COMPARISON OF DIFFERENT ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

A Team Effort by

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Preface

Wireless sensor networks (WSN) are becoming increasingly popular. WSN's continue to evolve and grow in both practical and research domains. The routing protocols determine the efficiency of the wireless sensor networks. Recent advances in wireless sensor networks have led to many new routing protocols. These routing protocols differ depending on the application and network architecture. This paper analyses three different routing protocols for wireless sensor networks and presents a comparison of the routing protocols and measure their performance.

Acknowledgements

We would like to express our heartfelt gratitude to Dr. Prof Ming-Hwa Wang for his valuable time and guidance and for giving us the opportunity to work together as a team and to think about the problem and how to derive the solution. Also we would like to thank each member of our team for listening and discussing and coming to common best solution for the various tasks/issues we had in this project.

Contents

List of figures

Abstract

Wireless sensor networks (WSNs) consist of small nodes with sensing, computation and communications capabilities. The sensors attached to the nodes measure ambient conditions related to the environment in which they are deployed, process the data and transmit them to the base station. The base station acts like a gateway between the WSN nodes and the end users. The data exchange between the nodes is supported by multihop communications. Routing protocols are in charge of discovering and maintaining the routes in the network. These routing protocols differ depending on the application and network architecture of the WSN.

The efficiency of sensor networks strongly depends on the routing protocol used. In this paper, we analyze three different types of routing protocols: Flooding, Gossip and Multihop Low Energy Adaptive Clustering(Multihop-LEACH). The goal of this paper is to study and evaluate the design, interactions, and performance of the three protocols using NS2. Network simulation is the most useful and common methodology used to evaluate different network topologies without real world implementation. The ns2 simulator is the most popular and widely used simulation environment for networking research. It is a discrete event driven simulator which allows the user to send the packet at the specified start and stop time.

2. Introduction

2.1 Wireless Sensor Networks

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. These sensors perform a collaborative measurement process.

A wireless sensor network is made up of three parts – the sensor nodes to send and receive data, the protocol which is used to communicate the data, and the base station (an external system) to gather or show the data to the end users.

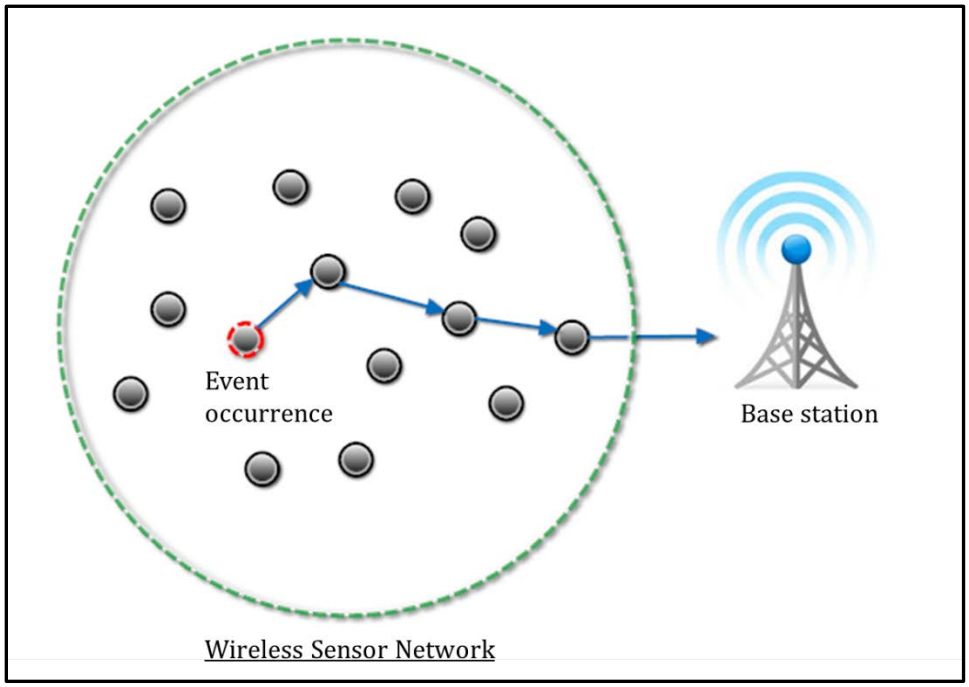


Figure 2.1. An example of Wireless Sensor Network showing transmission of data from the nodes to the base station

The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the sink where the application lies. The data is propagated by the intermediate nodes so that a route with multiple links or hops to the sink is established. Several routing protocols exist which can find the routes from a source node to a specified destination node.

