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Reliable and Energy Efficient Data Gathering Protocol in Wireless Sensor Networks

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Abstract: A sensor network is a set of small autonomous systems, called sensor nodes which co-operate to solve at least one common problem. Sensor nodes in Wireless Sensor Networks (WSN) are generally used to collect, aggregate and communicate the fused data to the Base Station (BS). In sensor networks, the nodes are having the limited energy which is one of the most critical issues in WSN. The energy gets reducing when the nodes are collecting information. So data gathering is required to be efficient, adaptive and robust. The paper provides solution for the energy issues by developing the energy efficient data gathering algorithm called Mark Based Data Gathering (MBDG) algorithm, which proposes to minimize the energy and delay in the process of gathering and communicating the fused data the BS in WSN. The proposed algorithm is compared with existing algorithms namely LEACH, PEGASIS, EMLN-DG and GBE-DG. The result shows that the proposed algorithm considerably improves network lifetime, reducing delay and energy consumption compared with existing algorithms.

Keywords: Energy, Delay, lifetime, WSN, Mark and Algorithm.

I. INTRODUCTION

People on planet are very much interested to know and monitor the entity in and around them. Data gathering in WSN is emerged issues at present sensing technologies so the nodes (devices) can be used energy efficiently in collection of data.

In peer action, WSN has been used in large number for monitoring the environment in which many parameters are considered to measure with the aid of sensor networks. Sensor network is entered into many applications such as industrial process monitoring and control, health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control.

The proposed protocol is implemented through NS2 simulation to measure the performance of proposed work. It is compared with performance of LEACH, PEGASIS, EMLN-DG and GBE-DG. The simulation result shows that the proposed protocol can outperform in terms of network lifetime, energy and delay.

II. RELATED WORK

In WSN, data gathering is a vast research area at present world. It finds the problem of communicating data between the base station and remote data sources via intermediate sensor nodes in sensor network [1-4]. The lifetime of sensor nodes are affected due to limitation of power source, path length and path cost [5-9].

LEACH [1] is one of the popular algorithm used for data gathering, where the nodes organize themselves into local clusters, with one node acting as the local base station or cluster leader. If the cluster leaders are chosen a priori and fixed throughout the system lifetime, it is easier to see that the unlucky sensor nodes chosen to be cluster leaders would die quickly, ending the useful lifetime of all nodes belonging to those clusters. However, the LEACH’s leader nodes waste considerable energy during gathering and sending data to the base station.

PEGASIS [1, 4] is one of another protocol for data gathering, where one is chosen as leader node. The leader node sends the fused data to the BS per round. In the protocol, it may be the bottleneck of the network causing delay by using only one leader node. This protocol never considers the distance of BS from the leader node when a leader node is selected. When a leader node selects, its energy level does not consider.

Another algorithm [2] is Energy aware Maximal Leaf Nodes Data Gathering tree (EMLN-DG) developed for wireless sensor networks.

The energy aware maximal leaf nodes data gathering tree algorithm uses commonly known factors about how much energy nodes expend based on their location within the cluster of all nodes in a topology. It is energy- aware node selection algorithm for sensor networks that is capable of sensing both nodes having the greatest residual energy, and nodes having the greatest amount of neighbors to be data – forwarding nodes.

The outermost nodes, called the leaf nodes, tend to be the most susceptible to energy overuse since their sole purpose in data gathering trees amounts to only transmitting their data to other more important nodes, and not gathering To save energy expended[8.9] by these nodes, their processing any data while they are turned on. To save energy expended by these nodes, the EMLN-DG algorithm attempts to both maximize the number of these leaf nodes, while minimizing their activity as much as possible.

Another one of the recently developed data gathering algorithm [3] is Grid Block Energy-based Data Gathering algorithm (GBE-DG) also attempts to minimize on the burden of long-distance transfers by arranging divided sections of nodes called grid blocks.

