Sink Repositioning Method to Improve the Energy Consumption in Wireless Sensor Networks

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Abstract

This work proposes an approach of improving the energy efficiency and extending the lifetime of the wireless sensor network by the use of sink relocation underlying with Maximum Energy Path (MEP) routing algorithm. In wireless sensor network the sensor devices have to observe and monitor the environmental events, and report the data collected to a nearest information collector, referred to as the sink node. Sensor nodes which are far away from the sink relay their data via multiple hops to reach the sink. This way of communication makes the sensors near the sink deplete their energy much faster than distant nodes because they carry heavier traffic. So communication hole appears around the sink. Consequently, these nodes will quickly drain out their battery energy and shorten the network lifetime. In this work sink is relocated in different position and gathers the information. This avoids the communication hole problem around the sink and enhance the lifetime of the network. The performance is analyzed in ns 2 and results proved that multi relocation of sink, enhance the lifetime of wireless sensor network than single sink relocation.

1. Introduction

Wireless sensor network (WSN) is a wireless network that consists of distributed sensor nodes that monitor specific physical or environmental events or phenomena, such as temperature, sound, vibration, pressure, or motion, at different locations. Wireless sensor networks are now used in many civilian application areas, including habitat monitoring, healthcare applications, home automation, and traffic control. In the case of a sensor node detecting an abnormal event or being set to periodically report the sensed data, it will send the message hop-by-hop to a special node, called a sink node [1], [2]. In general, due to the sensory environments being harsh in most cases, the sensors in a WSN are not able to be recharged or replaced when their batteries drain out of power. The battery drained out nodes may cause several problems such as, incurring coverage hole and communication hole problems [3]. The sensor node near the sink will quickly drain out its battery power after relaying several rounds of sensed data with reported tasks being performed by other sensor nodes, and consequently the WSN will die. The dead node is called as a hot- spot. In the case of the sink being capable of moving, before the hot spot node drains out all of its battery energy, the sink can move to another position to relieve the situation of heavy energy consumption of node. The sink relocates its position from the nearby node to new node [4],[5]. This paper proposed a sink relocating scheme to guide the sink where to move [6]. Main objective of this protocol is to route the packets through the higher energy node to the sink. The Performance of Single Sink and Multi Sink Relocation algorithm is simulated in NS 2.

2. Related Works

In wireless sensor networks sensor nodes communicate with each other and deliver the sensed data to the base station or sink node. Some authors dealt with the Half quadrant based strategy and made the sink to move to the particular quadrant and collect data from that quadrant in their works. This quadrant selection depends upon the total number of residual energy of that Quadrant. Take the nearby sensor nodes residual battery energy into consideration and then drive the sink to a position with a larger amount of total residual energy than others. The sink is positioned to different quadrants depends upon their energy [7], [8]. Here routing method is not incorporated. The routing protocol does greatly affect the resulting performance and reduces the network lifetime. Energy efficient data collection method using a mobile sink and clustering sensors for large wireless sensor network[9]. Before collecting data, a mobile sink clusters sensor network using Kmeans algorithm and calculates travelling. The greedy algorithm is used to calculate the travelling paths of the mobile sink [10]. When the mobile sink arrives to a cluster, it broadcasts message to cluster members. The message contains the identification number of each node in the cluster. The node which has received broadcast message and matches it's ID, replies its collected data to the mobile sink [11], [12]. The disadvantage of the mobile sink is that data gathering time is longer than a stationary sink because it should travel entire wireless network area. There is a possibility to lose data if the mobile sink does not visit at the right time [13]-[16].

3. Energy Path Routing Protocol (MEP)

Maximum Energy Path (Dynamic routing protocol) is used as the underlying routing protocol of the proposed sink relocation method. The MEP has also been demonstrated to perform well in prolonging network lifetime in a WSN.

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Routing protocol is a major scenario for creating the network, the proper routing protocol route the packets in a correct path rather than collision or loss of packet. WSN always have a routing protocol underlying in it. An efficient routing algorithm would greatly improve the network lifetime as well the performance of the overall network. The MEP is chosen instead of energy efficient protocols. Here the packets have to route in load based. The node which has the higher energy should be chosen instead of low energy node. At the same time MEP should consider the location also. Since transmission range that is allocated for each node is limited.

