources since these nodes engage in the routing of a large number of messages (on behalf of other nodes) to the base station [2, 3].

In order to design effective and better protocols for wireless microsensor networks, it is important to understand the parameters that are relevant to the sensor applications. While there are many ways in which the properties of a sensor network protocol can be evaluated, we use the following metrics.

A. Ease of Deployment:

Sensor networks may contain hundreds or thousands of nodes, and they may need to be deployed in remote or dangerous environments, allowing users to extract information in ways that would not have been possible otherwise. This requires that nodes be able to communicate with each other even in the absence of an established network infrastructure and predefined node locations.

B. System Lifetime:

These networks should be functional for the longest period possible. It may be inconvenient or impossible to recharge node batteries. Therefore, all aspects of the wireless sensor network, from the hardware to the protocols, must be designed to be extremely energy efficient.

C. Latency:

Data from sensor networks are typically time sensitive, so it is important to retrieve the data in a timely fashion.

D. Quality:

The notion of "quality" in a microsensor network is very different than in traditional wireless data networks. For sensor networks, the end user does not require all the data in the network because 1) the data from neighboring nodes are highly co-related; making the data redundant and 2) the end user cares about a higher-level description of events occurring in the environment being monitored. The quality of the network is, therefore, based on the quality of the aggregate data set, so protocols should be designed to optimize for the unique, application-specific quality of a sensor network.

In this work, we tried to improve the quality of a wireless network based on these four metrics. We generated a cluster tree from a cluster which is constructed from a dense network where message flooding is reduced to a large extent. Here, we propose that in a cluster tree, only those nodes with maximum distance in the cluster will be given the responsibility of becoming the next cluster head and broadcasting the data to the following nodes which are under its range, i.e. the cluster it generated within its range. In this way, we save energy consumption because we are restricting the data forwarding capabilities of the nodes; only nodes which are placed at the maximum distance will send the data to other nodes. Thus, energy efficiency is ensured because with this method the number of cluster construction is decreased, and we know that the less the quantity of cluster, the less the energy consumption.

Finally, we present a thorough set of graphical analysis performed through ns-2 simulation to judge the performance of our proposed scheme for WSN in a real setting.

The following sections are organized as follows: in Chapter 2 we discussed the related works .We defined our network model and assumptions in Chapter 3. In Chapter 4, we discussed the problems of existing WSN protocols we worked with. Chapter 5 explains our proposed scheme. Performance evaluation of the proposed scheme is presented in Chapter 6 and we conclude in Chapter 7, summarizing our work and relishing the opportunities of possible future works in Clustered Wireless Sensor Network. Followed by Chapter 7 are the references.

CHAPTER-2

RELATED WORKS

Related Works:

Wireless sensor networks have become an attractive research area nowadays. Significant research has been done to investigate how the efficiency of wireless sensor network can be increased. To be more specific, these researches were concentrated on achieving efficiency in terms of energy consumption. The researches that were more related to our work are hereby described in short:

2.1: Constructing a 6LoWPAN Based on a Cluster Tree [IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY MARCH Wireless Sensor Network 2012]:

This paper compares the performance parameters of Least Cluster Change algorithm with Lowest-ID, Root-based Lowest-ID cluster constructing mechanism, and a part of the proposed scheme, including the cluster-tree topology stability, the routing memory cost, and the routing update cost.

The first task of this paper is cluster generation. If a sensor node's ID is x, then it is abbreviated as sensor node x. After isolated node x receives a beacon frame that was sent by its neighbor node n, it checks if there is an entry for node n in its neighbor table. If not, node x adds to its neighbor node table an entry for n. If x does not receive the beacon frame from node n within a specified time, it deletes the entry for node n from its neighbor node table.

If there is at least one cluster head in isolated node x's neighbor node table, then node x selects the neighbor cluster head with the smallest ID and requests to join the cluster identified by the cluster head. If there is not a single isolated node or cluster head in node x's neighbor table, then node x remains the isolated node.

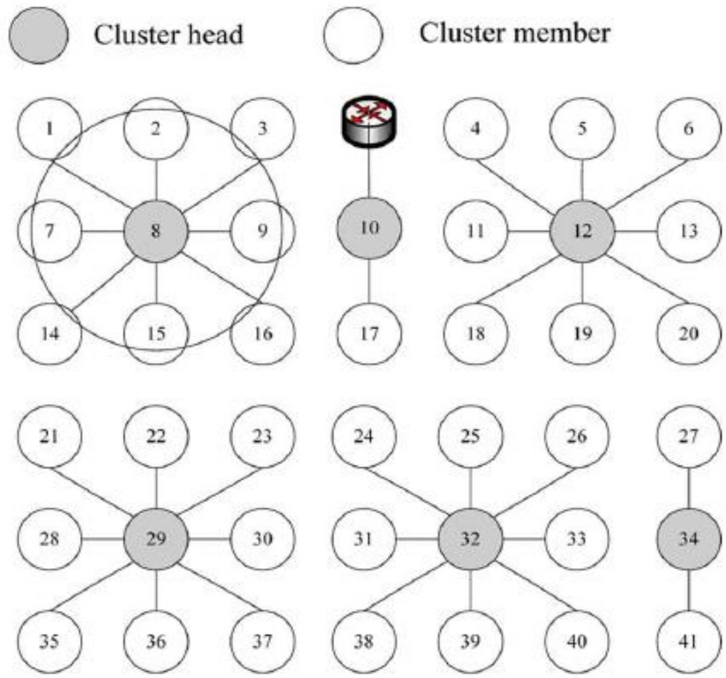

Fig. 2.1.1: Cluster Tree Construction (Taken from Constructing a 6LoWPAN Based on a Cluster Tree [IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY MARCH Wireless Sensor Network 2012])

The second task is to construct a “cluster tree” from the generated cluster. If a cluster member or a cluster associate node receives a beacon frame from its neighbor cluster head or cluster associate node, then it forwards to its cluster head the beacon frame with the maximum number of neighbor cluster heads and cluster associate node.

