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Mitigation of Hotspot Problem in Wireless Sensor Networks

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Abstract
In multi-hop wireless sensor networks that are characterized by many-to-one (converge-cast) traffic patterns, problems which are related to energy imbalance among sensors often appear. When the range of transmission is not dynamic for nodes throughout the network, the amount of traffic that sensors are required to spread increases rapidly as the distance to the data sink becomes lesser. Thus, sensors closest to the data sink have less life time, leaving areas of the network completely unmonitored and causing network partitions. Alternatively, if the entire number of sensors transmits the information to the data sink directly, the furthest nodes from the data sink will die much more quickly than those close to the sink. Average lifetime can be enhanced to a restricted degree by the utilization of a more astute transmission control strategy that makes an adjust of the vitality utilized as a part of every hub by requiring hubs more far from the information sink to transmit over more prominent separations (in spite of the fact that not specifically to the information sink).However, transmission power control alone is not enough to solve the hot spot problem. Rather, policies such as data sink movement or data aggregation are necessary for the network to operate in an energy efficient manner. Since the development of the information sinks and the organization of an aggregator hub might be essentially more costly than the arrangement of a normal small scale sensor hub, there is a cost exchange off included in both of these methodologies.
The present algorithms for cluster head election from among the nodes which transfers data to the data sink, mainly has two problems associated with it. Firstly it does not consider the location of the base station from where the sensor nodes originate. Secondly in case of multi hop transmission there is the hotspot problem associated with it, which means that due the limited energy supply of the sensor nodes, the nodes which are located near the target sink gets their battery energy drained out very fast as the data transmitted from the remote nodes to the target sink always pass through the limited number of nodes located nearest to the sink in case of multi hop transmission.
General belief about cluster based WSNs is that in that order to alleviate hotspot problem ,clusters located near to the sink should be smaller in size than the ones further from the sink. Other responsible factors that may affect the lifetime of the network are the number of the tiers, node density and communication radio coverage radius. All these parameters are examined for all possible combinations in detail.

Keywords: Sensor node, mesh, djisktra, clustering, single hop, multi-hop, Efs, Emp, target sink, hotspot

Introduction
Large scale wireless sensor networks are a developing innovation that has as of late picked up consideration for their potential use in applications, for example, natural detecting and portable target following. Since sensors normally work on batteries and are in this way constrained in their dynamic lifetime, the issue of outlining conventions to accomplish vitality productivity to broaden organize lifetime has turned into a noteworthy worry for system creators. Much consideration has been given to the lessening of pointless vitality utilization of sensor nodes in territories, for example, equipment plan, synergistic flag handling, transmission control polices, and all levels of the system stack. In any case, decreasing an individual sensor's energy utilization alone may not generally enable Networks to understand their maximal potential lifetime. What's more, it is imperative to keep up adjust of power utilization in the network so that specific hubs don't bite the dust

considerably sooner than others, prompting unmonitored territories in the network.

Past research has demonstrated that due to the attributes of wireless channels, multi-jump sending between an information source and an information sink is regularly more vitality proficient than direct transmission. In view of the power model of a particular Sensor hub stage, there exists an ideal transmission go that limits general power utilization in the Network. When utilizing such a settled transmission go by and large ad hoc networks, vitality utilization is genuinely adjusted, particularly in mobile networks, since the information sources and sinks are normally thought to be conveyed all through the zone where the network is sent. Be that as it may, in sensor networks, where numerous applications require a many-to-one (unite cast) movement design in the network, vitality awkwardness turns into an essential issue, as a hot spot is made around the data sink, or base station. The nodes in this hot spot are required to forward an excessively high measure of activity and ordinarily bite the dust at an early stage.

I. On the off chance that we characterize the network lifetime as the time when the principal sub-district of the earth (or a critical segment of nature) is left unmonitored, then the leftover vitality of alternate sensors as of now can be viewed as squandered. Instinct persuades that the hot spot issue can be understood by fluctuating the transmission run among Nodes at various separations to the base station so that vitality utilization can be all the more uniformly appropriated and the lifetime of the network can be amplified. In any case, this is just consistent with some degree, as vitality adjusting must be accomplished to the detriment of utilizing the vitality assets of a few nodes wastefully. We finish up from our review that transmission control can mitigate the hot spot issue just to a certain point, and option arrangements are important for the network to work in a more vitality effective way. In this paper, we plan the transmission run conveyance enhancement issue and investigate the points of confinement of network lifetime for consistently sent wireless sensor networks, which are effectively gotten by utilizing a down to earth vitality related heuristic arrangement.