The MEP protocol first establishes the path by considering the neighbouring node, it compares the energies of the neighbouring nodes. The node that has the higher energy with limited distance to the sink node is selected. (in)This case the node selection purely depends upon the neighbour node. Then the path is established to sink once if the node transported its sensed information the energy updated to the transported nodes. Energy depletion of each node depends upon the data carried by them. The path which leads to the low energy node will not be chosen. The node which is near to sink will make take the ordinary route. Sink will be relocated randomly based on the location MEP protocol is executed. The layered graph for this protocol is executed in such a way it gives the good result in the ending which improves the network lifetime directly. MEP also (can be)used for static sink. It gives the same result but it results in the sink hole problem finally. This protocol suits only for the sink relocation scenarios. Figure. 1 shows the path taken by the sensed node. Consider W be the node sensed it has X,Y,Z neighbours each having its different energy 20,40 and 5, the protocol takes the higher energy node Y as apath

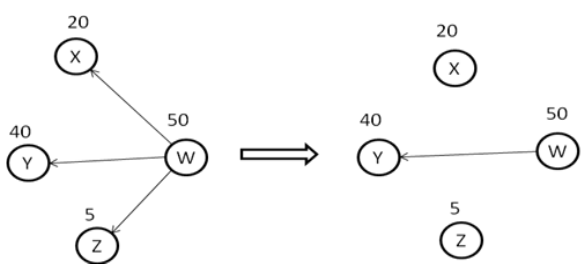


Fig: 1. Energy Choosing in MEP

Fig. 2, 3, 4 are the examples to illustrate the procedure steps of the MEP routing algorithm. WSN and its current residual battery energy state of sensor node can be modelled by a capacity graph G =(V, E), where set V denotes the collection of sensor 0nodes and E denotes all of the possible direct communication between sensor nodes. And let R be the residual energy to represent each sensor node. Figure. 2 Node S stands for the sink with infinite energy due to the fact that it can plug in to a power line or is equipped with an extremely large capacity battery compared to that of the sensor nodes. The value that is associated with node X is equal to 50, which stands for the current residual battery energy R of sensor node X.

The MEP mainly consists of three procedure steps. They are,

(1) Layering graph G

(2) Determine the maximum energy path for each sensor node

(3) Routing performed and residual energy updated. The MEP will iteratively perform the above three steps for each round of message reporting.

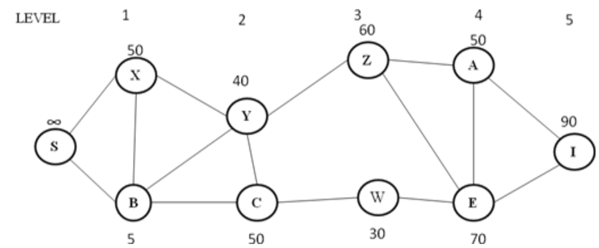


Fig: 2. Layered Graph

Detailed operations for layering the graph, in the first step are as follows. Let level number LV with respect to each sensor node v ∈ V denotes the shortest path length from V to the sink S. Figure. 3 The shortest path length from nodes A and E to node takes 4 hops, LA = LE =4. The layered network N can be obtained from graph G by deleting the edges (U, V)∈ E such that LU = LV. since LX = LB = 1 and LA = LE = 4, then edges (X,B) and (A,E) will be deleted from G. Then the layered network N obtained from G is a directed graph, such that for all of the remaining edges (U,V)∈ E after the deleting operation the Figure. 3 shows the graph obtained from Figure. 2.

