

Multiple Sink Positioning and Relocation For Improving Lifetime In Wireless Sensor Network

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Abstract

In Wireless Sensor Networks, potential sink selection and sink movements are costly in terms of node energy. In this paper, we propose K -Partitioned Minimum Depth Tree using the optimal search in Placing Optimal Number of Sinks in Sensor Networks for improving the Network Lifetime Maximization. Initially the optimal number of sinks is determined using the optimal sink algorithm satisfying the h-hop constraint. Then a K-Partitioned Minimum Depth Tree (k-PMDT) is constructed for positioning multiple sink nodes and setting up the routes. After determining the optimal number of sink positions and routing, best sink reposition is selected by optimum search method. Link movement is done by intelligent movement and it limits the sinks movements while maintaining their direction to the optimal positions. The main advantage of this method is to improve the lifetime of WSN's.

Introduction

Wireless Sensor Networks

The collection of nodes that are ordered into a cooperative network is called as wireless sensor network (WSN). There is a large range of sensor networks. Wireless sensor network was mainly designed for military application. Each node in wireless sensor network having the capabilities for processing, contain multiple types of memory, have a power source, have a RFC transceiver, and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Systems of 1000s or even 10,000 nodes are anticipated. Such systems can revolutionize the way we live and work. [1][2][3][4]

A sensor network is collected of a large number of sensor nodes and they are heavily deployed either very close to it or inside the phenomenon. Here the phenomena is thermal, optic, acoustic, seismic, and acceleration events, while the processing and other components analyze the raw data and formulate answers to specific user requests. The recent advances in technology mentioned above, have paved the way for the design and implementation of new generations of sensor network nodes, packaged in very small and inexpensive form factors with sophisticated computation and wireless communication abilities. Currently, wireless sensor networks are beginning to be deployed at hurried pace. We can expect that in next 10-15 years that the world will be covered with wireless sensor networks with access to them via the Internet. [2][3][4]

This new technology is moving with new technologies such as military, transportation, environmental, medical, homeland defense, entertainment, crisis management and smart spaces. In these scenarios the WSNs are usually deployed randomly in wide areas, and the network elements form a self-organizing ad-hoc multi-hop network. Once deployed, sensor nodes begin to observe the environment, communicate with their neighbors (i.e. nodes within communication range), collaboratively process raw sensory inputs, and perform a wide variety of tasks specified by the applications at hand. The ability to be deployed in very large scales without the complex pre-planning, architectural engineering, and physical barriers that wired systems have faced in the past, these factors that makes wireless sensor network so unique and promising both in terms of research and economic potentials. Many wireless sensor networks also utilize minimal capacity devices which places a further strain on the ability to use past solutions. [2][4]

Sink Repositioning

Sink repositioning means a moving node which has the ability to move around to collect data from sensors nodes and reposition is based on the collected data. To know the real time information on the sink position is the major challenge is that the sensor nodes. We need an estimation strategy is required at each hop to improve the effectiveness of WSN. Deployment of nodes in the network relies independent of metrics that base the state of the network or it assumes a pattern of network operations, which remains unchanged throughout the network lifetime. The nodes can be distributed adaptively based on the requirement as either controlled or random. [5][6]

Issues of Sink Repositioning

It is very complex to finding an efficient strategy for optimal gateway location. They are the two characteristics of gateway that are responsible for complexity. Those are one is gateway movement and second one is temporary location finder. The first responsible characteristic for complexity is the gateway can be moved to infinite possible positions. The second responsible characteristic for complexity is the temporary location finder. We will construct the new multi-hop network topology for a solution to the temporary discovery gateway location. The new multi-hop network topology is to confirm that the current temporary solution is qualifyable than previous

temporary solution. The mathematical expression for this problem will require more parameters such as positions of all deployed sensors and state parameters like energy level and transmission range. [6][7]

How we can handle the data traffic during the gateway's movement is the most important basic issue. Given the traffic distribution and network state at that time, gateway relocation must be based on the motivation by the inefficient pattern of energy depletion or an intolerable increase in the missed deadlines whenever real time packets are used. If such condition is detected, then to enhance the network performance the gateway should identify the most suitable location. [6][7][8]

Sink repositioning techniques

Sink repositioning can be performed in the following ways.