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The structure of these blocks closely resemble the structures of trees resulting from the aforementioned popular data gathering algorithms, for the blocks can take on either the form of a chain like PEGASIS, or a cluster like the LEACH [1]. Each grid block is measured for energy usage among its nodes, which solely determines the structure of the tree from root to leaf. The algorithm [10, 11] uses these measures to determine the block harboring the most residual energy amongst all its nodes, and therefore the block most fit to transmit data to the sink without losing all of its power doing so.

III. METHODOLOGY

For WSN, many researches are preferred the one model [1,5] which is first order radio model particularly used for energy calculation. This is a very much deal of research in the area of low energy radios. The first order radio model is considered for WSN, where the radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and ϵ_{amp} = 100 pJ/bit/m^2 for the transmitting amplifier. The parameters are slightly better than the current state of the art in radio design. Thus, to transmit a s-bit message through a distance "d" using radio model, the radio expands:

$$E_{Tx}(s,d) = E_{Tx\text{-}elec}(s) + E_{Tx\text{-}amp}(s,d)$$

$$E_{Tx}(s,d) = E_{elec} * s + \epsilon_{amp} * s * d2 \qquad (1)$$

And to receive this message, the radio expends:

$$E_{Rx}(s) = E_{Rx\text{-}elec}(s)$$

$$E_{Rx}(s) = E_{elec} * s \qquad (2)$$

This is not a low cost operating for receiving a message for the above parameters values. The protocols have been used to minimize not only the transmit distance but also reduces the number of transmit and receive operation for each message [7]. The algorithm 1 is uses to find the leader node and leaf nodes for performing both transmit and receive operation.

The algorithm 1 runs based on the procedure of leader node and leaf node. In the network as shown in figure 1, each node can contact with one another within its transmission ranges and forma a graph. Identifiers of some integer values, which are on each node, are generated in sequential order. Before the first round of the data gathering, random generator assigns a Mark value to all sensor nodes which are all in the network. The leader and leaf nodes can chosen based on the basis of highest values which are produced by random generator device because all nodes are having equal energy for first round of data gathering.

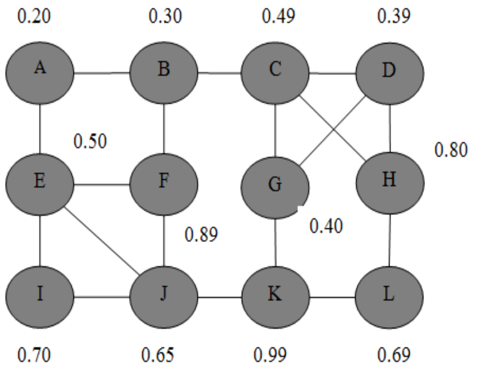

Figure 1: Network Graph

For each round of data gathering, a request is made to the sink node for assign new values to each node. In subsequent nodes, the Mark values of nodes are determined based on residual energy available on each node. The Euclideean distance formula which uses to find the distance between two nodes. If their distance is less than or equal to the preset transmission range, then an edge is placed in such manner that it lies between the first node and the second node. A tree map data structures is used to form an adjacency list after all edges are placed within the graph.

Finding the Leader node and Leaf node

Step1: A node which is having the highest energy (expect first round) among all its neighbor.

Step2: If a node 'n' is not selected as leader node in step1, then the neighbor node 'm' can be chosen as leader node. Then the node 'n' becomes a leaf node for m.

Step3: If a node cannot be assigned as leaf node for any leader node selected in step1, then the node itself selects as one of the leader node which can be added in leader node's list.

Step4: Based on step1 to step3, a complete graph is formed.

Step5: The formed graph is step4 is run by kruskal's algorithm (MST).

Step6: The MST formed in step5 is transformed to a rooted directed DG tree with the root being the leader node with the largest available energy.