2.2 Flooding Protocol

Flooding is the simplest and the most straight forward approach to routing. In this algorithm, the WSN nodes broadcast the data which are consecutively retransmitted in order to make them arrive at the intended destination. However, its simplicity brings about significant drawbacks. Firstly, an implosion is detected because nodes redundantly receive multiple copies of the same data message. Then, as the event may be detected by several nodes in the affected area, multiple data messages containing similar information are introduced into the network. Moreover, the nodes do not take into account their resources to limit their functionalities.

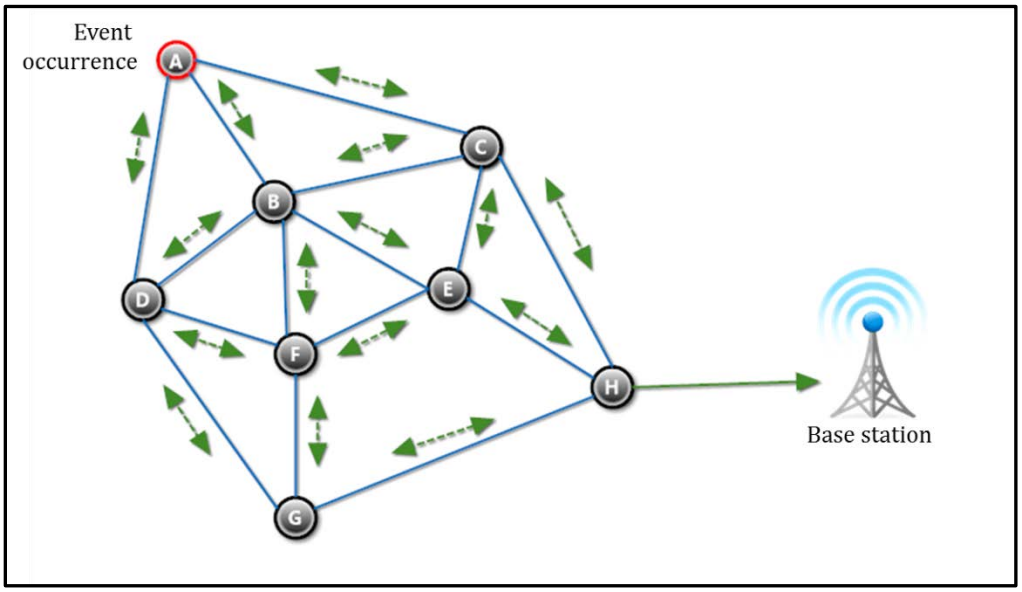


Figure 2.2 An illustration showing the flow of data from the WSN node to the base station using the Flooding protocol

2.3 Gossip Protocol

Gossip (or epidemic) communication protocols are an attractive technique which can manage the inconsistencies that arise in the flooding protocol. In this protocol a node can choose a peer node randomly to exchange information with. Gossiping avoids implosion as the sensor transmits the message to a selected neighbor instead of informing all its neighbors as in the classical flooding algorithm. However, overlap and resource blindness are still present. Furthermore, these inconveniences are highlighted when the number of nodes in the network increases.

2.4 Multihop-LEACH

An energy efficient routing protocol is the major concern in the field of wireless sensor network. LEACH stands for Low-Energy Adaptive Clustering Hierarchy and it was one of the first cluster-based hierarchical protocols. The LEACH protocol outperforms the flooding and gossip protocols by using adaptive clusters and rotating cluster-heads, allowing the energy requirements of the system to be distributed among all the sensors.

Among all sensor nodes one node acts as a cluster head (CH) inside from the local cluster. The main aim of the clusters is to distribute the energy load equally among all sensors in the network which ultimately gives result of a longer life to the node's battery. The major role of CH is to collect data from their respective cluster and aggregate those collected data and finally sent to the base station. In this manner, LEACH enables scalability and robustness for dynamic networks, and incorporates data fusion into the data gathering process to reduce the amount of data to be transmitted.