1.2.3.1. Multiple Sink Deployment: when we are using the single sink, the reposition will be take more time. The deploying multiple sinks may decrease the average number of hops a message has to pass through and the data will always be send to the closest sink.

1.2.3.2. Sink Mobility: if a sink moves fast enough to deliver data with a tolerable delay then it is called as mobile capacity and the WSN will take the advantage of this mobile capacity. Hence with the mechanical movements, the mobile sink picks up data from nodes and transports the data. Therefore for the reduction of energy consumption of nodes, this approach trades data delivery latency.

1.2.3.3. Deploying Multiple Mobile Sinks: In this case, without delay and without causing buffer overflow, the multiple sinks are deployed so that the sensor data can be acquired. [7][8][9][10]

Literature Review

Yu-Chen Kuo et al., [11] have proposed fast sensor relocation algorithm to arrange redundant nodes to form redundant walls without GPS. Redundant walls are constructed in the position where the average distance to each sensor node is the shortest. Redundant walls can guide sensor nodes to find redundant nodes in the minimum time. When the sensor node fails, our algorithm replaces the faulty node by the cascaded movement. The main advantage of this algorithm is it can find the proper redundant node in the minimum time and reduce the relocation time with low message complexity.

Wint Yi Poe et al., [12] have proposed local search technique for sink placement in WSNs that tries to minimize the maximum worst-case delay and extend the lifetime of a WSN, simultaneously. Since it is not feasible for a sink to use global information, which especially applies to large-scale WSNs, they introduce a self-organized sink placement (SOSP) strategy. The main goal of this research is to provide a better sink placement strategy with a lower communication overhead. Avoiding the costly design of using nodes' location information, each sink sets up its own group by communicating to its n-hop distance neighbors.

Xu Xu et al., [13] have proposed an optimization framework for Placing Optimal Number of Sinks in Sensor Networks for Network Lifetime Maximization and it

improves network performance from several aspects, including the network lifetime prolongation, network scalability improvement, and the average data delivery delay reduction. Furthermore, it also enhances the network robustness substantially, since the sensing data generated by all sensors will be collected by multiple deployed sinks regardless of the network connectivity.

Hui Zhou et al., [14] have proposed a multiple dimensional tree routing protocol for multisink WSNs based on listening and ant colony optimization. The proposed protocol is as follows: (1) listening mechanism is used to establish and maintain multidimensional tree routing topology; (2) taking into consideration hops, packet losses, retransmission, and delay account, a distributed ant colony algorithm is proposed. When nodes select routes in the data transmission, the algorithm is utilized to realize the real-time optimization by coordination between nodes.

L. Friedmann et al., [15] have proposed a new dynamic approach to extend the lifetime of a sensor network based on both mobility and multiplicity of sinks. According to the evolution of the network, in terms of energy dissipation and distribution, this approach aims to find the optimal position for all the sinks in order to optimize the lifetime of the network and move accordingly these sinks in an intelligent manner.

Problem Identification

The approach which is proposed in [13] is to place Optimal Number of Sinks in Sensor Networks for improving the Network Lifetime Maximization. The main aim is to find the optimal number of sinks and their locations in a monitoring region for data gathering such that the network lifetime is maximized, subject to the following two constraints: One is that each sink can only be placed at one of the given potential sink locations.

The following drawbacks are observed in this approach:

1. In this scheme the tree is constructed using the set of sink locations and they are not considering the node energy.
2. There is no optimal searching solution when the sink is repositioned.

Overview

We propose K -Partitioned Minimum Depth Tree using the optimal search in Placing Optimal Number of Sinks in Sensor Networks for improving the Network Lifetime Maximization.

Initially the optimal number of sinks is determined using the optimal sink algorithm satisfying the h-hop constraint. Then a K-Partitioned Minimum Depth Tree (k-PMDT) is constructed for positioning multiple sink nodes and setting up the routes.