The cluster-tree construction is demonstrated in the following figure:

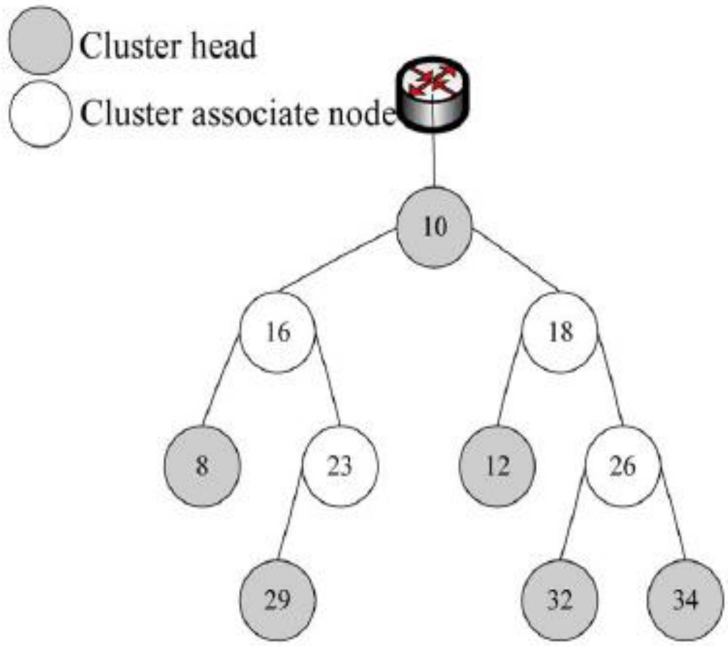

Fig. 2.1.2: Cluster Tree Construction (Taken from Constructing a 6LoWPAN Based on a Cluster Tree [IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY MARCH Wireless Sensor Network 2012])

Afterwards, a cluster repair algorithm is generated that will be used if any cluster head expires. The main problem of this paper is message flooding. A node hast to send a lot of message and then it has to get reply from every neighbor to be the cluster head. This results in a lot of energy consumption.

2.2: A Scalable Approach for reliable Downstream Data Delivery in Wireless Sensor Networks [ACM Mobihoc 2004]:

In this paper, a core construction method is introduced. Here, the sink sends the first packet; it stamps the packet with a band id. When a sensor node receives the first packet, it increments its band id by one. In this way the band id which is a multiple of 3, will be of the form “3i”. Here , *i* is an integer and *i= 1,2,3,…..n.* Then it will form a cluster.

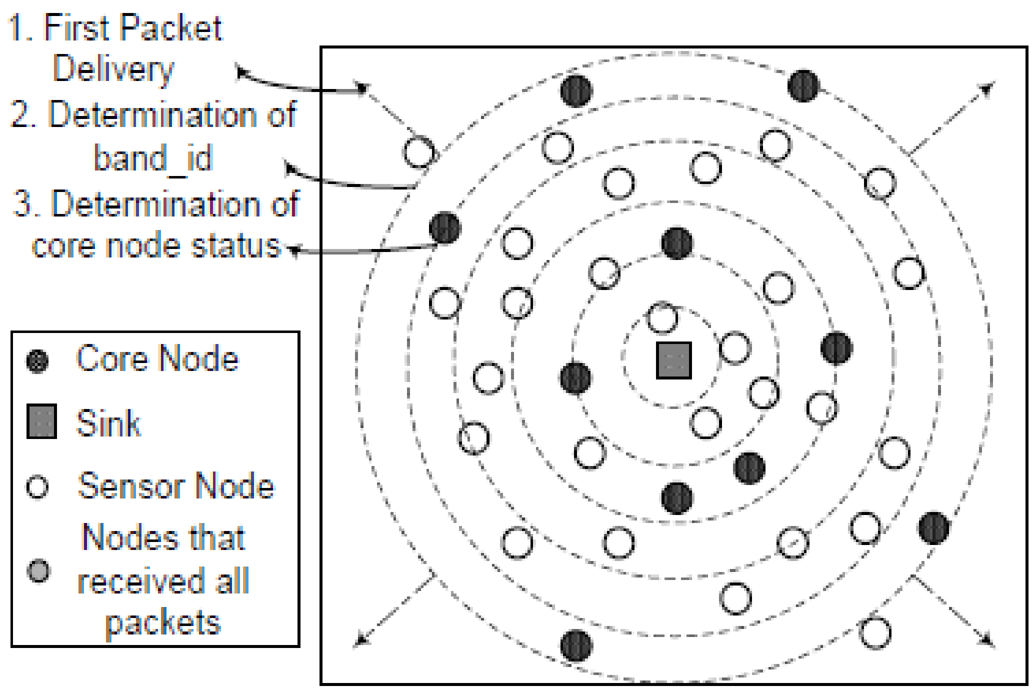

Fig. 2.2: Cluster construction [Taken from A Scalable Approach for reliable Downstream Data Delivery in Wireless Sensor Networks [ACM Mobihoc 2004]

According to these schemes there lies the same situation or problem that we have seen in the first paper. The quantity of request and reply messages is too much. The cluster head has to get messages from all the neighbors. So, there is a big problem of message over flooding.

2.3: An Application-Specific Protocol Architecture for Wireless Microsensor Networks [IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 1, NO. 4, OCTOBER 2002]:

LEACH-C utilizes the base station for cluster formation. During the setup phase of LEACH-C, the base station receives information regarding the location and energy level of each node in the network. Using this information, the base station finds a predetermined number of cluster heads and configures the network into clusters. The cluster groupings are chosen to minimize the energy required for non-cluster-head nodes to transmit their data to their respective cluster heads.

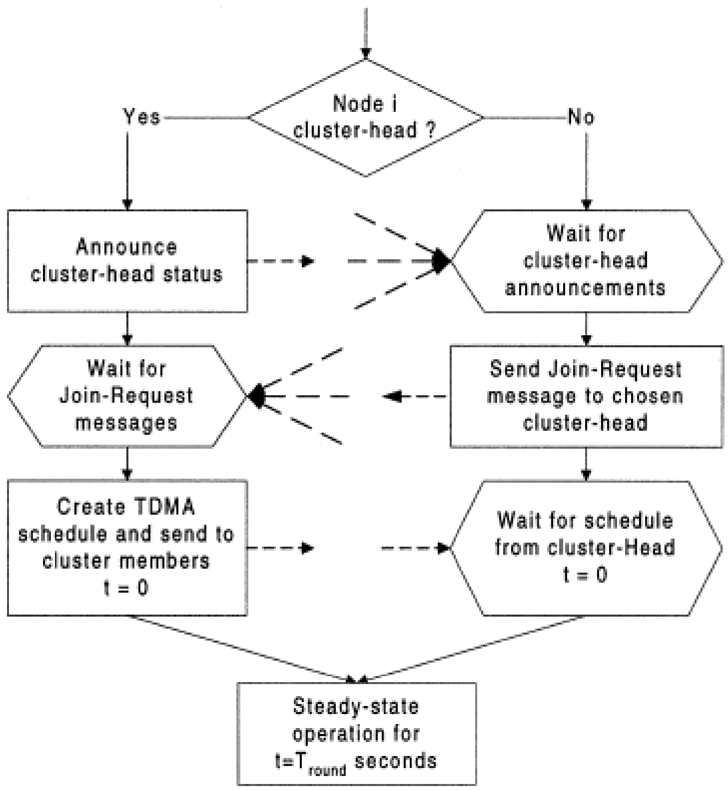

Fig. 2.3: Workflow of LEACH-C

[Taken from An Application Specific Protocol Architecture for Wireless Microsensor Network- W. B Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, IEEE Transactions on Wireless Communications, OCT.2002]

2.4: Power Efficient Gathering in Sensor Information Systems (PEGASIS) [Aerospace Conference Proceedings, 2002. IEEE]:

In PEGASIS, nodes are organized into a chain using a greedy algorithm so that each node transmits to and receives from only one of its neighbors. In each round, a randomly chosen node from the chain will transmit the aggregated data to the base station, thus reducing the per round energy expenditure compared to LEACH.