In any case, as ideal transmission go appropriation can't completely tackle the hot spot issue, we investigate two option procedures: the work of numerous data sink areas, actualized by utilizing either a portable data sink or a few sinks conveyed amid the underlying network organization, and the arrangement of data aggregation clusters. We research the viability of these strategies in mix with the improvement of transmission range dispersion to decide their adequacy in augmenting network lifetime. Since applying these systems amid network arrangement may present additional costs, we investigate the exchange of between utilizing these more propelled arrangements and the cost, and we propose cost proficient recommendations for pragmatic sensor organizations. Whatever is left of this paper is composed as takes after. Segment II addresses related work. Area III audits the transmission power control issue and investigates its viability in relieving the hot spot issue. Area IV examines the viability and cost proficiency of information sink development and the arrangement of numerous aggregator hubs, individually, as option answers for the hot spot issue. Segment V closes the paper.

Literature Survey

These papers talk about the essentials of wireless sensor networks. Amir and Siraj (2013) proposed an exploration hypothesis on Wireless Sensor Network Technology. As Wireless Sensor innovation enhances; an expanding number of associations are utilizing it for an extensive variety of purposes. ZigBee innovation is another standard in Wireless Personal Area after Bluetooth. After a prologue to this innovation, another remote meter-perusing framework in light of ZigBee Protocol has developed. This framework, which is involved ZigBee Network and Database Management System, has numerous vital points of interest, for example, minimal effort, low power utilization, and low date rate. Venkateswarlu e.t al (2014) proposed a hypothesis on Zone based steering Protocol for Wireless Sensor Networks, which is really an honorable vitality based zone based directing Protocol. To stay away from problem area issue in customary bunching techniques, unequal grouping instrument has been presented. Legitimate system configuration space with effective grouping procedure could tackle the issue. Jones e.t al (2014) recommended that as remote administrations keep on adding more abilities, for example, media and QoS, low-control configuration stays a standout amongst the most essential research ranges inside remote correspondence. Inquire about must concentrate on diminishing the measure of energy devoured by the remote terminal.

These papers examine about energy utilization issues identified with Wireless Sensor Networks. Zahhad e.t al (2015) suggested that Energy utilization in WSNs is critical because of constraint of energy sources. In their paper, a review of WSNs obliges and judgment measurements, for example, lifetime and idleness are given. Additionally, they have given a prologue to wellspring of vitality utilization at each layer. Seah e.t al suggested that remote sensor organizes that are controlled by encompassing vitality collecting is a promising innovation for some detecting applications as it wipes out the need to supplant batteries. Moreover, the capacity to collect vitality from the earth is exceedingly reliant on numerous natural variables and these need additionally research to comprehend and abuse. Renner proposed energy-mindful planning, or energy budgeting, is a developing examination region of energy-gathering sensor networks. His proposal added to that field in three ways. Models for foreseeing the rest of the vitality of super capacitors, which are as often as possible utilized for vitality stockpiling in reaping gadgets, are produced and surveyed.

These papers talk about the natural checking difficulties and its answer. Roseline and Sumathi (2014) proposed the way that ecological observing utilizing sensor networks shares some regular issues and essential difficulties that specialists are confronted with today, that incorporate immense measure of Data created each day. Saba Akbari proposed (2014) that it is important to note that frameworks for collecting and putting away energies should be outlined in view of the mix of at least two wellsprings of option vitality. For example, for those electronic frameworks performing outside, solar and wind Energies can be considered as hotspots for fueling the gadgets or on account of low power electronic gadgets found indoor, radio waves and warm vitality can be assigned. Shi al (2013) suggested that by utilizing discretization and a novel reformulation-linearization system, one can build up a provably close ideal answer for any coveted level of precision. Utilizing numerical outcomes, they exhibited the capacity of multi-hub Wireless Energy move innovation in tending to the versatility issue in a WSN. Habibullah e.t al proposed (2016) that the improvement of Energy utilization by system frameworks has huge negative effect on manageability which ought to be controlled.