After determining the optimal number of sink positions and routing, we will select the best sink reposition by optimum search method. In optimum search, we use the local search approach and the local search approach has obtained the optimal solution, it forgot about the current sinks positions. It will solve the optimal multi-sinks position problem in a network. After finding the optimum solution, we will move the

sinks using the intelligent movement. In the intelligent movement we will limit the sinks movements while maintaining their direction to the optimal positions.

The main advantage of this method is, we are using the node life time in the construction of tree so the tree lifetime will be improved and we are placing the optimal number of sinks in sensor network for improving the network lifetime. The main advantage of K-PMDT is computation will be ended in a polynomial time.

Optimal Sink Algorithm

Using this optimal sink algorithm, the optimal numbers of sinks are selected to maximize the network lifetime. “S” is set of sinks and “ps” is set of potential sinks. The set of potential sinks are derived from the set “S”. $N_h(ps)$ is the set of neighboring sensor nodes of sink s and $N_h(ps)$ is the number of the hops from v to s is no greater than h.

The collection of sets derived by the set S of potential sink location is $C = \{N_h(ps) / ps \in S\}$. Each sensor node reach one of the chosen sinks with no more than h hops and that is equivalent to finding a sub-collection $ps \in S$. the set cover problem is NP complete problem. Instead NP complete, a greedy heuristic is employed then it delivers an approximation solution to the problem with the approximation ratio of $(\log B)$, where $B = \max_{s \in S} \{|N_h(s)|\} \leq n$.

Consider a sensor CV is referred to be covered by a sink s if the number of hops from CV to S is no more than h; otherwise, CV is uncovered by s. If the sink is uncovered means it is not covered by the sink s.

1. Start
2. Define S = set of sink
3. Input V = set of sinks covered by s
4. S = set of sink
5. ps = 0 // Initially all sensors in CV are uncovered
6. while S $\neq$ 0
7. {
8. If($S \cap N_h(ps) = \max$)
9. Select a set $N_h(ps) \in S$
10. $ps \leftarrow ps \cup S$
11. $S \leftarrow S - N_h(s)$
12. $C \leftarrow C - \{N_h(s)\}$
13. }
14. return ps
15. End

Algorithm 1: Optimal Sink Algorithm

In algorithm (1), initially all sensors in CV are uncovered and PS is set to empty. The while loop run iteratively and each time it compare the sensors in the set with the covered sensors in the list.

Example for Optimal Sink Algorithm

Consider the given diagram. S is the set and it contains all the nodes (both potential and un-potential nodes). ps is the set contain potential sets. In the optimal sink algorithm initially PS is set to empty. The algorithm runs iteratively and each time it selects the node which has high potential.

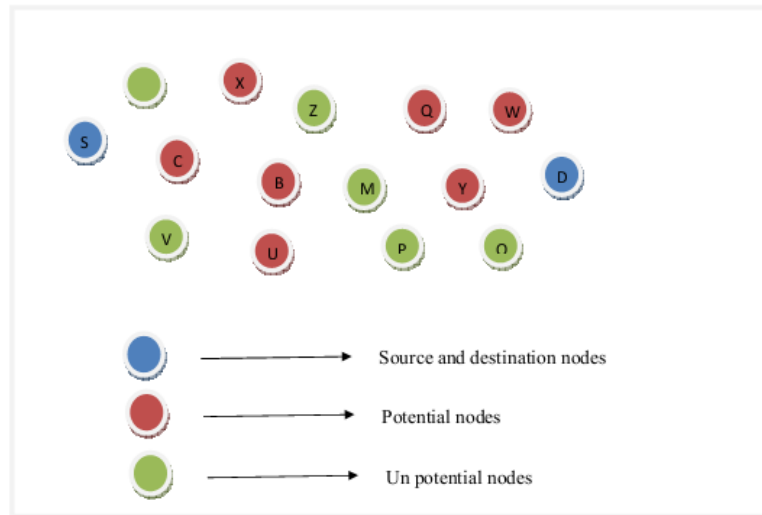


Figure 1: Example for Optimal Sink Algorithm

If the number of hops from CV to S is no more than hop count then sink covered the sensor. If the hop count is same those are nodes covered by the sink, otherwise those set to be uncovered nodes. All covered nodes are comes into the ps set.