The nodes are classified into leader node list and leaf node list based on steps followed by figure2. Initially, the nodes without labels are listed in the common node list. Before categories nodes, leader node and leaf node is set to zero and then each node in the common node list is assigned mark 0 to 1 by using random generator. Leader node is one which receives data from leaf node or other subordinate leader node whereas leaf node is the one which collects the data from the environment itself. After mark is assigned, two nodes are taken from the common nodes list and their Marks are compared. The node which is higher in mark is listed in leader node list and the one lower in mark is listed in the leaf node list.

Algorithm 1: Detection of Leader Nodes and Leaf Nodes

Input: Network Graph G = (V, E);

Variables declaration and Initialization:

Node-List, Adjacency-List of neighbours for each node,

Leader_node = true
Leader-Node-List = Φ Leaf-Node-List = Φ

Begin Selection – Leader and Leaf Nodes
for every vertex ←u ∈Node-List do
rank(u) = random number assigned from 0 to1
end for
for every vertex u∈Node-List do
Leader_node = true
for every vertex v ∈Adjacency-List(u) do

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if (rank(v)>rank(u)) then
Leader_node = false
else
Leaf-Node-List= Leaf-Node-List U{v}
end if
end for
if (Leader_node = true) then
Leader-Node-List = Leader-Node-List U {u}
end if
end for
for every vertex u ∈Node-List and u ∉Leader-Node-List and u ∉ Leaf-Node-list do
for every vertex v ∈Leaf-Node-List do
if (rank(v)>rank(u)) do
rank(u)= random number between max(Leaf-Node-List) and 1
end if
end for
Leader-Node-List= Leader-Node-List U {u}
end for

The execution of MBDG as shown in figure 2 is performed by applying the procedure of detection of leader node and leaf nodes. The leaf nodes are generated if a node is adjacent to an leader node, and its mark must be lower than one of its adjacent nodes to be considered as a leaf node. Based on the execution of MBDG algorithm, the six nodes A, B, E, F, I and J form of one group. Other groups in the network are (C, D, G and H) and K and L.

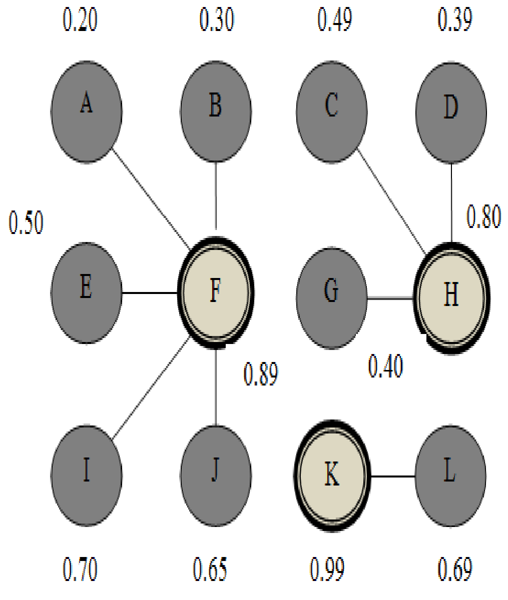

Figure 2: The execution of MBDG algorithm

IV. TREE STRUCTURE FOR MBDG

After accumulating all the nodes by simulator, a complete graph is formed among the nodes. The construction of the complete graph has a few similarities to the construction of the original graph. Then the simulator does not consider about the transmission range when it is creating edges. It automatically connects every node to other nodes in the leader node list. It maintains a list of the edges and their corresponding weights for future reference when it forms a minimum spanning tree. After formation of the complete graph, a minimum spanning tree algorithm must be run in order to form a tree. In this work, it uses kruskal's algorithm [3] because prim's algorithm have low memory usage.