2.5: A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks [IEEE Radio Communications March 2005]:

This paper proposes a centralized routing protocol called Base-Station Controlled Dynamic Clustering Protocol (BCDCP), which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings.

During each setup phase, the base station receives information on the current energy status from all the nodes in the network. Based on this feedback, the base station first computes the average energy level of all the nodes, and then chooses a set of nodes.

The BCDCP protocol uses a CH to- CH multihop routing scheme to transfer the sensed data to the base station. Once the clusters and the cluster head nodes have been identified, the base station chooses the lowest-energy routing path and forwards this info to the sensor nodes along with the details on cluster groupings and selected cluster heads.

2.6: Energy-efficient distributed clustering in wireless sensor network [Journal of Parallel and Distributed Computing April 2010]:

Here, the authors propose an energy-efficient distributed clustering protocol for wireless sensor networks, called GESC from the initials of the words GEodesic Sensor Clustering that considers energy consumption and topological features of the nodes. The proposed method exploits the localized network structure and the remaining energy of neighboring nodes in order to define a new way for estimating dynamically the cluster heads. GESC is compared with LEACH [19], which is a well-known, established clustering proto- col for wireless sensor networks, and with the most efficient algorithms reported for mobile ad hoc networks.

The GESC protocol complies with all requirements:

- It is localized, and thus distributed; it can exploit one-hop, two-hop or k-hop neighborhood information, presenting different tradeoffs in efficiency vs. communication cost, but for the sake of readability we present it here assuming knowledge of the two-hop neighborhood of a sensor node.
- Network lifetime is prolonged by distributed energy consumption. The cluster heads are estimated dynamically depending on the originator node, which wishes to transmit a message; thus the cluster heads are not static, avoiding fast depletion of their energy.
- It describes a new way for capturing a node's significance/ presence w.r.t. the fact that the node resides in network paths that will definitely be traversed by the majority of the transmitted messages.

- It computes a node's significance in time linear in the number of nodes and linear in the number of edges of the network neighborhood of the node, irrespectively of the degree of each node .
- It allows for fast network clustering; thus it is appropriate for reclustering operations.

CHAPTER-3

NETWORK MODEL AND ASSUMPTIONS

3.1: Network Model:

Our network model consists of a dense network. Dense network is a network where nodes can be scattered to different positions. According to our proposed scheme, there are three types of nodes. Firstly, there is a sink node which is the source node. It gathers data from the cluster-heads and sends them to the remote server. Then there is a cluster-head node. The cluster-head is the node which has typically more resources and energy than the other nodes. It has the responsibility to send the data to other nodes. Basically, the cluster-head node gets aggregated data from all other nodes and then they forward this aggregated data. Whenever the energy of the cluster-head is dissipated, there is an option to replace the cluster-head with a new one. Finally, the last type of node to be mentioned is the member node. Normally, all the nodes other than the sink and the cluster-head are called the member nodes. Here, we assume the network to be the same as [1] and [2] have.

3.2: Assumptions:

We assume that –

- ✓ A node cannot transmit and receive packets simultaneously.
- ✓ The cluster head will only send data to the other nodes.
- ✓ This network will be a dense network.
- ✓ Only the furthest node will be declared as the cluster head.

A node is restrained from the privilege of simultaneous data transmission and reception. The node will first send a message to all other nodes. Upon receiving the messages, the nodes will send to it an acknowledgement that they have received the message. If this is done in case of all nodes in the network, it will lead to message flooding, which is described in details in the "Problem Scenario of Message Flooding" section in Chapter-4.

In order to prevent such hazards, we can restrict the message sending responsibility to the cluster-head node only. Only the cluster-head node, instead of the member-nodes, will transmit the message and receive ACKs. This way, we can reduce the number of messages in the network to some extent, but still it is not enough to prevent message flooding.

One possible solution to this problem can be the selection of cluster-head. Only nodes which are situated furthest from a cluster-head node currently being dealt with can be selected as cluster-head node. Thus, nodes within the range of a cluster-head with minimum distance can be ticked-off from being selected as a cluster-head node, let alone transmitting messages.

CHAPTER-4

PROBLEM DESCRIPTION

Problem Description:

In this section, we discuss the problem issues we worked with, i.e. energy consumption and message flooding. We also discussed here the problem with sender initiated schemes.

4.1: Energy consumption:

In our proposed scheme, we aim to make the wireless sensor network energy efficient. The main problem with the related papers is that their proposed protocols can be achievable at the cost of a lot amount of energy consumption. We have tried to restrict this unwanted energy consumption. In the related papers, when a node gets data, it creates a cluster within its range and sends the data. Thus, a huge number of clusters are existent within the sensor network. From our observation and analysis of the previous works, we have come to know that energy consumption is directly related to the number of clusters present in the wireless sensor network. That's why; our goal is to create a wireless sensor network with minimum number of clusters to ensure minimal consumption of energy.

4.1.1 Problem Scenario of energy consumption:

For simplicity of description, we discuss the problem with a simple figure shown in Fig. 4.1.2