K-Partitioned Minimum Depth Tree

K-Partitioned Minimum Depth Tree (k-PMDT) is designed for a sensor network which has multiple sink nodes and a Minimum Depth Tree (MDT) is a tree constructed, that MDT minimizes the cost from each vertex. In k-PMDT, k means the number of sink node and it divide the sensor network into k disjoint partitions.

The k-PMDT algorithm is applied on k sink nodes and for every possible combination of k sink node. The set of sink nodes which maximize $V_{\min}$ is chosen. $V_{\min}$ is the minimum volume produced at a sensor node. The k-PMDT algorithm is given below.

1. Start
2. Define
3. For ($\sum_{i=1}^k C_i \neq 0$)
4. {
5. For each sensor node in the list
6. {
7. For each sink node

8. {
9. Shortest path is calculated for each sensor node to sink node.
10. }
11. Choose the sink node as a root of the MDT which has shortest path among the all paths to several links
12. }
13. Calculate the $V_{\min}$ for each partitioned MDT using the equation (2)
14. Select the minimal $V_{\min}$ as a K-PMDT $V_{\min}$
15. }
16. Choose the best set of sink nodes which maximizes K-PMDT $V_{\min}$
17. End

Algorithm 2: k-PMDT algorithm

In k-PMDT algorithm, shortest path is calculated for each sensor node to sink node in list. For example, if there are n sensor nodes and k sink nodes. The k-PMDT algorithm runs approximately n_{C_k} times to get the best set of sink nodes.

First calculate the number of children for each sensor node in MDT and then calculate the link cost to parent. The total data volume produced at each sensor node can be calculated from the following [16]

$$V_{node} = \frac{E_i}{NC * PR + (NC + 1) * PT_{child}} \quad (2)$$

In equation (2),

E_i = Initial energy of sensor node

NC = the number of children

PR = Receiving power consumption per bit

PT = Transmitting power consumption per bit

V_{node} = the total data volume produced at sensor node

The k-PMDT algorithm solves the shortest path problem from each sensor node to a sink node. There are multiple sink nodes in the sensor network, so a sensor node calculates the shortest path to each sink node. Then, the sensor node selects one sink node as a root of the MDT which has the shortest path among the paths to several sink nodes. This process is repeated for every sensor node in the sensor network.

In the given example, MDT is formed using the potential sink nodes. The potential sink nodes are selected using the Optimal Sink Algorithm.

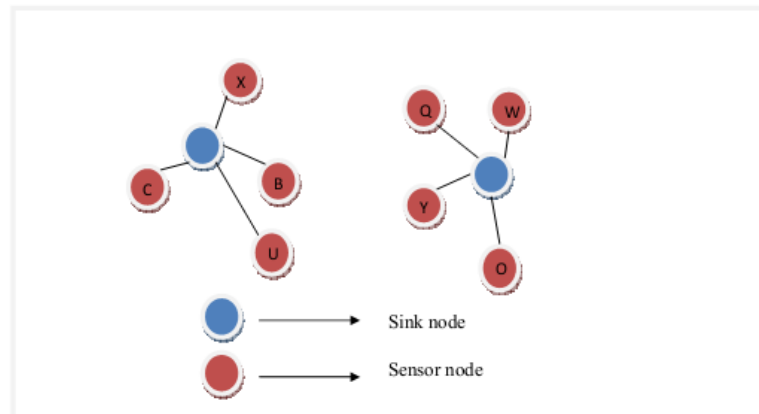


Figure 2: k-PMDT algorithm

In optimum search, we use the local search approach and the local search approach has obtained the optimal solution, it forgot about the current sinks positions. It will solve the optimal multi-sinks position problem in a network. After finding the optimum solution, we will move the sinks using the intelligent movement.