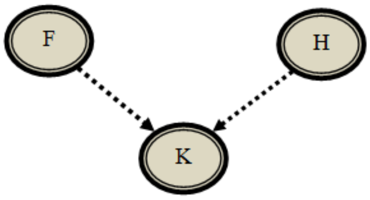

Figure 3: Rooted Directed Tree

A breath first search (BFS) is run on the tree after the formation of a spanning tree. When it executes the breath first search as shown in figure 3, root node has to be found first, which will be known as the sensor node with the highest mark among the leader nodes, which is also the highest markd node out of the entire network. This method is known as RDT (Rooted Directed Tree). As the BFS iterates, it keeps track of a parent and its downstream nodes. When the BFS is completed, it maintains a list on an upstream node and its downstream children, which includes its leaf nodes from the decision phase and its downstream nodes from MST. The MBDG is now completed when the newly birthed rooted directed tree is formed form the BFS. Now the rooted directed tree is applied to the entire network and forms the MBDG tree.

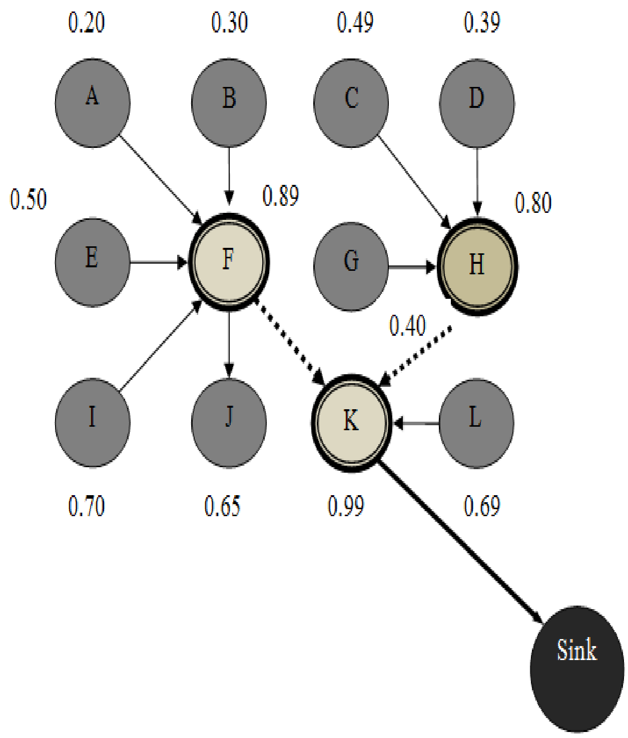

Figure 4: Mark based Data Gathering tree (MBDG)

The formed MBDG tree is shown in figure 4 . The tree it consists of 12 nodes and one sink. It has 9 leaf nodes and three leader nodes detected by procedures of detection of leader and leaf nodes. Here node F is the root node because it has the highest mark among all leader nodes. If the user requests any information in the sensor field, sink has to communicate thorough node F. the node F collects the results of all leader nodes.

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The superior leader node sends the information to sink with the help of same radio. Finally, the user gets information through satellite or internet.

Tree Based Energy Calculations for MBDGL: For selecting the leader node, random generator is used to produce random value for the first round of data gathering. In subsequent rounds, the mark value of a node is based on the residual energy available in the sensor node. The MBDG graph is converted into the tree structure for energy calculations.