Barbarossa and Gesualdo (2014) suggested that there exists an ideal transmit control that limits the general vitality utilization important to accomplish the worldwide gauge inside a given exactness and that this power relies on upon the system topology. Morreale e.t al (2013) showed that general execution of the usage of the prescient model has been certain. Expectations are exact to a differing degree, notwithstanding any sudden natural move. Kavya e.t al (2015) proposed thorough examination of distributed computing, its antagonistic impacts on the earth and how it can be decreased by observing utilizing WSN. By utilizing this procedure one can diminish the discharge of Carbon Di-oxide to a maintainable degree.

Nedevschi e.t al(2014) proposed the plan and assessment of basic power administration calculations that adventure these states for vitality preservation and demonstrate that – with the correct equipment bolster – there is the potential for sparing much vitality with a little and limited effect on execution, e.g., a couple of milliseconds of postponement.

These few papers talk about the vitality proficient bunching arrangements of remote sensor systems. Dali Wei and Yachio Jin (2013) proposed a vitality productive grouping arrangement on Wireless Sensor Networks. This paper proposes an appropriated bunching calculation, Energy-effective clustering (EC) that decides reasonable group sizes relying upon the bounce separation to the information sink, while accomplishing rough evening out of hub lifetimes and lessened vitality utilization levels. Wankhade e.t al (2016) proposed an exploration paper on Energy productive unequal grouping calculation for Wireless Sensor Networks. Novel energy efficient unequal clustering calculation for bunched Wireless Sensor Network is proposed, the choice of choosing group heads by the sink depends on the lingering vitality and separation to the base station, plus, and the group head likewise chooses the most brief way to achieve the sink. Recreation comes about demonstrate that our approach upgraded the execution than customary steering calculations, for example, LEACH and EEUC. Preeti and Geetika (2016) proposed the clustering approaches on Wireless Sensor Networks. Clustering comprises of number of points of interest like lessening the deferral, vitality productive, versatile and so on. In clustering hubs are separated into bunches through clustering algorithms and each cluster chooses its cluster set out toward data aggregation. Calculations can be equivalent clustering algorithm or unequal clustering algorithm.

These papers are identified with methodologies for mitigating the Hotspot Problem. Dilip Kumar and RB Patel (2010) proposed an examination paper on Multi-jump information correspondence for bunched Wireless Sensor Networks. In this paper, we tended to the issue of building up a vitality effective multi-bounce information correspondence calculation (MDCA) for bunched heterogeneous Wireless Sensor Networks (WSNs). The multi-jump correspondence approach is received for both intra-group and between bunch correspondence components. At long last, recreation comes about demonstrate that MDCA can significantly adjust vitality utilization of a whole Network and in this way broadens the network lifetime and soundness over EEHC and MLCRA, separately. Perillo e.t al (2014) proposed procedures for mitigating the Hotspot Problem. In multi-bounce Wireless Sensor Networks that are portrayed by many-to-one (meet cast) activity designs, issues identified with vitality awkwardness among sensors frequently show up. At the point when the transmission range is settled for hubs all through the system, the measure of movement that sensors are required to forward increments drastically as the separation to the data sink ends up noticeably littler. Rivas e.t al (2014) proposed the problem area issue in remote sensor systems is brought on by the way that the sensor hubs around the base station need to forward a larger number of parcels to the base station than different hubs. In this way, these hubs conceivably come up short on vitality initially shaping a basic range. Since it is by and large accepted that sensor hubs will end up noticeably cheap a straightforward answer for this issue is to include supplementary hubs in the problem area region.

Devika e.t al (2014) proposed to keep the Hotspot Problem by utilizing the super clustering mechanism. Clusters are framed by utilizing the separation trait. The proposed algorithm gives versatility and data aggregation. Adaptability is better when contrasted with the immediate transmission technique and cluster transmission strategy. Accumulation decreases the repetition of information. The execution of the algorithm is assessed through recreation. In the proposed technique all hubs are considered by separation parameter. Balamurali and Kathiravan (2016) proposed the Hot-spot issue in WSN and proposed a basic and productive calculation to relieve the problem area impact and to enhance the general system life-time. The arrangement proposed is an exchange off between number of sensor hubs in every level and the general life-time of the WSN.