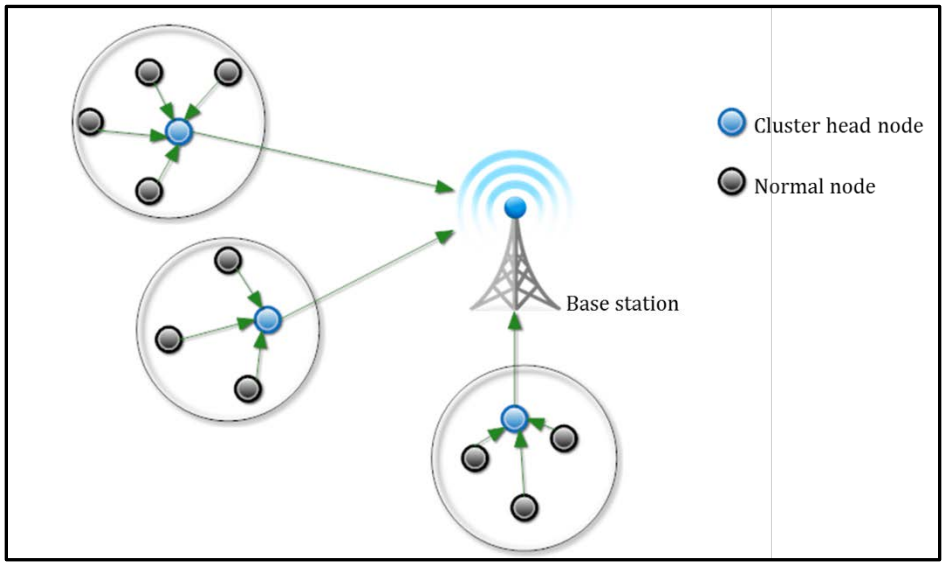


Figure 2.3 Cluster organization in LEACH protocol

2.5 Objective

This paper presents the results of comparing three different routing protocols – Flooding, Gossip and LEACH. Our goal is to study the performance of the routing protocols using different input parameters and comparing the results.

2.6 Problem description

Though different protocols are available to solve the multi-hop routing problem in wireless sensor networks, each of them are based on different assumptions and intuitions. Very little information is known about predicting performance of the three protocols, and no attempt has previously been made to directly compare them in a realistic manner.

2.7 How is this project related to the class?

Wireless sensor network is an emerging technology in the field of Computer Networks. . The routing protocols along with their metrics jointly determine the performance of a wireless sensor network.

2.8 Why our approach is better?

By analyzing the results we can find the efficient routing protocol depending in the given parameters.

2.9 Area and scope of investigation

The wireless sensor network technology covers a wide area ranging from medical to military and from home to industry. The WSN can gather data with unprecedented sensing capabilities and deliver it to a remote user. In order to deliver the results an efficient routing protocol can be used.

3. Theoretical basis and literature review

3.1 Definition of the problem

In order for wireless sensor networks to operate efficiently appropriate routing protocols have to be incorporated. To find the most efficient routes from source to destination we need to consider different parameters. Some of the characteristics of the routing protocols are quick route recovery, efficient power consumption, high connectivity etc. We have chosen three protocols in order to find their characteristics.

3.2 Solution to solve this problem

In this project we compare the three routing protocols – Flooding, Gossip and Multihop LEACH using NS2 simulator. By comparing and measuring the performance we can conclude the efficiency of the three routing protocols.

3.3 How our solution is different from others?

The efficiency of sensor networks strongly depends on the routing protocol used. These routing protocols differ depending on the application and network architecture of the WSN. No other solution has been proposed to directly compare the three routing protocols in a realistic manner.

3.4 Why our solution is better?

In this paper we have chosen three routing protocols which have different characteristics. We have chosen flooding which is the most simplest of all protocol, gossip which is a slight enhancement of flooding and LEACH protocol which aims at preserving the energy of the routes and finding the most energy efficient route.

4. Hypothesis/Goals

4.1 Positive/Negative hypothesis

- Find the most energy efficient routing protocol.
- Find the routing protocol with the more connectivity.
- Find the routing protocol with less delay.

5. Methodology

5.1 Collection of input data

The input data is the collection of node locations, size, sensing range, communication range, location and cost of event and the power capacity. The following are the input data which are generated randomly and used for the three protocols.

```
gridSize = 64; /* Size of a nxn sqaure network*/
noofSources = 1; /* Number of Sources in the network */
noofDestinations = 1; /* Fixed Number of Destinations in the Network*/
noofNodes = 10; /* Number of Intermediate Nodes in the Network*/
powerCapacity = 3000; /* Max power capacity  that each of the node has */
sensingRange = 16; /* Sensing ranges wich is the same for all the nodes in the network*/
communicationRange = 32; /* Also is responsible for the cluster size in the leach protocol*/
chcommunicationRange = 40; /* the communication range of the cluster heads in leach protocol*/
totalpower = 0;
```

5.2 How to solve the problem

The three routing protocols are compared by running the program with different data.

5.3 Algorithm design

Flooding is a simple routing algorithm in which all the incoming packet is sent to every outgoing link except the one it arrived on. In gossip protocol the node chooses a random neighbor from the list of neighbors and passes the message to the neighbor. This process is repeated until we reach the destination node. In LEACH protocol clusters of nodes are formed, a cluster head is chosen based on the highest energy node and the message is passed from the nodes to the cluster head and the cluster head directly communicates with the destination. This protocol is a hierarchy based protocol where the nodes are divided as regular nodes and cluster heads.

5.4 Language used

C and C++

5.5 Tools used

Linux server to run the code.

IDE: Eclipse

5.6 Generating the output

The following outputs are generated for the three different routing protocols:

Path: The path formed from the source to the destination.
Number of hops: The number of hops taken from the source to the destination.
Distance: The metric distance covered from the source to the destination.
Power: The power consumed by the nodes during transmission.