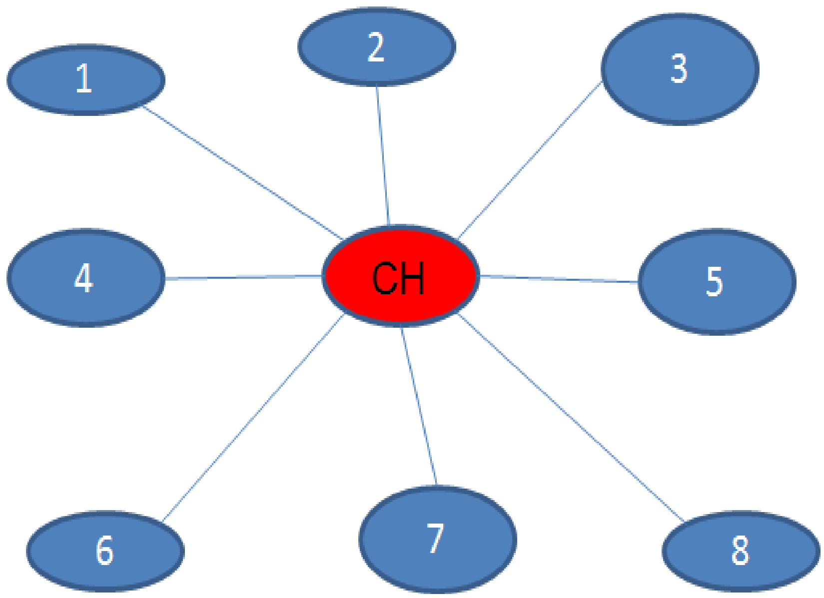

Fig. 4.1.1: Simple mesh network scenario

Suppose, the source node is node 1, now node 1 has a data to send to the destination node 6. So, node 1 constructs a cluster. In node 1's cluster there are two nodes node 2 and node 3. The closest node is node 2. So, node 2 gets the data first. When it gets the data it again constructs a cluster and also sends the data to all the nodes within its cluster. A member of node 1's cluster, node 3 also constructs a cluster and sends it to the nodes when it gets the data. So, we can see there are extraneous clusters which are unnecessary. Node 2 does not have to construct a cluster and send data because when node 3 sends the data it can cover all the nodes which are within node 2's range. So, energy consumption is increased because energy consumption is

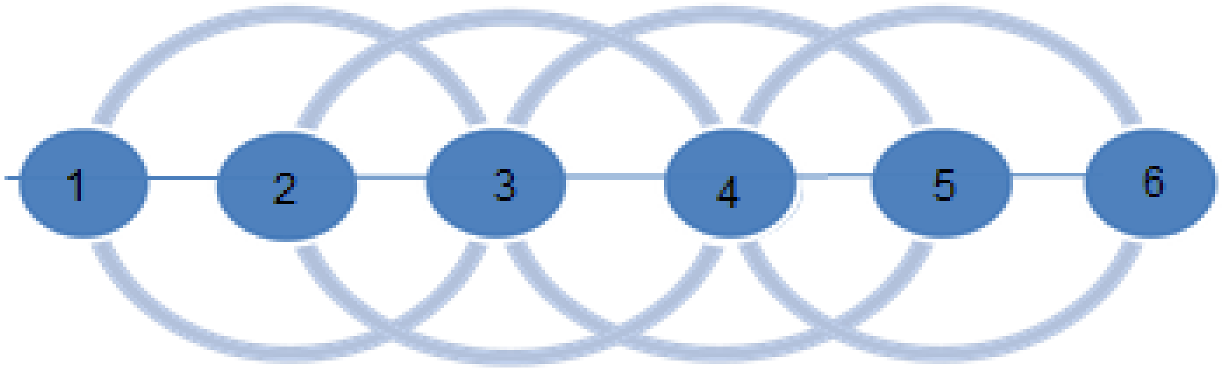

Fig. 4.1.2: Hidden node problem

directly related to the number of existing clusters.

4.2: Message flooding:

Message flooding in a network occurs when all the nodes send messages to each other and then receive an ACK message or acknowledgement, showing that they have received the message successfully. Form our previous works, we have found that a cluster-head node is supposed to send messages to all the other nodes in its cluster, and then receive ACKs from them. This leads to message flooding phenomena. In our proposed work, we have tried to prevent this by restricting the message transmission to the furthest node in a cluster head's range only.

4.2.1 Problem Scenario of message flooding:

Suppose, node 1 is a node which wants to be a cluster head. So, at first it will send its status to all the nodes which are its neighbor. The neighbor nodes also send their status to the node 1. Then if he gets message from all the nodes it checks their status. If its status is better than the other nodes then it makes itself the cluster head. Then it sends its cluster head news to all the nodes. All the neighbors then send a reply that they acknowledge its being cluster head. In this way, to select a cluster head a lot of message transmission occur and results in high expense of energy.

4.3: Message flooding when a cluster head expires:

When a cluster head expires, the network has to choose another cluster head to maintain the role of the cluster head. The networks described in all the paper do that in an expensive fashion. When a cluster-head node fails, all the nodes send messages to each other to know their neighbors. Then they send data about their current status. Observing everybody's status, if a node finds itself to be a node of highest status among all other nodes, it selects itself as a cluster head and sends data to others. Then all other nodes send acknowledgment to it. So, we can see there is a lot of message transmission and ACK messages which makes it a less energy efficient network.

CHAPTER-5

PROPOSED TECHNIQUE

“Energy Efficient Clustering”

5.1: Overview:

In this work, we tried to improve the quality of a wireless network. We made a cluster tree from a cluster which is constructed from a dense network where message flooding is reduced to a large extent. Here, we propose that in a cluster tree only node with maximum distance in the cluster will be given the responsibility of becoming the next cluster head and broadcasting the data to the next nodes which are under its range. In this way, we save energy consumption because the nodes which are placed at the maximum distance will send the data to other nodes exclusively. Hence, we are trying to induce energy efficiency within the sensor network because with this method the number of cluster construction is decreased, and we know that the less the quantity of cluster the less the energy consumption.

First of all we must assign a condition. This condition will let us decide which node will get the data from the transmitter node first and how the node will get data in quickest of time covering the entire network. The node that is the furthest from the sending node should send data after the first node sends it the data. This way, the nodes are prioritized based on their distance. The more their distance from the sending node, more priority they get in sending data. Thus the data traverse the entire network quickly and create less message overheads. Hence, message flooding is prevented. The equation to determine distance is:

Where,

RSSI=Received Signal Strength Index

And **d**=Distance from the sending node

So the node which has the least RSSI is the furthest node from its sender node. Another related equation is:

Actually, the larger the distance from the sending node, the quicker the message sent from the sending node traverses the entire network. The time a message traverses the channel/network is called the Channel Access Time and thus it is inversely proportional to *d*, hence directly proportional to RSSI.

Another solution that we have proposed is a Cluster Refreshment Algorithm. The entire network is refreshed upon Cluster refreshment. Prior to cluster refreshment, the old cluster head of the 3i band maintains a certain neighbor list. This neighbor list is preserved after the cluster refreshment is done. Cluster refreshment means to generate a whole new cluster with a new cluster head arbitrarily selected form the 3i band. Since the neighbor list is maintained, the new cluster head need not to send packet to member nodes and get their acknowledgements again. Hence, message flooding that has been a problem in [6] is resolved.