Optimum Search Method

After determining the optimal number of sink positions and routing, the best sink reposition is done by optimum search method.

In the Local Search Approach, X_0 is the initial solution and a finite series of solutions X_i is generated with a systematic change of neighborhood. X_{i+1} is derived from x_i such that for all i , $f(x_i) > f(x_{i+1})$. f is the evaluation function of the solution. There three levels of transformation to derive the neighborhood of a solution

One Sink Movement:

In this method, only one sink relocated in respect to the initial position. This movement performs in eight directions. North(N), South(S), East(E), West(W), N-E, N-W, SE, S-W.

Two Sinks Movement:

In this method, two sinks simultaneous movement to neighborhood of a solution. It avoids the deadlock situation. Using the cardinal points, the transformations are limited. Total 16 movements are possible for the couple of sinks.

Three Sinks Movement:

sinks are relocated simultaneously.

Once the optimal sinks positions found, the relocation problem of each sink to it final position big problem. The linear sink movement is costly in terms of energy constraints. Local search does not consider the sink velocity, the distance to travel, and the dynamics of the network. We proposed an approach based on a local search in a constrained space to perform an intelligent movement.

Intelligent Move:

In the intelligent move, the sink movements are limited by maintaining their direction to the optimal positions. ld is liberty space and it is based on the current and optimal locations of the sink. "G" is the point located at a distance d from the current position of the sink on the line formed by the current position "cp" and the optimal position of the sink.

Sink new target is defined as the constrained space and a local search is activated in the constrained space using the same principle used to find the optimal position. The constrained optimums are generated by constrained local search to help to perform efficient and power-aware movements towards the optimum position.

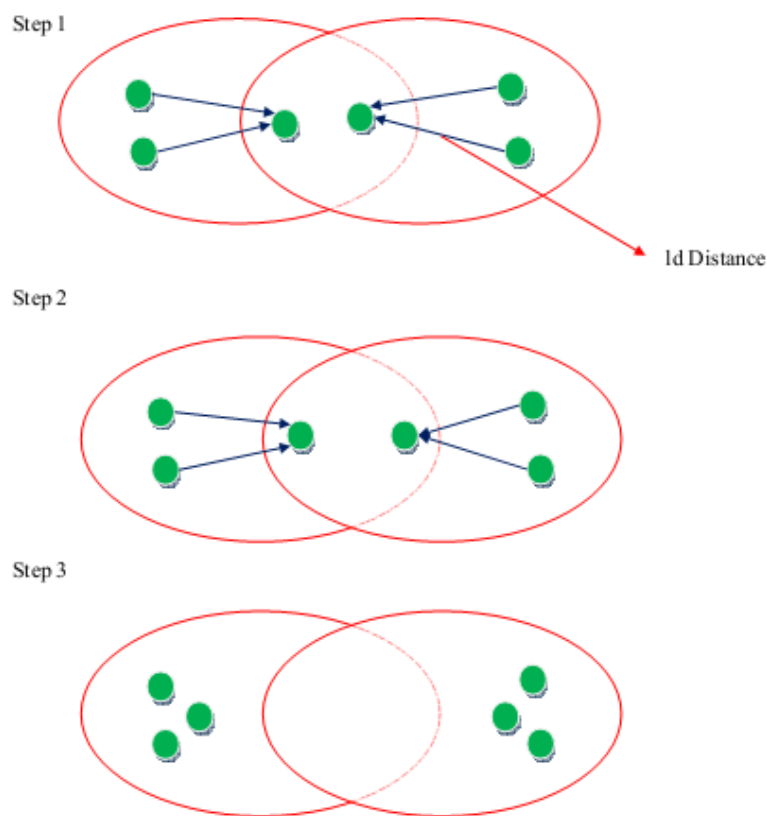


Figure 3: Sink Movements

Consider the figure (3), the sinks are there and each sink contain two nodes. The nodes between the two sinks calculate the ld distance and based on the ld distance it moves the corresponding node. The movement is based on the nearest node and optimum position with less number of moves.