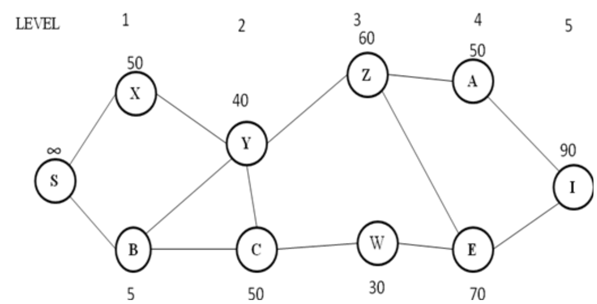


Fig: 3. Customizing the Network

Fig: 3 the maximum energy path for each node can be assigned. Let KUS = u, u1, u2... ul, s be a path from node U to the sink S in N. And let the energy e(KUS) of path KUS be the minimum value of residual battery energy in path KUS; that is, e(KUS) = min{ r(u), r(u1), r(u2),...,r(ul)}. Let K∗US be the maximum energy path with the maximum energy value among every path from node U to S. The resulting graphs of the union of each maximum energy path K∗US, will be the routing paths for message reporting. For example, Figure.4 shows the resulting maximum capacity paths obtained from the layered graph N of Figure. 3. The above operations are the second procedure steps of the MEP. Now, as a sensor node U detects an abnormal event or has sensed data to report to the sink node S, then the message will be relayed along the maximum energy path K∗ us to s. The maximum capacity path K∗ES = E, Z, Y, X, S after the message relaying from node E to S along path K∗ES, the residual battery energy of each sensor node in the path is updated accordingly. The three procedure steps will be repeated for each transmission round until one of the nodes drains out its battery energy.

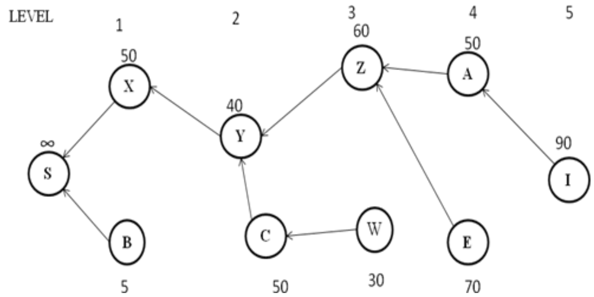


Fig: 4. Final Layered Graph

Algorithm of MEP protocol

INPUT:

No of Nodes n;(a,b,c,d,etc.,)

Initial Energy Ei;

Destination Node S;

Neighbouring Node for 'a'(b,c,d).....

MEP_CONSTRUCT

{

For (every t seconds)

Energy Updated (a,b,c,d,etc.,)

{

If ('a' detects the event)

(b>c>d)||(c>d>b)||(d>b>c)

(Packet routed via highest energy node within the transmission range to S)

Energy updated

(a,b,c,d...etc)....

}

}

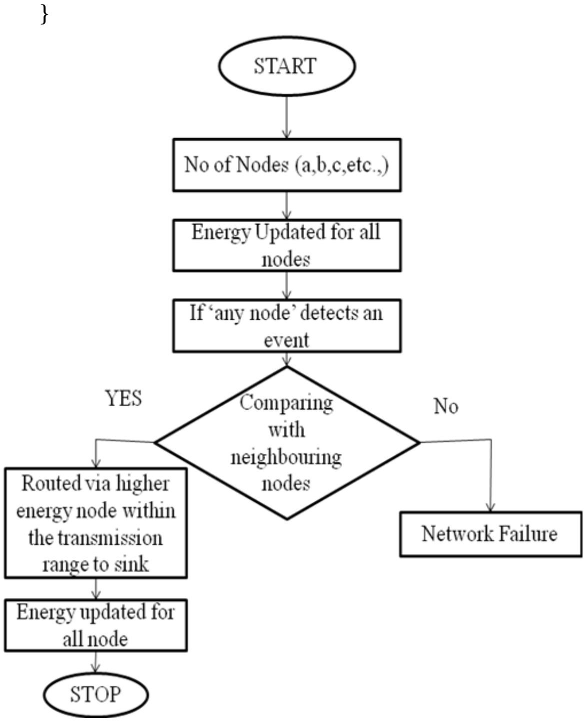


Fig: 5. MEP Operation Flowchart

Fig. 4 shows the path routing that the each node in the MEP protocol takes the maximum energy path taken by node I is e(K*IS)= I,Z,Y,X,S and C is e(K*CS)= C,Y,X,S. The MEP updates the energy once it completes its cycle. MEP operation Flowchart is shown in Figure. 5.