Drawbacks of Existing Algorithm

In the previous papers we saw till now that the minimum wasted energy for data transmission from a particular node to the target sink used the greedy algorithm to compute or some other energy efficient clustering algorithm. In this paper we use djisktra’s algorithm to compute the path for multi hop data transmission through the sensors nodes with least energy consumption. We connect the edges between all possible nodes and compute the costs of the edges given by the formula discussed in Section of Problem Formulation, and then calculate the shortest path from source node to target sink using Djisktra’s because:

Finds shortest path in O (E+ V Log (V)) if you use a minimum priority queue.

The time complexity of the algorithm is much less, so it will be greatly useful and much faster in case of comparing the energy consumptions of several nodes in a relatively larger Wireless Sensor Network.

Its only limitation is that it cannot use negative weights, however it is not applicable here since wasting energy cannot be negative

Previous Papers did not consider the shortest path from a single node to all other nodes in the same or different cluster, however in Djisktra,s algorithm we find the minimum energy for all the cases.

Problem Formulation

Assuming there are n sensor nodes distributed in a wireless sensor networks.

The total number of clusters is equal to x, and from the formula we calculate firstly the energy required to transmit L bits of data over a distance d to the destination sensor nodes.

We also calculate for each sensor node Popt the optimal probability to be a cluster head.

We assume the threshold distance of any sensor node to the cluster head is d0 and we also compute experimental the energy dissipated per bit to run the transmitter.

We calculate the total energy consumed altogether by the cluster heads and non-cluster heads.

Finally we calculate the optimal number of clusters Xopt which will be helpful in mitigating the hotspot problem from the respective WSN Considering the sensor nodes being uniformly dispersed (Dilip and Patel, 2011).

The parameters E_f and E_m are energy dissipation factors in the power amplifier for free space and multipath fading channel propagation models respectively.

E_f - This is the power consumption in free space propagation. It is proportional to d^2 power loss.

E_m- This is the power consumption in multipath propagation. It is proportional to d^4 power loss.

We use the free space or the multi path model depending on the distance between the source node and destination target sink.

$$E_T(L,d) = L*(E_{el} + E_f * d^2) \quad if\ d \le d_0$$
$$L*(E_{el} + E_m * d^4) \quad if\ d >= d_0 \quad \text{.....................................(1)}$$

Where,

$E_T(L,d)$ - Energy to transmit “L” bits of data over a distance “d”.

E_{el} - Energy dissipated per bit to run the transmitter, or the energy for driving electrons.

$$d_{BS}^2 = \int_A (x^2 + y^2) \times \frac{1}{A} = 0.765 \times \frac{M}{2}.$$

d_0 - Minimum distance of any node from CH (cluster head).

D_0= (E_{fs}/E_{mp})^(0.5) ----------- (2)

$$E_C = (\frac{n}{x} - 1) * L * E_{el} + \frac{n}{x} * L * E_{da} + L * E_{el} + L * E_f * d_{BS}{}^2 \quad \text{-------------------------- (3)}$$

Where,

E_C - energy dissipated in the CH(cluster head) node in a round.

E_{da} - processing cost of a bit

x - number of clusters.

d_{BS} - average distance between cluster head and sink.

n- Number of nodes.

A – area of x-y plane over which wireless sensor network is distributed.

$$E_{NN-CH} = L * E_{el} + L * E_f * d_{CH}{}^2 \quad \text{--- (4)}$$

$$d_{CH}^2 = \int_0^{x_{max}} \int_0^{y_{max}} (x^2 + y^2) \times \rho(x,y)\,dx\,dy = \frac{M^2}{2\pi k}, \quad \text{-- (5)}$$

Here,

P(x, y) is the node distribution over the x-y plane.

d_{CH} - Average distance between cluster member and cluster head.