Total Work Flow

Initially the optimal number of sinks is determined using the optimal sink algorithm satisfying the h-hop constraint. ps contains set of contain potential sets. The algorithm runs iteratively and each time it selects the node which maximum high potential.

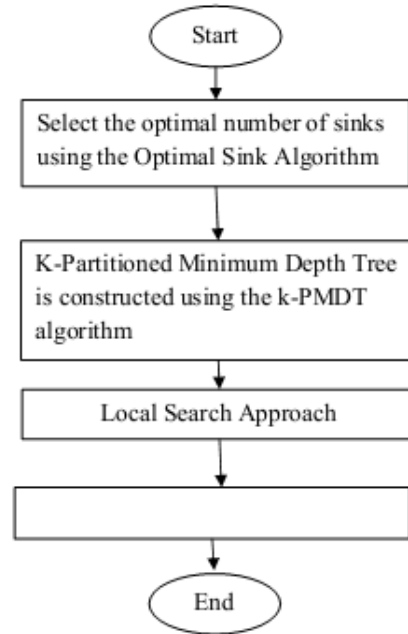


Figure 4: Total Work Flow

A K-Partitioned Minimum Depth Tree (k-PMDT) is constructed for positioning multiple sink nodes and setting up the routes. In k-PMDT algorithm, shortest path is calculated for each sensor node to sink node in list.

There are multiple sink nodes in the sensor network, so a sensor node calculates the shortest path to each sink node. Then, the sensor node selects one sink node as a root of the MDT which has the shortest path among the paths to several sink nodes. This process is repeated for every sensor node in the sensor network.

After determining the optimal number of sink positions and routing, we will select the best sink reposition by optimum search method. In optimum search, local search approach is used and the local search approach has obtained the optimal solution, it forgot about the current sinks positions. It will solve the optimal multi-sinks position problem in a network. After finding the optimum solution, it moves the sinks using the intelligent movement.

Simulation Results

Simulation Model and Parameters

The Network Simulator (NS2) [17], is used to simulate the proposed architecture. In the simulation, the mobile nodes move in a 500 meter x 500 meter region for 50 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).

The simulation settings and parameters are summarized in table.

No. of Nodes	20,40,60,80 and 100
Area Size	500 X 500
Mac	IEEE 802.11
Transmission Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Initial Energy	20.1J
Transmission Power	0.660
Receiving Power	0.035
Rate	50Kb

Performance Metrics

The proposed Multiple Sink Positioning and Relocation (MSPR) is compared with the k-PMDT technique []. The performance is evaluated mainly, according to the following metrics.

- **Packet Delivery Ratio:** It is the ratio between the number of packets received and the number of packets sent.
- **Packet Drop:** It refers the average number of packets dropped during the transmission
- **Residual Energy:** It is the amount of energy in the nodes after data transmission.
- **Delay:** It is the amount of time taken by the nodes to transmit the data packets.

Results

1) Based on Nodes

In our experiment we vary the number of nodes as 20,40,60,80 and 100.