4. Sink Relocation

Sink is relocated at different position randomly. Data transmission to the sink happens either by hop by hop to sink or direct communication. Hop by hop communication takes place when the event detection node lies far away from the sink. Direct communication involves when nodes are neighbours to sink. If the allocated time exceeds the limit sink will consider relocating to a new position. Figure. 6 shows the sink relocated to the new position in order to avoid the communication hole problem.

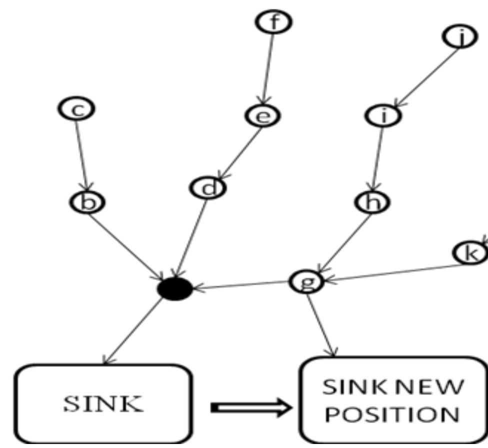
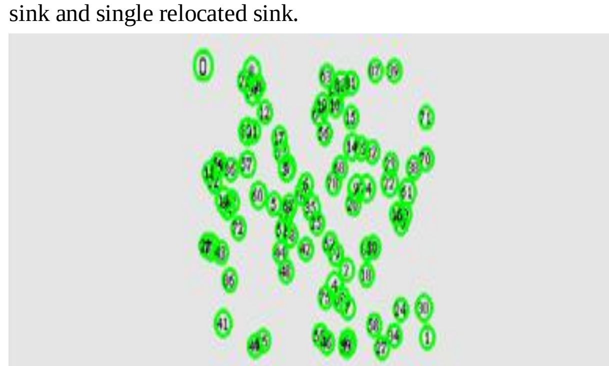


Fig: 6. Sink Relocation

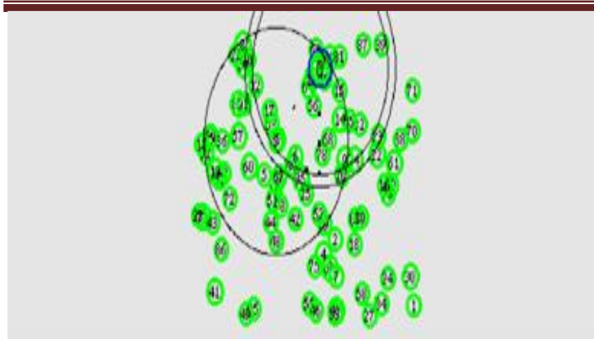
All sensor nodes relay their packets to be transmitted via node 'Black' to sink. Now the sink relocated to new position this enhance the lifetime as well as avoids communication hole problem.

4.1 Single Sink Relocation

In single sink relocation, the sink is relocated once. Figure. 7(a) shows the network animated result for static sink. Sink is located in a fixed position and communication is made for first 20 seconds. Figure. 7(b) shows the network animated results for Single sink Relocation, after 20 seconds, the sink is relocated to the new position and nodes start to transmit it detected events to newly located sink. This process is carried out for certain period of time. The MEP protocol is underlying for the packets transmission to the sink. The lifetime of the network is calculated for static sink and single relocated sink.



(a)

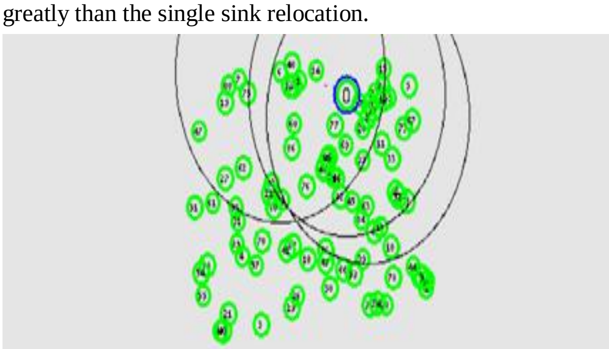


(b)