6. Implementation

6.1 Design document and Flowchart

From the main function the input data is generated randomly and the input is passed on to the 3 functions for flooding, gossip and leach. The output is displayed accordingly. The flowchart for the program is as follows:

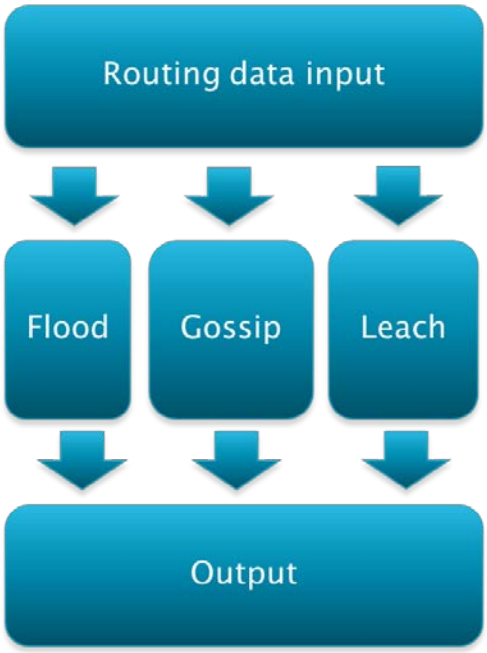


Fig 6.1- Flowchart of the program

7. Data Analysis and discussion

7.1 Output generation and Analysis

We try to compare three of the important parameters in our discussion here ☐

- Number of Hops taken from the Source to the Destination.
- Metric Distance from Source to destination.
- Power Consumption .

Number of Hops :

This parameter gives an estimate of efficient way of connection between the source and destinations. Ideally speaking we prefers a very less no of hops so that they can consume less power. The number of nodes that have a route to the base station will be used to assess the node connectivity provided by a particular routing protocol.

Metric Distance:

This parameter is used to estimate and associate the delay that could be expected as the delay is directly proportional to the distance. So in an ideal situation we want it to be as small as possible. We can really draw a distinction between the number of hops and the Metric distance , but since we have introduced a parameter called the Cluster Head Communication Range which is different from Node to Node Communication Range they differ in their relationship.

Power Consumption:

This parameter is a simple indication of the cost that each of this nodes has to bear when transmitting or establish a connection between the next node. So again power consumption can also be related to the success rate over a period of time . At the rate of Power consumption will give the quality of the efficiency of the network over a period of time.

Comparison of the three protocols using no of nodes:

We can see in the below graphs that the Flooding is very aggressive in it approach because it can lead to multiple paths and each of them again diverges into different paths . So we approximate the Flooding to a condition of only selecting 5 out of those paths .Even with this constrain the resources are being drained at a ver aggressive rate in all if the three metrics under comparisons. But The only pros of a Flooding is that we can improve the connectivity even with a now no of nodes.

I case of a Gossip and leach protocol we see that they are considerately more enery efficient and also the delays caused are considerably low. But major advantage of both of these protocols is the sustainability of the network for a loner periods of time and also the complexity is very highly reduced.

Result of evaluation clearly indicates that Flooding is the worst in case of power efficiency. Gossiping provides some improvement over Flooding in terms of power usage per message. Power usage per message is less for Multihop-LEACH when compared to other two protocols.