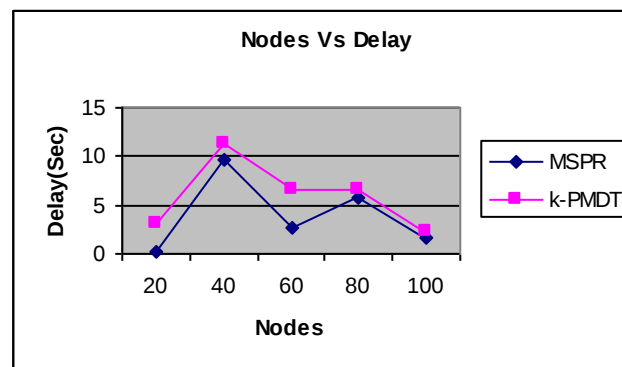


Figure 5: Nodes Vs Delay

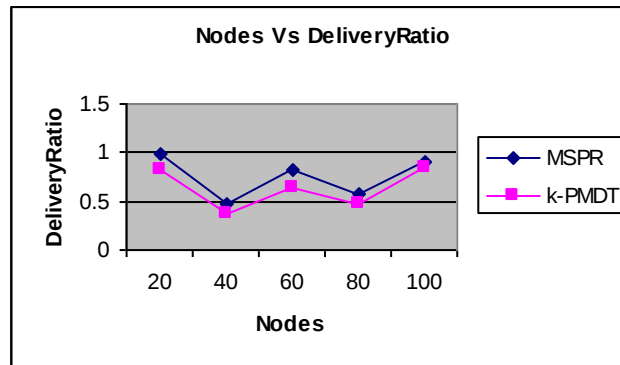


Figure 6: Nodes Vs Delivery Ratio

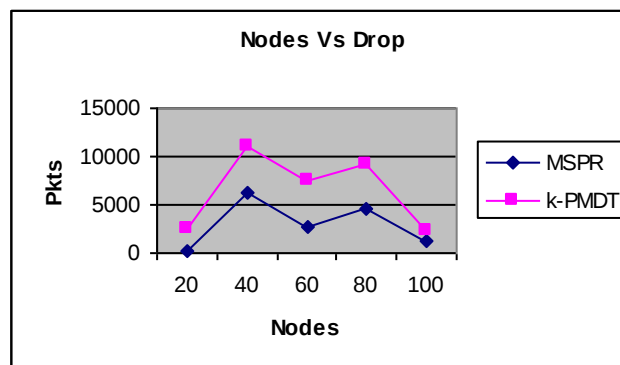


Figure 7: Nodes Vs Drop

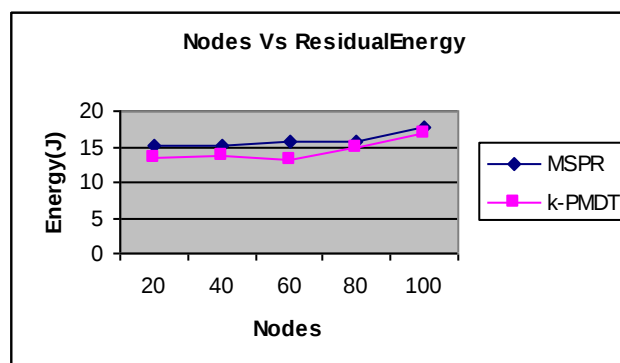


Figure 8: Nodes Vs Residual Energy

Figure 5 shows the delay of MSPR and k-PMDT techniques for different number of nodes scenario. We can conclude that the delay of our proposed MSPR approach has 42% of less than k-PMDT approach.

Figure 6 shows the delivery ratio of MSPR and k-PMDT techniques for different number of nodes scenario. We can conclude that the delivery ratio of our proposed MSPR approach has 18% of higher than k-PMDT approach.

Figure 7 shows the drop of MSPR and k-PMDT techniques for different number of nodes scenario. We can conclude that the drop of our proposed MSPR approach has 59% of less than k-PMDT approach.

Figure 8 shows the residual energy of MSPR and k-PMDT techniques for different number of nodes scenario. We can conclude that the residual energy of our proposed MSPR approach has 9% of higher than k-PMDT approach.

Conclusion

In this paper, we proposed K -Partitioned Minimum Depth Tree using the optimal search in Placing Optimal Number of Sinks in Sensor Networks for improving the Network Lifetime Maximization. Initially the optimal number of sinks is determined using the optimal sink algorithm satisfying the h-hop constraint. Then a K-Partitioned Minimum Depth Tree (k-PMDT) is constructed for positioning multiple sink nodes and setting up the routes. After determining the optimal number of sink positions and routing, best sink reposition is selected by optimum search method. Sink movement is done by using the intelligent movement and it limit the sinks movements while maintaining their direction to the optimal positions. The main advantage of this method is, using of node life time in the construction of tree the tree lifetime will be improved and the optimal numbers of sinks are placed in sensor network for improving the network lifetime. The main advantage of K-PMDT is computation will be ended in a polynomial time.

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