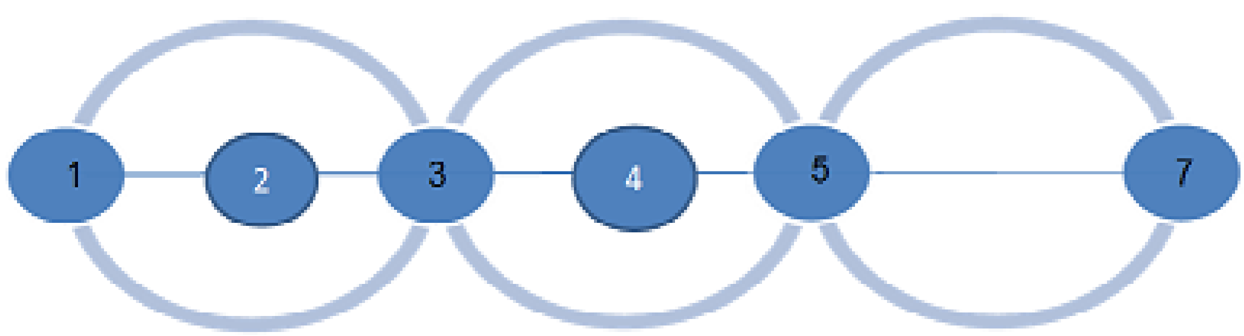

Fig. 5.1: Resolving the hidden node problem

5.2: The main protocol:

- When a node or the source has a data to send it makes a cluster within its range.
- Then the node sends the data to all the nodes within its range or within the cluster.
- When all the nodes get the data then all the nodes do not start sending data to its neighbor nodes.
- When all the nodes get the data they all check their RSSI (Received Signal Strength Index).
- The node which has the least RSSI is situated farthest from the sending node.
- Then the node which has the least RSSI forms a cluster within its range.
- Then the selected node sends data to all the nodes within its range.
- In this way, data is transmitted to the destination.

5.3: Cluster Refreshment Algorithm:

The entire network is refreshed upon Cluster refreshment. Prior to cluster refreshment, the old cluster head of the 3i band maintains a certain neighbor list. This neighbor list is preserved after the cluster refreshment is done. Cluster refreshment means to generate a whole new cluster with a new cluster head arbitrarily selected form the 3i band. Since the neighbor list is maintained, the new cluster head need not to send packet to member nodes and get their acknowledgements again. When the cluster head gets the information about its farthest node, they also copy the information of the other nodes which resides very far from it. In this way, when a farthest node expires or its power is off then the cluster head checks its information table and makes the second farthest node as the next cluster head. In this way, we can save a lot of energy because in other works we have seen that when a cluster head dies, every node sends data to other nodes to make an election about which will be the next cluster head. Then after getting acknowledgment from everyone a specific node makes itself the cluster head. With the help of this process, we don't have to send any message to any other node. The cluster head will send message to the next cluster head. This will reduce message flooding to a great extent.

CHAPTER-6

SIMULATION and PERFORMANCE EVALUATIONS

6.1: Simulation Setup:

In this section we study the performance of the proposed mechanism through simulation. Here we conducted our simulation using the unmodified IEEE 802.11 MAC implementation in Network Simulator.

- ✓ NS : V.2.35
- ✓ Traffic Type : TCP
- ✓ Packet Size : 800 Bytes
- ✓ Transmission Range : 300m
- ✓ Experiment Runtime: 1300s
- ✓ RTS-CTS : Enabled

The machine where the simulation work was carried out was a Dell notebook computer of model Inspiron N5010 with Intel Core i3 processor, 3 GB DDR3 RAM, 250 GB internal harddisk and 512 GB built-in PCI card.

Performance metrics:

The performance metrics that we have considered during our simulation work are:

1. Number of nodes
2. Energy Dissipation
3. Number of messages forwarded

4. Number of connected nodes

5. Number of clusters

6. Simulation Time

7. Number of alive nodes

6.2: Simulation Result and Comparison:

We compared our simulation results between EEC (Energy-Efficient Clustering), LEACH-C, PEGASIS and BCDCP that is shown below:

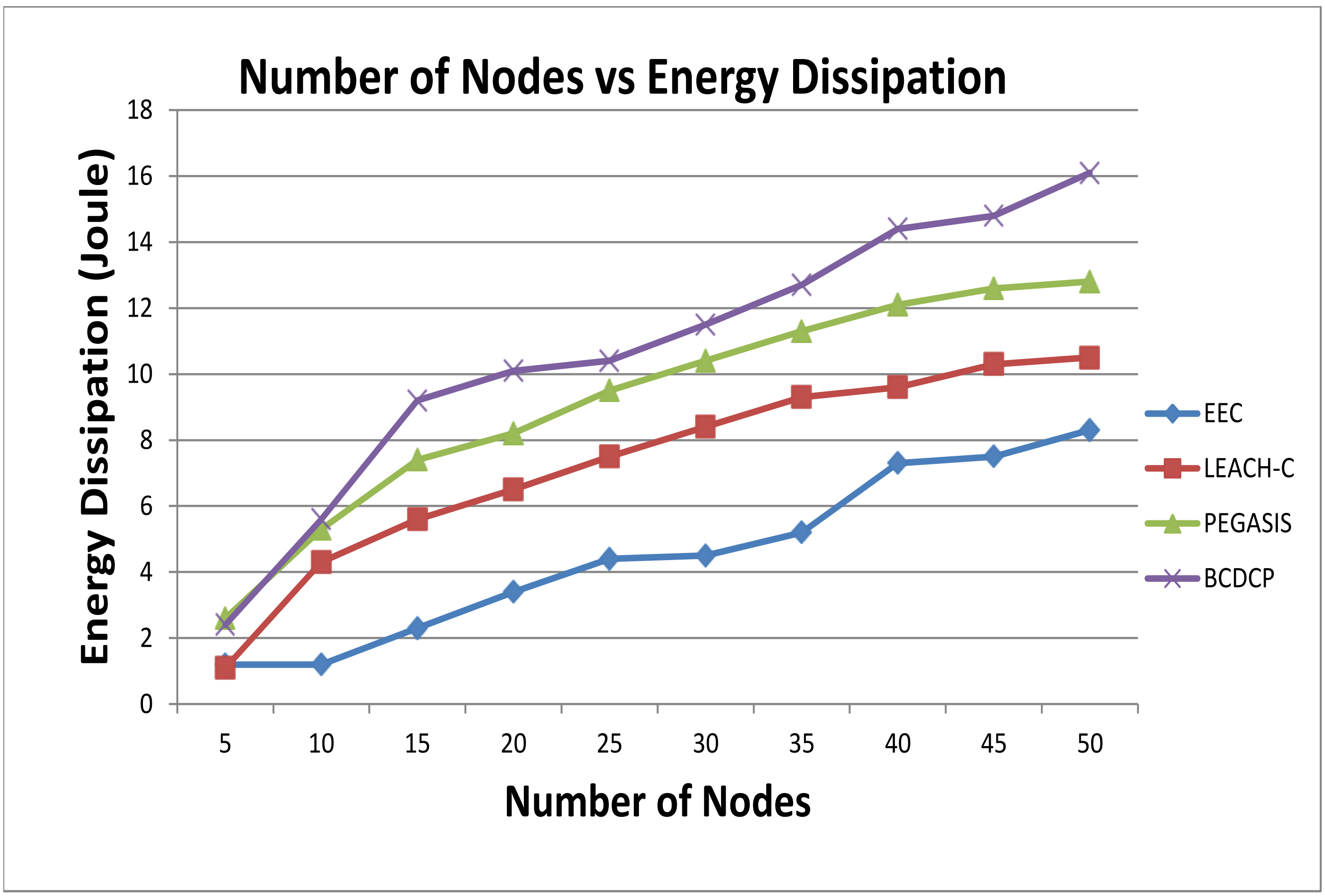

Fig. 6.2.1: Number of nodes vs Energy Dissipation

From the above curve, we can compare the performance of our proposed scheme with the BCDCP, LEACH-C, and PEGASIS protocols. It is obvious from the curve that BCDCP has the highest amount of energy dissipation which has peaked up to 16 Joules when we have used maximum 50 nodes. So definitely BCDCP gives the lowest performance in reduction of energy consumption. Similarly, PEGASIS and LEACH-C also has high amount of energy dissipation and hence, they are not efficient. Since our proposed scheme gives the best performance here compared to other protocols; because the maximum energy dissipation was only about 8 Joules for deployment of 50 nodes. Therefore, our proposed scheme is the most efficient solution for reducing energy consumption.

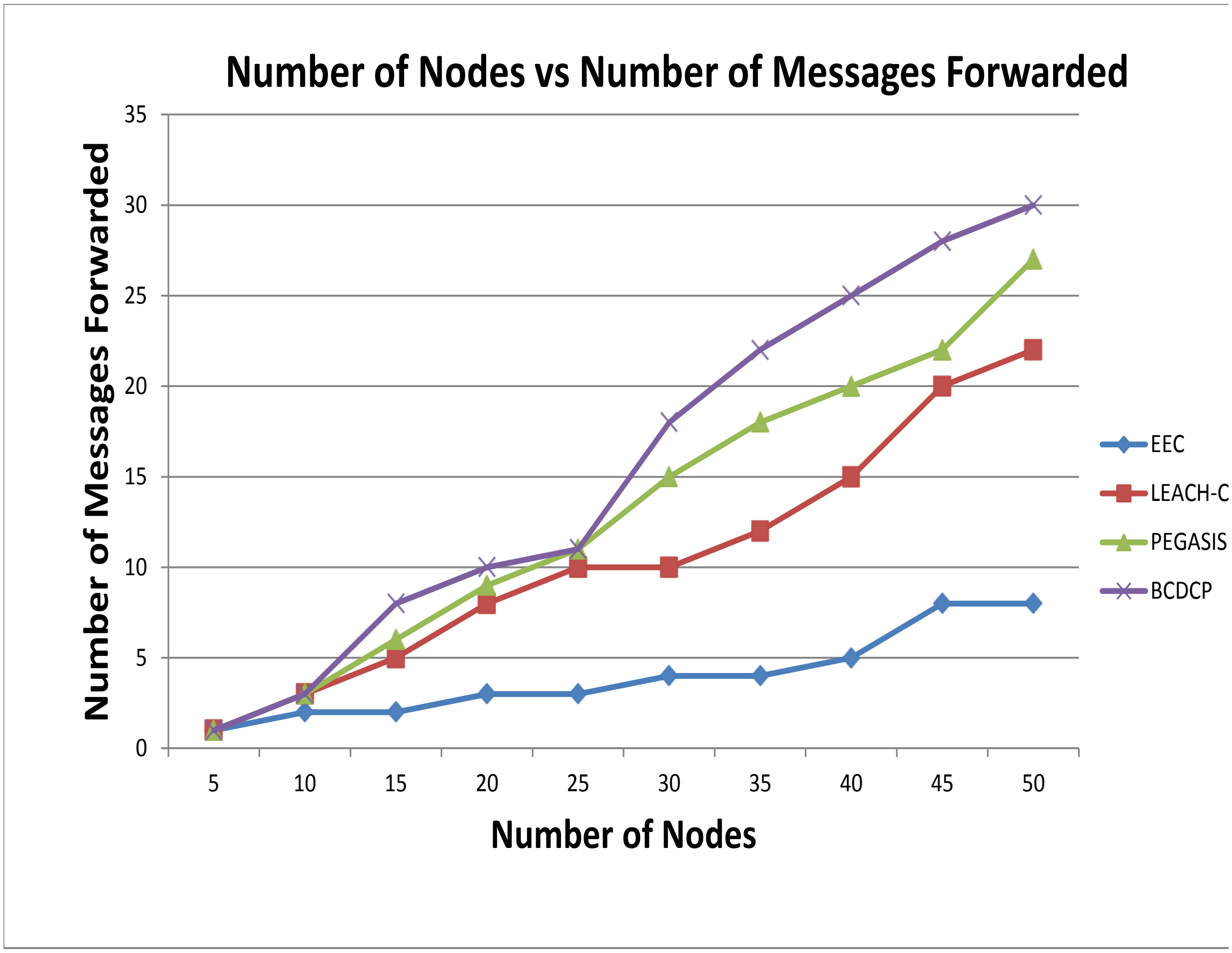

Fig. 6.2.2: Number of nodes vs Number of Messages forwarded

In the above curve, we compare our proposed scheme with the other protocols in perspective of the number of messages forwarded by each node. The BCDCP protocol shows poor performance as the number of messages forwarded per node is very high. The PEGASIS and LEACH-C protocol also have a high rate of messages forwarded. Only our proposed scheme gives the best performance compared to these four, the forwarded message per node is almost constant; hovering around 3-4 messages per node. The maximum number of messages forwarded for the deployment of 50 nodes is about 8, while it is about 30 in case of BCDCP. Thus, our proposed scheme is better than other protocols.