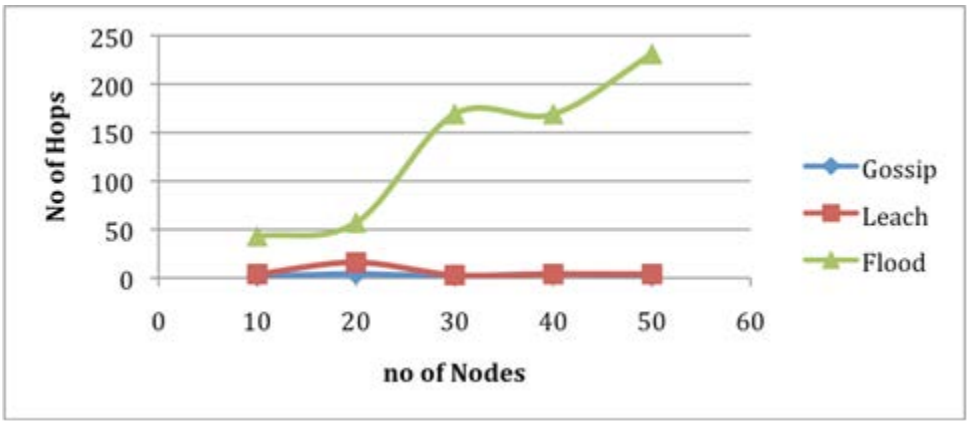


Fig a. No of Nodes Vs No of Hops

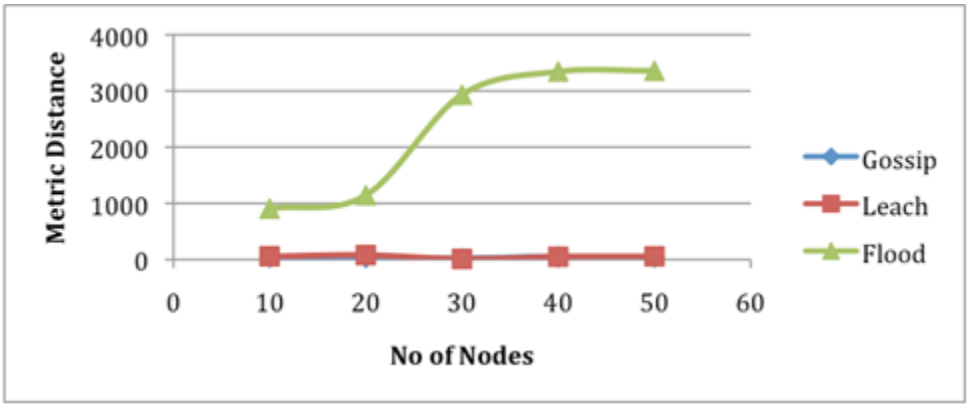


Fig b. No of Nodes Vs Metric Distance

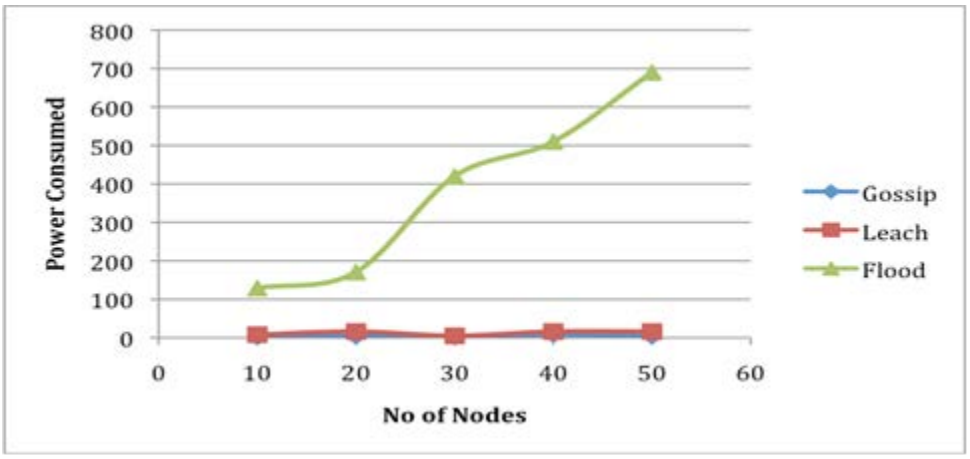


Fig c. No of Nodes Vs Power Consumed

Since we cannot extend our approach for larger values oh nodes we drop the Flooding algorithm as it leads to the segmentation faults in the programmimg methodology. The next two section furthermore compare the effect of nodes in case where the desinty of no of nodes is increased and also they change when the communication range between the nodes is increased.

Comparison in relation to number of Nodes

We compare both the Leach and Gossip with the number of nodes which also translates to the density at which the network is populated.

No of Hops:

We see in Fig a that the number of hops if case of a Gossip protocol is considerably large as the number of node increase as the probability of it circumventing around the destination is increase more so it is advantageous in the case of Gossip protocol to have less densely populated network. But at the same time we also observe that The Flooding protocol the number of hops has consistently remained the same indicating it to be a consistent protocol .

Metric Distance:

Consider Fig b ,this comparison also looks the same as the one with the number of hops but we can see the metric distance is much larger that the number of hops .This factor could influence the delay so nodes increase we would expect our delay to increase in case of Gossiping but once again we see that the delay would be consistent with any number of nodes in case of Leach protocol.

Power Consumed:

We see form the below Fig c the Power consumed is Relatiivley high for the Gossip protocol owing to its path along the network at a random pace . But in case of Leach we have a good reliabilty of the network as the rate at which the power is consumed if very uniform and low when compared to Gossip.