Total energy dissipated in Wireless Sensor Networks

$$E_{tot} = E_C + E_{NN-CH} \quad \text{-- (6)}$$

Optimal number of clusters

$$x_{opt} = \sqrt{\frac{n}{2\pi}} \sqrt{\frac{E_f}{E_m}} \frac{M1}{d_{BS}{}^2} \quad \text{-- (7)}$$

Where,

$$M1 = \sqrt{2\pi x} * d_{CH} \qquad (8)$$

AND

$$P_{opt} = \frac{1}{0.765}\sqrt{\frac{2}{n\pi}} * \sqrt{\frac{E_f}{E_m}} \qquad (9)$$

P_{opt} - optimal probability to become a CH(cluster head)

Proposed work

Hotspot problem in inter-cluster or intra-cluster node communication. Here in single-hop communication the further member nodes or CHs tend to deplete their battery faster than other nodes. In a multi-hop communication the main problem that occurs while transferring the data is that the energy of the sensor nodes close to the target sinks gets drained out very quickly. So this paper comes up with a solution to the hotspot problem that occurs during single hop and multi hop communication of inter-cluster nodes or intra-cluster nodes.

In Multi-hop Communication

We use the data transmission in Wireless Sensor Networks (WSN) by the directed weighted graph (shortest path method) using the djisktra's algorithm. Considering there are n sensor nodes distributed in a wireless sensor network. We have to transmit data from a particular node to the target sink. It occurs in multiple hops. So we assume a directed weighted graph where the nodes represent the vertices and the line connecting the nodes represents the edges. The weight of the edges Wij can be calculated from the formula given below. After calculating the weights of all the possible edges in the network, we will apply the djisktra's algorithm to find the shortest path from the source to destination. This will result in the minimum amount of energy consumed.

Here in the set of nodes in the wireless we use the optimal number of clusters which we derived from the previous formula

So X= {x1, x2, x3…., Xopt}

V= {n_1,n_2,n_3,……n_n}

$$G = \{V, E\}$$

V - set of sensor nodes in a cluster of nodes

E - set of edges connecting the nodes.

If V_i and V_j are the two nodes of Wireless Sensor Networks (WSN) for edge e(V_i , V_j) , W(e)= W_{ij}

W_{ij} - Weight of e

Here W_{ij} = wasting energy of node of node V_i

If V_i transfers data to V_j

d_0 - Minimum distance of any node from CH (cluster head).

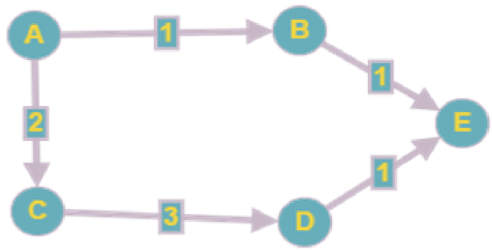
$$W_{ij} = L*(E_{ele} + E_f * d_{ij}^{\,2}) \quad if d_{ij} \le d_0 \qquad (10)$$

$$L*(E_{ele} + E_m * d_{ij}^{\,4}) \quad if\ d_{ij} >= d_0 \qquad (11)$$

Similarly V_j is the second hop node to transfer node to V_f

$$W_{jf} = 2*L*(E_{el} + E_f * d_{ij}^{\,2}) \quad if d_{ij} \le d_0 \qquad (12)$$

$$2*L*(E_{el} + E_m * d_{ij}^{\,4}) \quad if\ d_{ij} >= d_0 \qquad (13)$$



Here A,B,C,D,E are the sensor nodes of the graph and the edges are joined with the weights 1,2,3 given which is actually the wasting energy consumed in order to transmit the data.

Proposed Methodology

Algorithm

Let G={V,E} be the directed weighted graph where V represents the set of vertices or the sensor nodes distributed over the Wireless Sensor Networks. E represents the set of edges between the sensor nodes.

V1-initial sensor node containing the data.