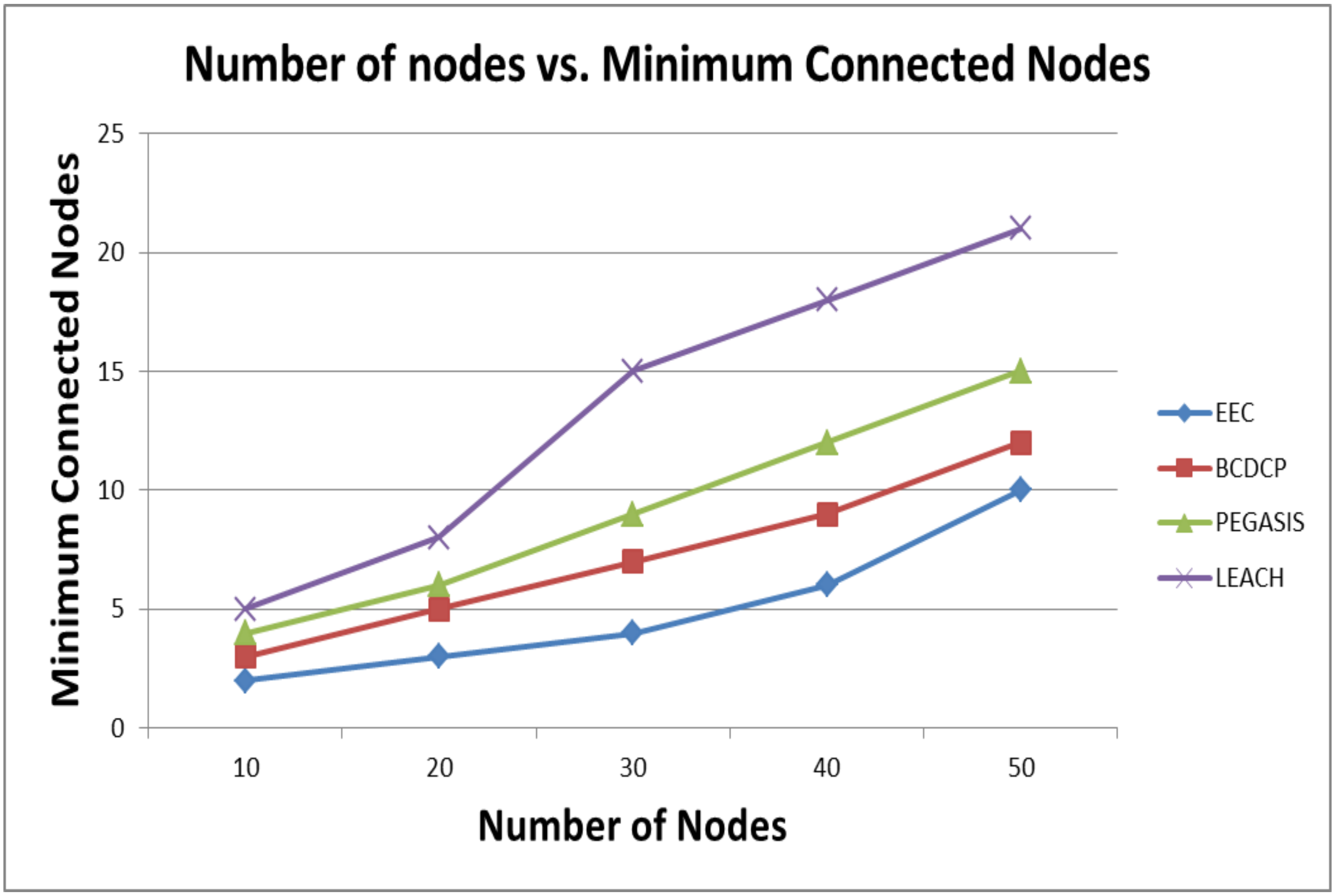

Fig. 6.2.3: Number of Nodes vs Minimum Connected nodes

The nodes in a clustered WSN that has some extra features, higher resources and extra responsibility in ensuring the connectivity of a network are known as connected nodes. From the above graph, we can see that the maximum number of connected nodes exist for the LEACH-C protocol, next for PEGASIS and BCDCP accordingly. Only our proposed scheme display minimum number of connected nodes for 50 nodes. Thus it confirms that the performance of our proposed scheme is better, reducing the amount of minimal connected nodes to preserve energy.

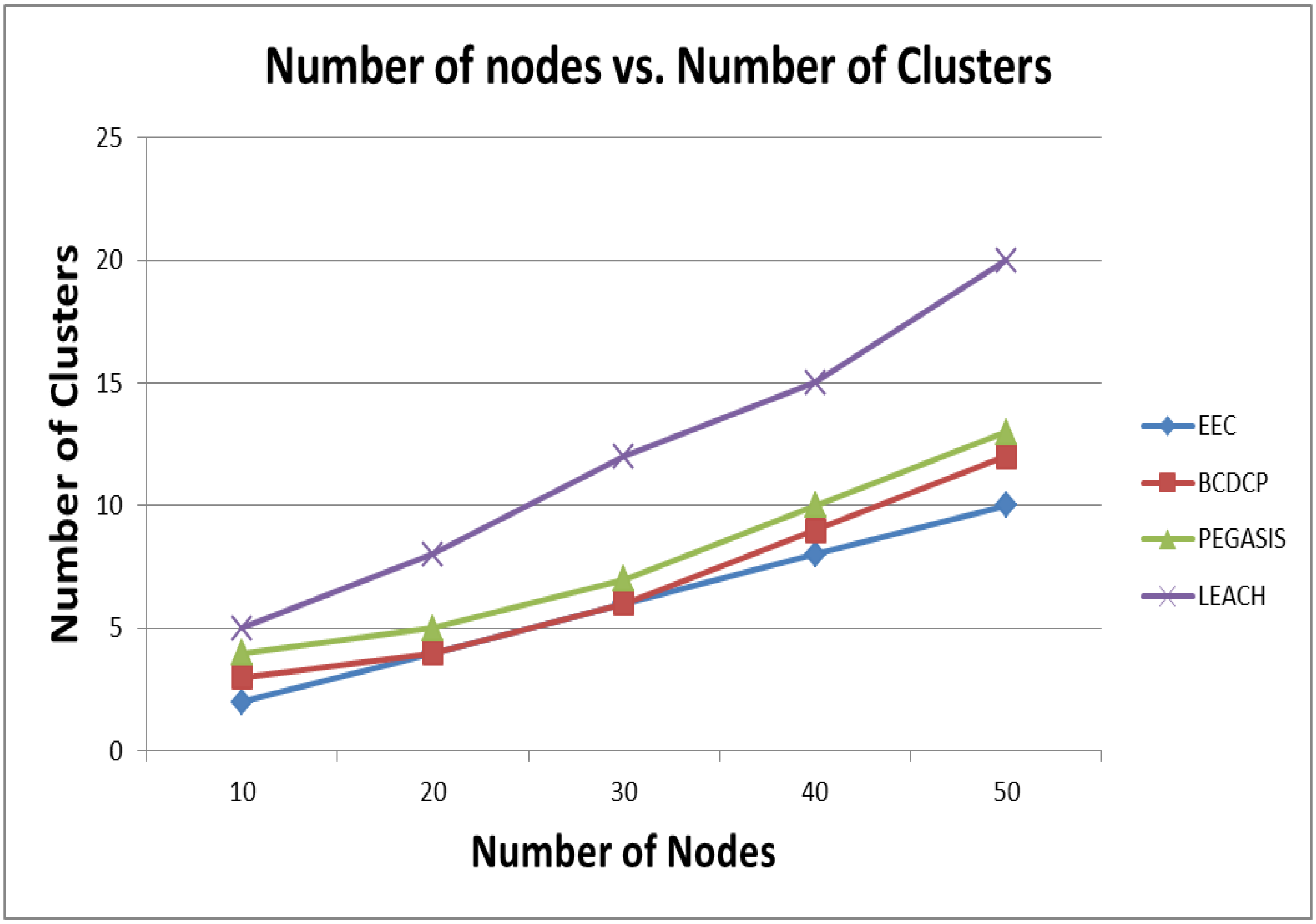

Fig. 6.2.4: Number of Nodes vs Number of clusters

From the above graph, we can see the BCDCP protocol has significantly high number of clusters generated for the deployment of 50 nodes. The graph is very close and sometimes overlapping with the proposed scheme, still our proposed scheme comes out with the fewest possible clusters for 50 nodes. The less the cluster quantity, the less is energy consumption. Thus, by creating fewest possible clusters, our proposed scheme achieves better result.