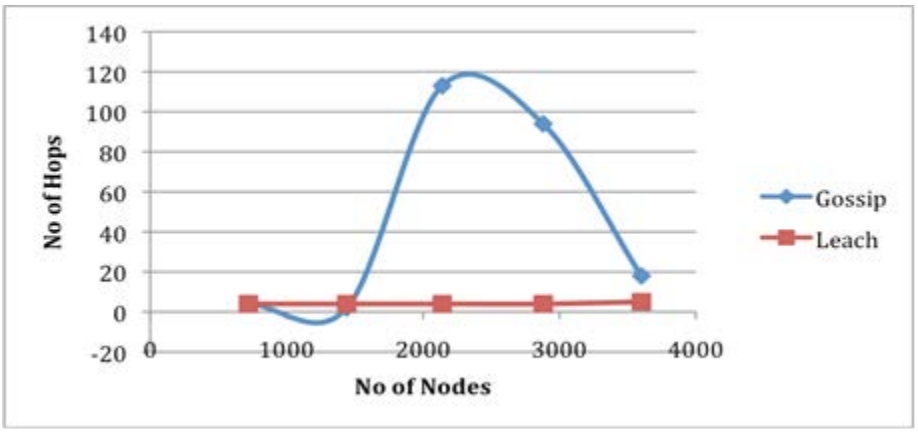


Fig d. No of Nodes Vs No of Hops

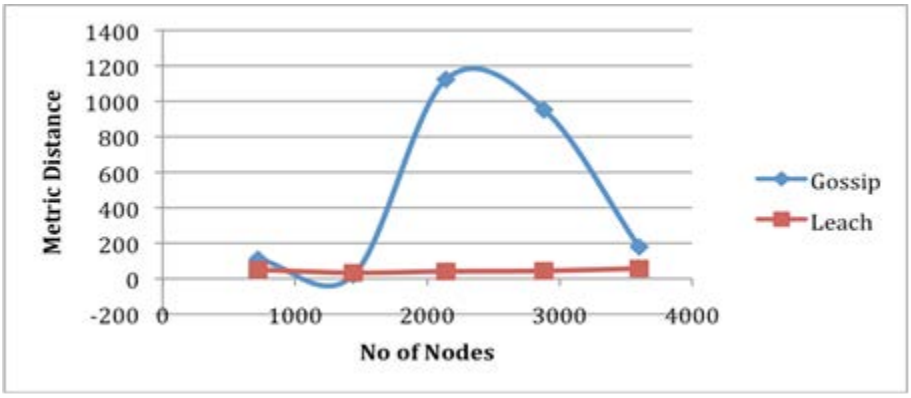
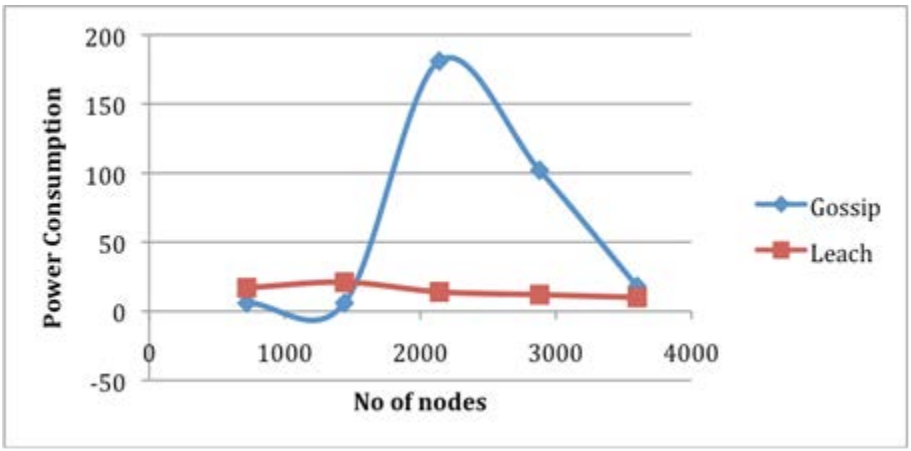


Fig e. No of Nodes vs Metric Distance



Figf1. No of Nodes vs Power Consumed

Comparison in relation to Communication range

Communication Range indicates the maximum distance at which one node can communicate to another node in a network

No of Hops:

In Fig d we can see the relation between the Communication range and the number of hops. Also as the communication range also translates to number of cluster implementations inside a Leach protocol according to our program we can also see this as the influence of the cluster size on the number of hops it takes. As expected in Gossip as the communication range is small translates to more nodes to be covered to reach the destination so we see large number of hops. In leach it seems that the communication range does not really effect the number of hops.

Metric Distance:

Fig e gives you the correlation between the metric distance and the communication range and we observe that in both the cases as the range increases the distance decreases. And also we observe that in Leach we see some increase in the metric distance covered as it has to traverse more clusters to reach the destination cluster.

Power Consumed:

Fig f gives us the power consumpption as we can see the communication range increases the accesiblity to the node increases and thus we use relative less node to get to the destination and hence low power is consumed. And also the power consumtion at higher comminication range for both the protocols does not vary much as in such case even Gossip try to gain access to the nodes which are far away thus covering huge distances in single hops.