EdgeCost (u, w) - It represent the weights of the edges between the nodes of u and w. The weights actually represent the amount of wasting energy in order to transfer data bits. The weights are calculated by the formula:

$$W_{ij} = L*(E_{el} + E_f * d_{ij}^{\ 2}) \quad if d_{ij} \le d_0$$ -------- from (10)

$$L*(E_{el} + E_m * d_{ij}^{\ 4}) \quad if\ d_{ij} >= d_0$$ -------from (11)

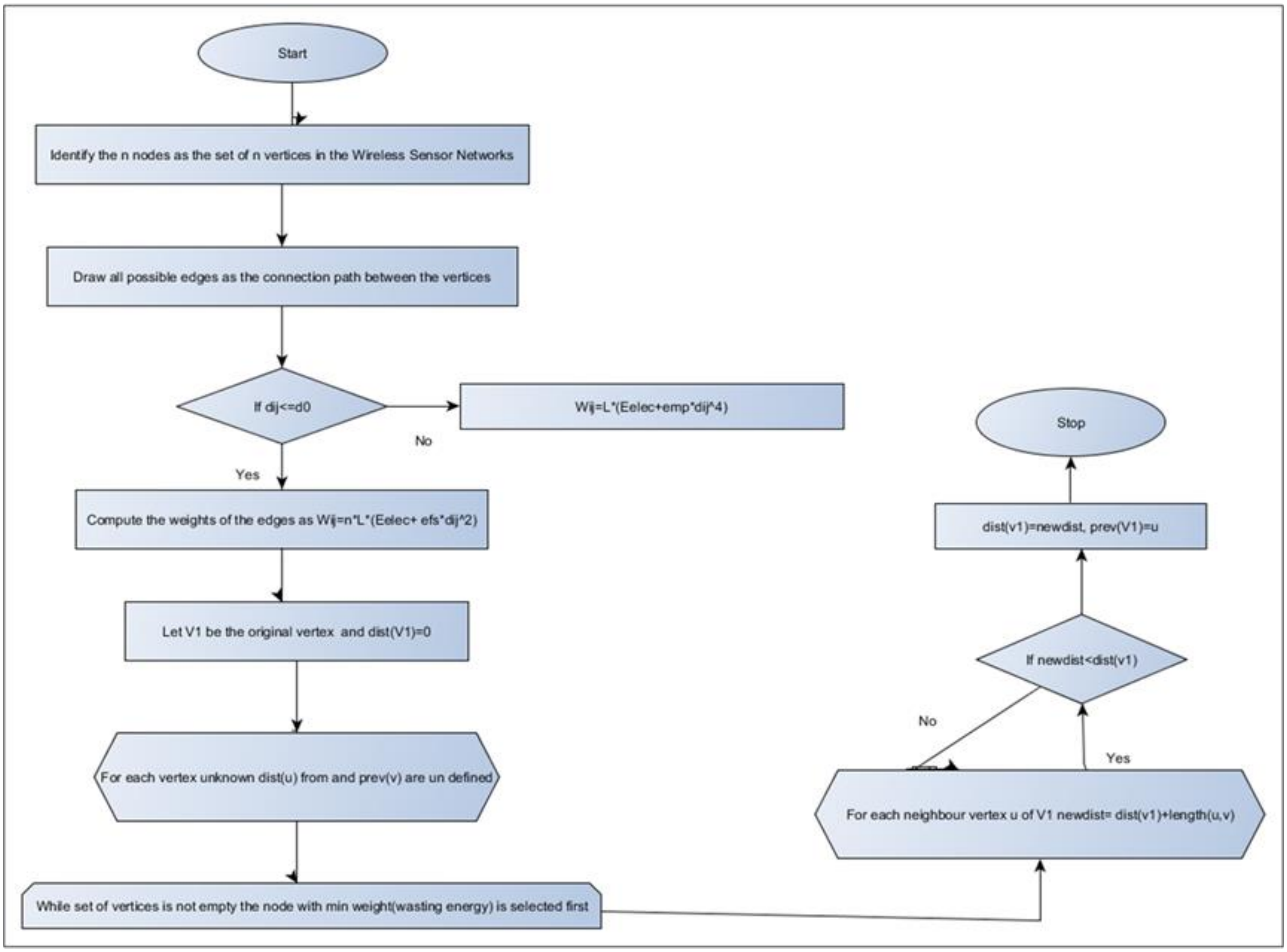
Here d_0 is the minimum threshold weight between two nodes in a distributed Wireless Sensor Networks