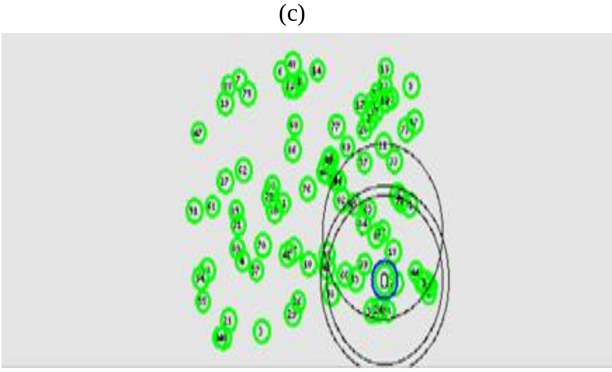
4.2 Multi Sink Relocation

In multi sink relocation the sink is relocated several times. Figure. 7(c) and (d) shows the network animated results, first 20 seconds communication is made with static sink. After 20 seconds sink is relocated to new position and at 40 seconds sink is again relocated to another new position. For every 20 seconds sink is relocated to different position. Due to the dynamic nature of sink, communication hole problem around the sink will be avoided and renders increase in lifetime of the wireless sensor network.

Multi relocation of sink involves direct communication and reduces the hop count for the senor node to transmit its detected events to destination where as the single sink relocation does not reduces the hop count for transmitting packets because it is relocated single time and became static. So the multi sink relocation improves the lifetime greatly than the single sink relocation.



(c)



(d)

Fig: 7. (a) Simulation of Static Sink generated by NAM, (b) Simulation of Sink relocated in single sink Relocation generated by NAM, (c) Simulation of Sink relocated after 20s generated by NAM, (d) Simulation of Sink relocated after 40s generated by NAM

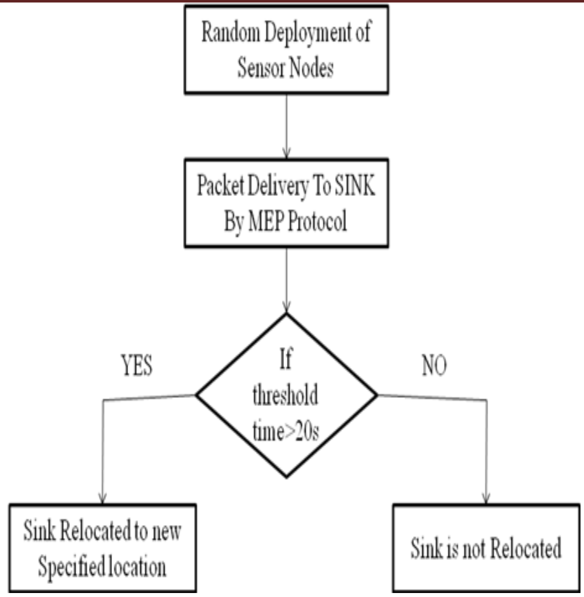


Fig: 8. Flowchart for Sink Relocation

4.3 Sink Relocation Algorithm

START
{
If (threshold time>20s)
Sink Relocated to new specified position
Else
    Sink is not relocated
}
END

Figure. 8 shows the flowchart for sink relocation, it brings the overall work that is implemented in the sink relocation. In wireless sensor networks the nodes are deployed randomly. The communication is made by multihop transmission to the sink by MEP protocol.

5. Analysis of Energy Calculation

Various models and analysis of Total Energy Remains(ER) have been proposed by researchers. Most of the researchers used heuristic-based approach for modelling the system. A heuristic model is proposed in this paper which is also based on the concepts of the research in [17], [18], [19].

Total Energy Remains (ER) is defined by

$$ER=Etot-Ec \quad (1)$$

Where, Etot is a total energy in the network and Ec is a total energy consumed in the network

$$Etot=Eo*n \quad (2)$$

Ec=(Etx+Erx)*n*T/2(for single hop at time period T)

Eo denotes Energy per node, n denotes No of nodes in the network, Etx and Erx denotes Energy consumed by the transmitter and receiver

$$Etx=(Eelec*K)+(Aamp*K) \quad (3)$$

$$Erx=(Eelec*K)+(Ddet*K) \quad (4)$$

Eelec is a electron component to carry K-bits. Aamp and Ddet is to drive amplifier and detection component.