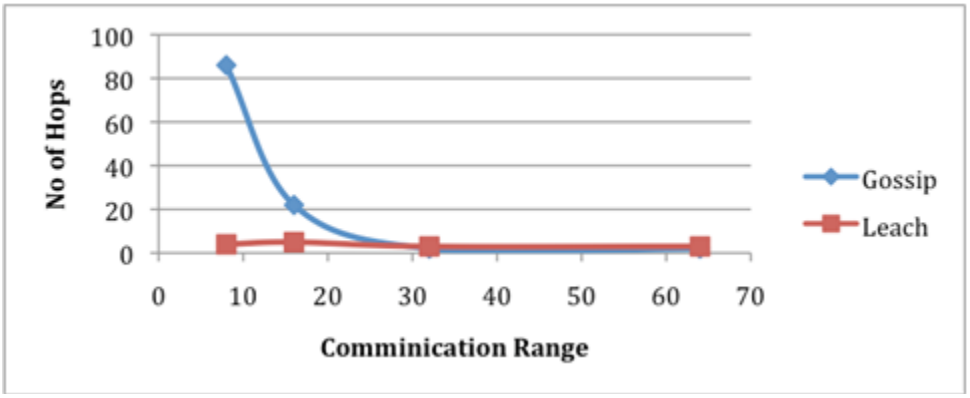


Fig g.Communication Range vs No of Hops

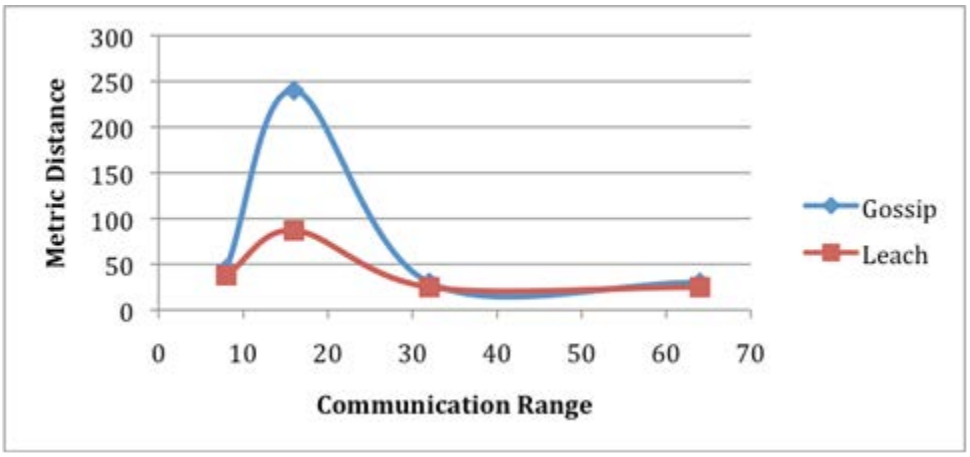


Fig h. Communication Range vs Metric Distance

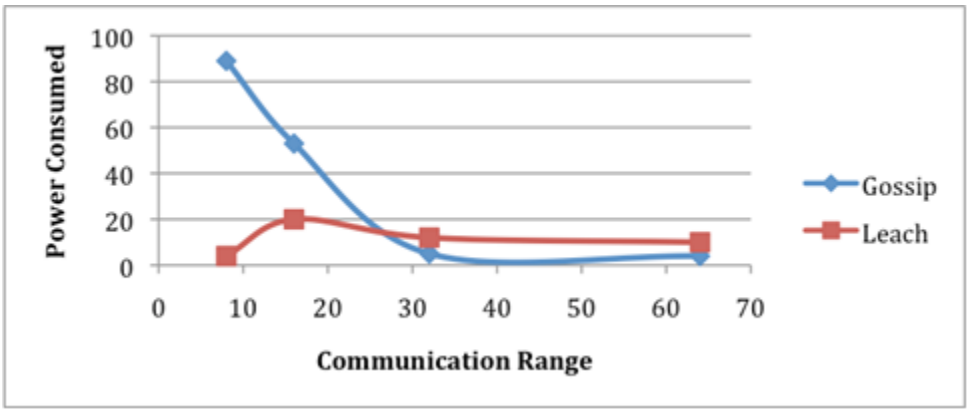


Fig i. Communication Range vs Power Consumed

7.2 Abnormal Case Explanation

Best Case and Worst Case Scenarios

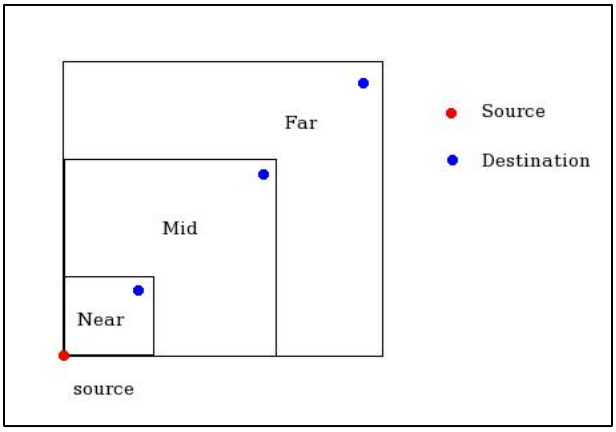


Fig j .Explaining the Best and Worst Cases.