Procedure (V: set of vertices 1· · n {Vertex 1 is the source}
Adj[1· · · n] of adjacency lists;
Edge Cost (u, w): edge-cost functions ;)
Var: sDist [1· · n] of path costs from source (vertex 1);
// Let v1 be the origin vertex,
// and initialize W and ShortDist[u] as
W: = {v1}
ShortDist[v1] :=0
FOR each u in V - {v1}
ShortDist[u] := T[v1,u]
// Now repeatedly enlarge W
// until W includes all verticies in V
WHILE W < V
// Find the vertex w in V - W at the minimum distance
// from v1
MinDist: = INFINITE
FOR each v in V - W
IF ShortDist[v] < MinDist
MinDist = ShortDist[v]
w := v
END {if}
END {for}
// Add w to W
W: = W U {w}
// Update the shortest distance to vertices in V - W
FOR each u in V - W
ShortDist[u]:= Min (ShorDist[u],ShortDist[w] + T[w,u])
END {while}

The function returns minimum wasted energy in order to send a data frame from a particular node to a target sink in a Wireless Sensor Network.

The function also traces the shortest path in terms of energy consumption from the source node to the target sink.

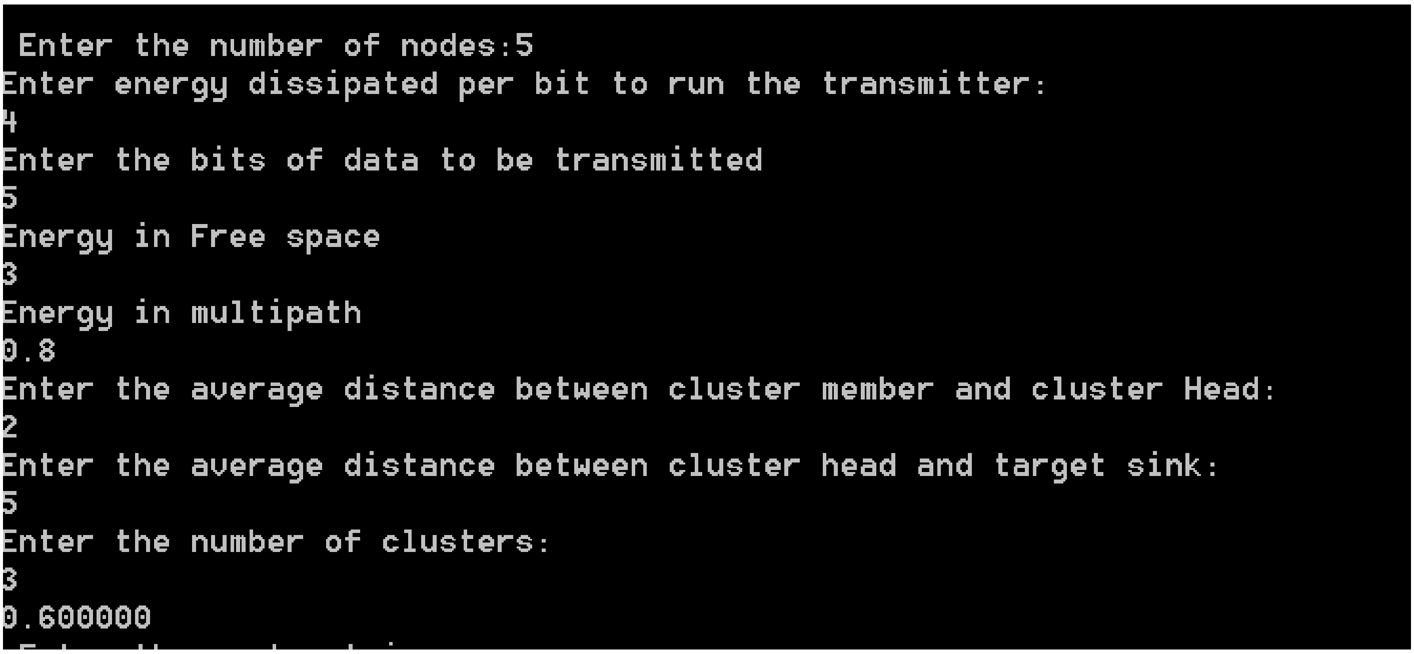
Flowchart



Code

```
// Application of Djisktras algorithm  in finding the shortest wasting energy path from source node to destination target sink
#include "stdio.h"
#include "conio.h"
#define infinity 999
void dij(int n,int v,float cost[10][10],float dist[])
{
int i,u,count,w,flag[10],min;
for(i=1;i<=n;i++)
flag[i]=0,dist[i]=cost[v][i];
count=2;
while(count<=n)
{
min=99;
for(w=1;w<=n;w++)
if(dist[w]<min && !flag[w])