A. Energy calculation

Let T=50sec; Energy per node(Eo)=100J; n=100; K=1bps; Electron component(Eelec)=0.05J; Amplifier component(Aamp)=0.05J; Detection component(Ddet)=0.05J;

Etot=Eo*n= 100*100

Total Energy in the network (Etot)=10000J

For 100 nodes Ec=(Etx+Erx)*n*T/2 (for single hop at time period T)

Ec=(0.1+0.1)*100*50/2

Total Energy consumed in the network Ec=500J

Eg: Multi Sink Relocation

70% ie 70 nodes uses single hop Ec=350J

25% ie 25 nodes uses double hops Ec*2=250J

5% ie 5 nodes uses three hops Ec*3=75J

For 100 nodes Ec= 675J

ER= Etot-Ec=10000-675 =>9325J

Total Energy Remains(ER)=9325J

Eg: Single Sink Relocation

40% ie 40 nodes uses single hop Ec=200J

30% ie 30 nodes uses double hops Ec*2=300J

30% ie 30 nodes uses three hops Ec*3=450J

For 100 nodes Ec=950J

ER= Etot-Ec =10000-950=>9050J

Total Energy Remains(ER)=9050J

This model is used for evaluating the Total Energy Remains(ER) in the network. The value of ER is calculated for Multi sink relocation and Single sink relocation by substituting energy per node, energy consumed and electron component to drive amplifier and detector. The result shows that the theoretical value matches with the experimental value in TABLE II.

6. Results

In order to investigate the performance of MEP, conducted several simulation in four different scenarios, the comparison factor is the network lifetime of wireless sensor network, for which the network lifetime is defined as the time from the start of the network operation to the death of the last node in the network. The nodes are all stationary after the deployment, but the sink is capable of moving when the condition is met (for every 20S).

The four simulation scenarios 9(a), (b), (c) and 4(d) compared the network lifetime algorithm by varying no of nodes, simulation time, simulation area and transmission range respectively.

6.1 Simulations

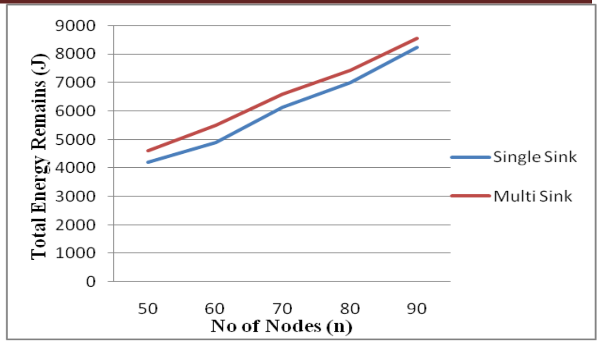
Simulation: 1. The simulation time is kept constant. By varying the no of nodes the total remaining energy is calculated for single and multi sink Relocation.

Simulation time= 50s

Energy per node=100J

Table: 1. Remaining energy in single and multi-sink relocation with respect to number of nodes

No of Nodes (n)	Single Relocation Total Remained Energy (J)	Multi Relocation Total Remained Energy (J)
50	4200	4600
60	4900	5500
70	6134	6602
80	7013	7417
90	8250	8551



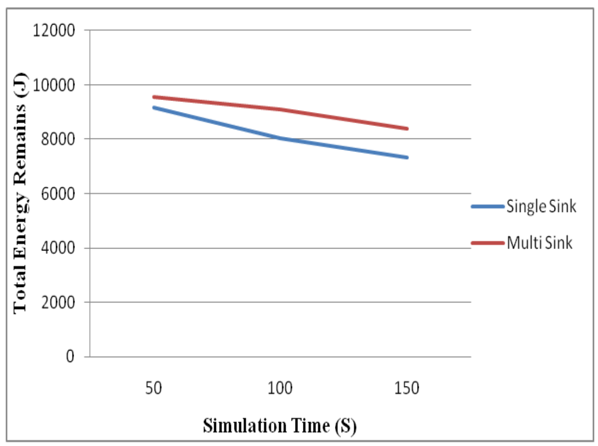
(a)

Simulation: 2. The total No of nodes is kept constant. By varying the simulation time the total remaining energy is calculated

Number of nodes=100

Table: 2. Update of energy in single and multi-sink relocation with respect to time