V. EXPERIMENTAL SETUP AND RESULTS

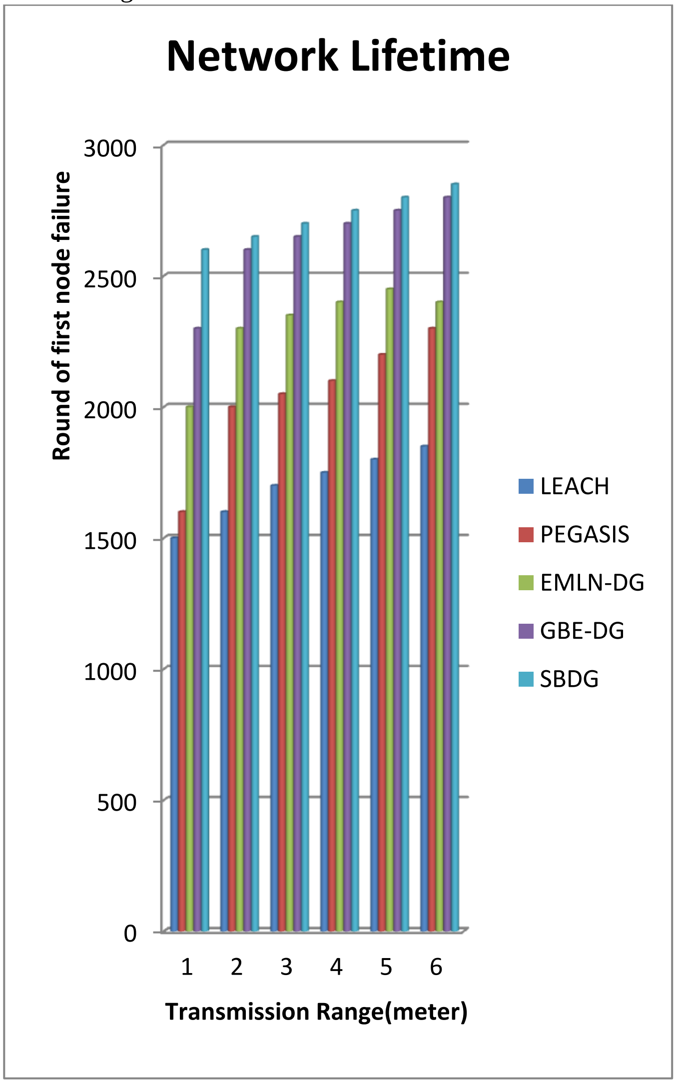
In order to analyze the performance of the MBDG algorithm, the simulation was run under the Network Simulator2. The simulator parameters are listed in Table 1. The network area is confined within 300× 300 m^2. Each node has a position and a velocity and moves about over a rectangular flat space. Each node in the network has a transmission range of 60m-120m.

The simulation of the MBDG was carried out on a discrete-event simulator.
This simulator has been used to successfully report simulation result of data gathering in sensor network. There are 150 sensor nodes that are randomly distributed throughout the network. The sink node is located outside of the sensor network at the location (300, 500). Each node is assumed to be able to allow data communication between it and its downstream nodes if any. As the energy consumption model is implemented, a node takes into account the distance between it and the node it must stream data to, allowing for a more accurate data communication sequence. With this simulator, the execution of MBDG with a transmission range of 60m to 120m is carried out with increments of 10. The simulations are conducted for both TDMA and CDMA systems. 100000 trials of the MBDG within a CDMA and TDMA system and the same for LEACH and PEGASIS, EMLN-DG and GBE-DG are simulated. Each node has been supplied with an initial energy of 1 Joule.

Table 1: Simulation Parameters

Parameter	Value
Simulator	NS2 (NS-2.28)
Network Area	300 x 300 m2
Transmission Range	60 m-120m
MAC Layer	IEEE 802.11
No of Nodes	150
Sink location(Approx.)	(300,500)
Node Initial Energy per node	1 joule
Data Packet Size	64 bytes
Bandwidth	2 Mbps
Simulation Time	100 s
Number of Trials	100000
Confidence Interval	93%

When there is a network of at least 150 sensor nodes, then the sensor network is considered to be completely covered. When simulated with sensor nodes with high transmission range, the number of rounds before a node fails, is decreased drastically. This is due to the small number of leader nodes and large amount of data aggregation done by the leader nodes. When simulated with a small transmission range, the network lifetime increases significantly in both the data gathering trees. The small amount of leaf nodes per leader node is the cause of this. In sensor networks, the energy consumption for communication is much higher than that for sensing and computation. When the network contains a small amount of leader nodes, the energy consumption for communication decreases for all leaders except for the root leader node. Likewise with the mark and energy based data gathering tree, the network lifetime increases as the transmission range decreases. The mark and energy based version displayed astonishing results with an increase in the lifetime of the sensor network when compared to the original mark- based protocol. When simulated with transmission range of 60meters to 110meters, the good performances of each parameter used in the system are shown in figure 5.