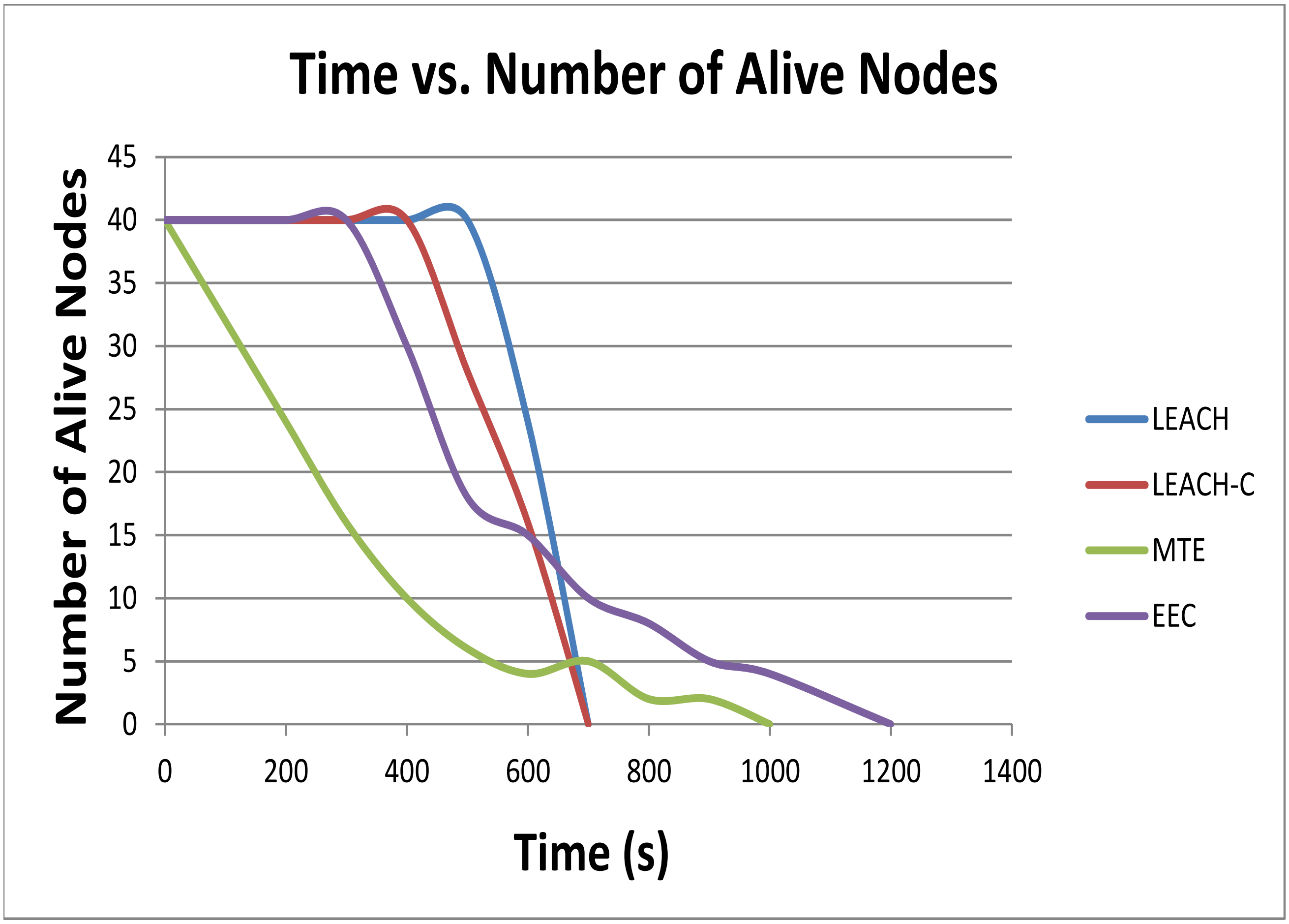

Fig. 6.2.5: Time vs Number of Alive Nodes

The last graph of our simulation work shows the lifetime of the node. From this, the network and energy consumption of the network can be assessed. From the graph, we can see that at a fixed time period, most of the nodes in the network are alive; and then all on a sudden nodes fail drastically within a very short period of time. In plain sight it may seem that our proposed scheme is not giving good performance compared to BCDCP, LEACH-C and PEGASIS protocols, but that's not the case. Actually, we have tried to show in the graph how long does it take for all nodes in the network to fail; which means how long the network will be alive. This is, in other words, the network lifetime, to be precise. As the network lifetime is increased significantly with our proposed scheme, this is an obvious implication that our proposed scheme is more energy-efficient than the protocols compared throughout the simulation procedure.

CHAPTER-7

CONCLUSION

7.1: Summary:

In our work, we tried to maintain energy-efficiency in a clustered WSN. We have shown that it is energy-inefficient to flood messages in a cluster formation by sending unnecessarily high amount of messages and acknowledgements. We have also shown that data that are transmitted from a band member nearer to the sending node takes a long time to traverse the entire network. That's why we have to propose a cluster refreshment algorithm to prevent message flooding and a distant node selection for message transmission priority. The distant node is determined based on its Received Signal Strength (RSSI) as RSSI is inversely proportional to distance.

7.2: Future Works:

The field of Clustering in Wireless Sensor Network is quite a mature field. Much work has been done in the past decade regarding clustering. The adequate amount of research done on clustering of wireless sensor network suggests that future works can't be something unique. Already various aspects of clustering in wireless sensor network are covered in many papers. Many papers have discussed methodologies to get around the energy-efficiency problem of the wireless sensor network. Thus, scope of future works in this field is very much narrow. However, some fusing of existing ideas can be done in near future and it is very likely that within the end of this decade, further research on clustering of wireless sensor network will come to a halt for a time being.

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