Simulation time (s)	Single relocation Total remained energy (J)	Multi relocation Total remained energy (J)
50	8970	9390
75	8561	9100
100	8000	8876
125	7651	8600
150	7310	8399



(b)

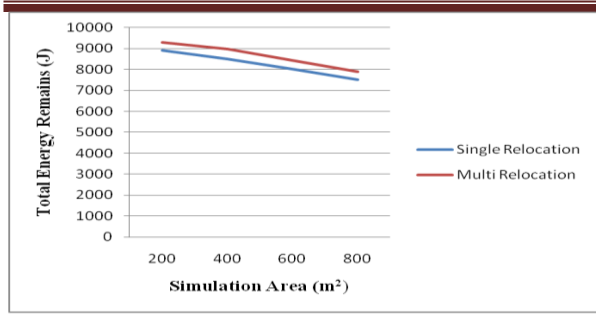
Simulation: 3. The simulation time is kept constant. By varying the Simulation area the total remaining energy is calculated for single and multi sink Relocation.

Simulation time= 50s

Energy per node=100J

Table: 3. Remaining energy in single and multi-sink relocation with respect to Simulation Area

Simulation Area (m^2)	Single relocation Total remained energy (J)	Multi relocation Total remained energy (J)
100	9321	9780
200	8900	9312
400	8500	9000
600	8012	8450
800	7500	7912



(c)

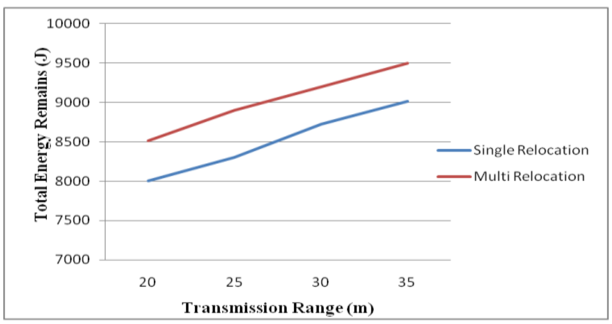
Simulation: 4. The simulation time is kept constant. By varying the transmission range the total remaining energy is calculated for single and multi sink Relocation.

Simulation time= 50s

Energy per node=100J

Table: 4. Remaining energy in single and multi-sink relocation with respect to Transmission Range (m2)

Transmission range (m^2)	Single relocation Total remained energy (J)	Multi relocation Total remained energy (J)
15	7600	8090
20	8000	8512
25	8300	8904
30	8720	9200
35	9012	9500



(d)

Fig: 9(a) No of nodes Vs total energy remains, (b)Simulation area Vs total energy remains, (c)Simulation time Vs total energy remains, (d)Transmission Range Vs total energy remains

Simulation: 5. Packet Loss Ratio

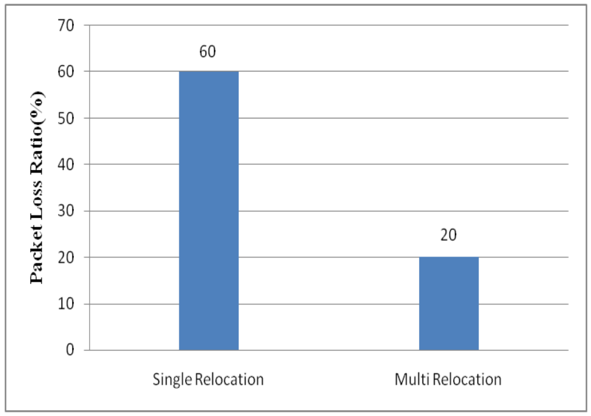


Fig: 10. Packet Loss Ratio (%)

Figure. 10 shows that Multi sink Relocation has low packet loss ratio than single sink relocation

Multi sink relocation consumes less energy than Single sink Relocation in all simulation scenarios as shown in Figure. 9 and 10

7. Conclusion

Relocatable sink is adopted in this paper with underlying Maximum Energy Path routing algorithm. This method can not only relieve the communication hole problem but can also enhance the lifetime of the network. The simulation results show that multi sink relocation method outperformed the single sink relocation method in the network lifetime comparisons under 4 different simulation scenarios as shown in Figure. 12 to 15

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