(a)

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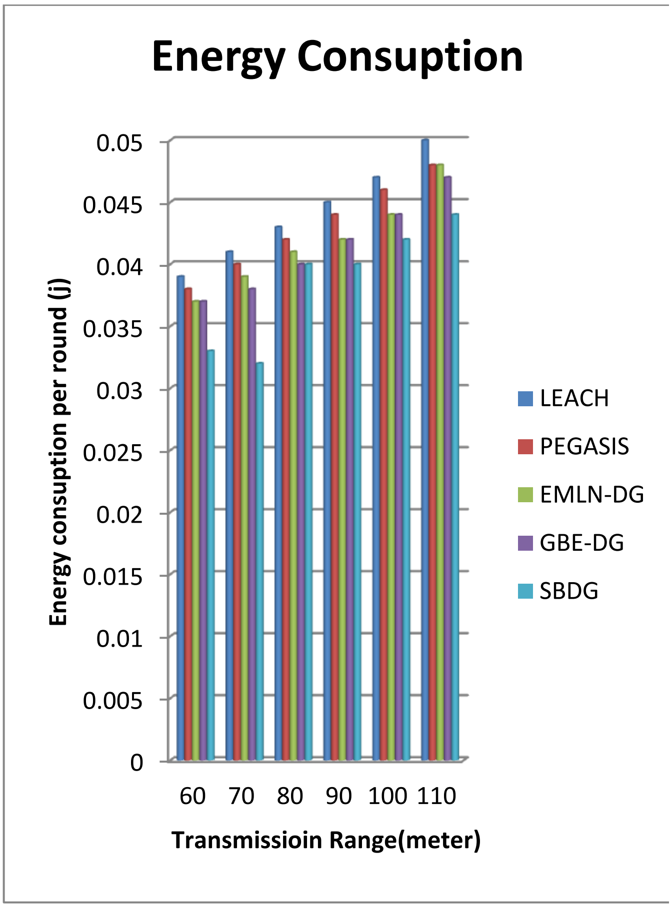
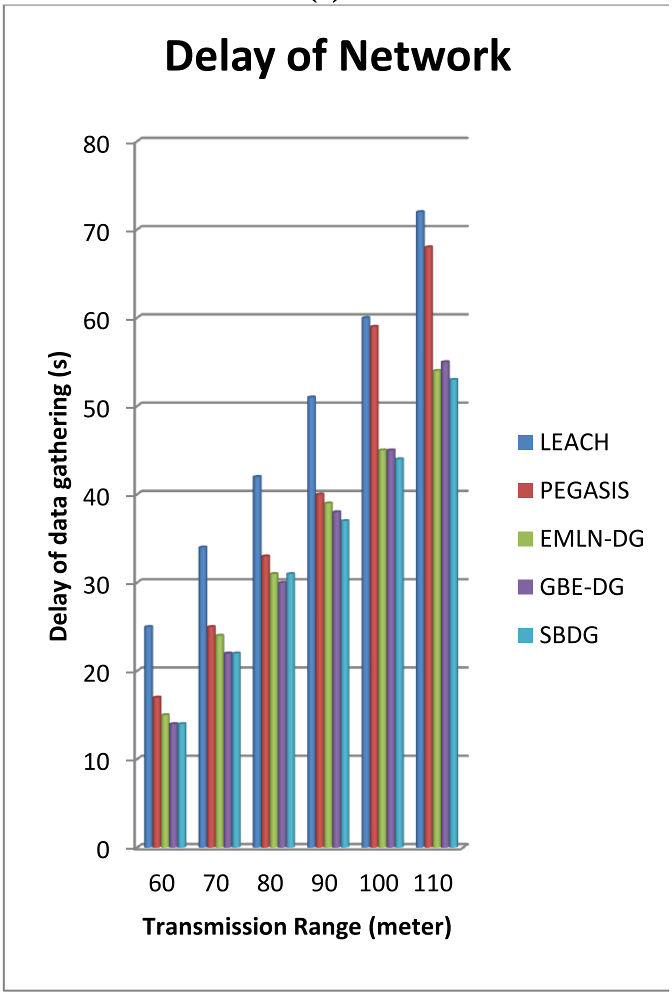