We can see from the above figure we can generalize the number of cases that can be possible given the source is fixed .

Source and Node are Near by : Implies in both the protocols it has the high probability that in can reach the destination using minimum requirements of the metrics and thus doesn't show much difference in their approach.

Source and Destinations are Far away: in this case we see that we need more number of hops between nodes incases of Gossip and hops between clusters in case of Leach so we and up consuming more resources.

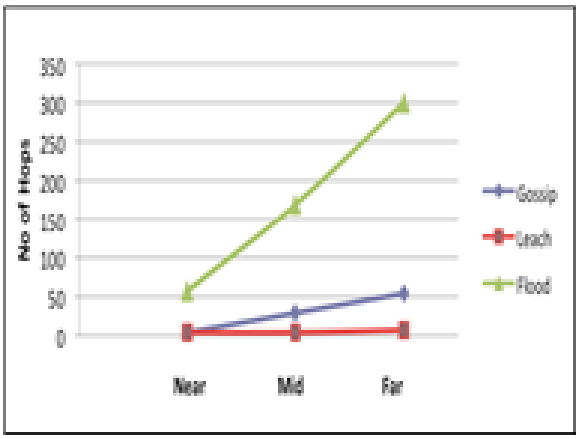


Fig k. Comparison with number of hops

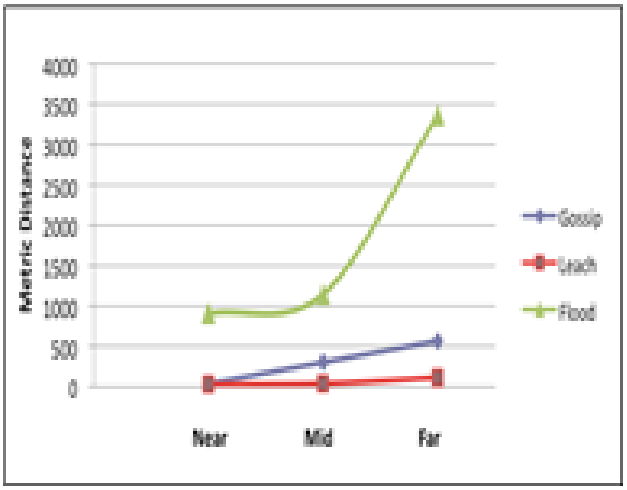


Fig k. Comparison with metric distance

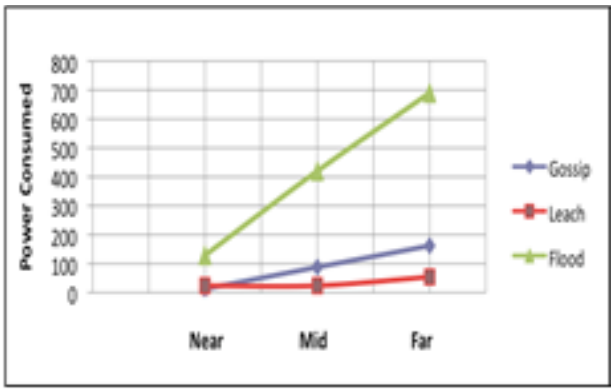


Fig k. Comparison with power consumed

8. Conclusions and Recommendations

8.1 Summary and Conclusion

Result of evaluation from the before section clearly indicates that Flooding is the worst in case of power efficiency. Gossiping provides some improvement over Flooding in terms of power usage per message. Power usage per message is less for Leach when compared to other two protocols. Connectivity and End-to-End delay are more in Flooding and Gossiping compared to Leach as Leach depends on distribution of cluster head nodes around the network. Success rate in gossiping is less because many packets will get dropped when the packets hop count reaches a maximum limit. In Leach success rate and connectivity are improved by increasing the probably of clustering for every nodes.

The overall conclusion is that Leach routing protocol is best choice to move towards a network with less energy consumption as it involves energy minimizing techniques like multi hop communication, clustering and data aggregation. For applications like military where energy consumption is not much to be bothered and more performance is required, Flooding is the best choice as at is simple to construct. For applications where network subjected to more scalability like environmental monitoring, Gossiping is the best choice as it uses a medium amount of power and no matter how large the network is, each node uses roughly the same amount of power. For applications where energy utilization is more critical like health monitoring, Leach is the best choice. Leach uses both inter cluster as well as intra cluster communication. The power usage, latency and success rate in Leach can further improved by increasing probability of clustering. We can still minimize the energy consumption and extend the network life time by improving the clustering technique.

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