(b)



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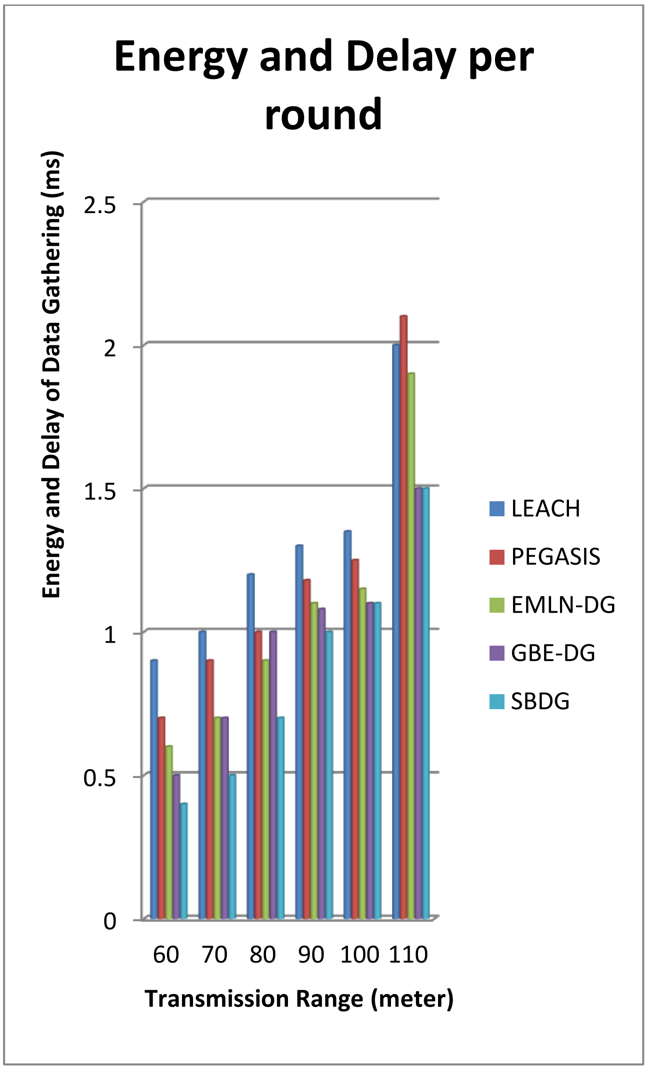

(d)

Figure 5: Performance of the proposed protocols: (a) Network Lifetime (b) Energy Consumption (c) Delay of network and (d) Energy and Delay per Round.

VI. CONCLUSION

This has developed the protocol which is MBDG to increase the network lifetime by reducing energy consumption in the process of data gathering. A technique to decrease delay during the gathering of data without substantially increasing energy consumption has been developed. Unlike LEACH, PEGASIS, EMLN-DG and GBE-DG, the delay per round of data gathering is considerably lower when MBDG is employed. The energy consumed per round of data gathering for MBDG is less than half of that incurred with LEACH, PEGASIS, EMLN-DG and GBE-DG. Compared with the exiting protocols, the proposed protocol is fair with node usage because of the mark system and residual energy respectively. Overall, the mark based data gathering protocol and its energy can be a significant addition to the list of data gathering algorithm that can simultaneously maximize the network lifetime as well as minimize the energy and delay per round of data gathering.

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