min=dist[w],u=w;
flag[u]=1;
count++;
for(w=1;w<=n;w++)
if((dist[u]+cost[u][w]<dist[w]) && !flag[w])
dist[w]=dist[u]+cost[u][w];
}
}
void main()
{
int n,v,i,j,L,Eelec;
int Dch;
int Dbs,x;
float cost[10][10],dist[10];
printf("\n Enter the number of nodes:");
scanf("%d",&n);
printf("Enter energy dissipated per bit to run the transmitter:\n");
scanf("%d",&Eelec);
printf("Enter the bits of data to be transmitted\n");
scanf("%d",&L);
float Efs, Emp;
printf("Energy in Free space\n");
scanf("%f",&Efs);
printf("Energy in multipath\n");
scanf("%f",&Emp);
float d0=pow(Efs/Emp,0.5);
printf("Enter the average distance between cluster member and cluster Head:\n");
scanf("%d",&Dch);
printf("Enter the average distance between cluster head and target sink:\n");
scanf("%d",&Dbs);
printf("Enter the number of clusters:\n");
scanf("%d",&x);
float
Xopt=pow((n/(2*3.14)),0.5)*d0*Dch*pow((2*3.14*x),0.5)
/(Dbs*Dbs);
printf("%f",Xopt); // Rounded of to the nearest whole number
printf("\n Enter the cost matrix:\n");
for(i=1;i<=n;i++)
for(j=1;j<=n;j++)
{
scanf("%d",&cost[i][j]);
if(cost[i][j]<=d0)
{
cost[i][j]=L*(Eelec+Efs*pow(cost[i][j],2));
}
else
cost[i][j]=L*(Eelec+Emp*pow(cost[i][j],4));
if(cost[i][j]==0)
cost[i][j]=infinity;
}
printf("\n Enter the source matrix:");
scanf("%d",&v);
dij(n,v,cost,dist);
printf("\n Path with least energy wastage:\n");
for(i=1;i<=n;i++)
if(i!=v)
printf("%d->%d,cost=%f\n",v,i,dist[i]);
getch();
}
```

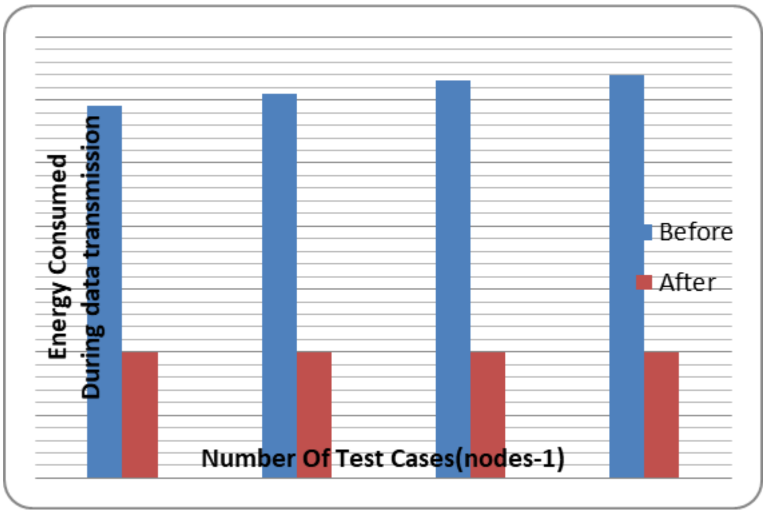
Results and Conclusion

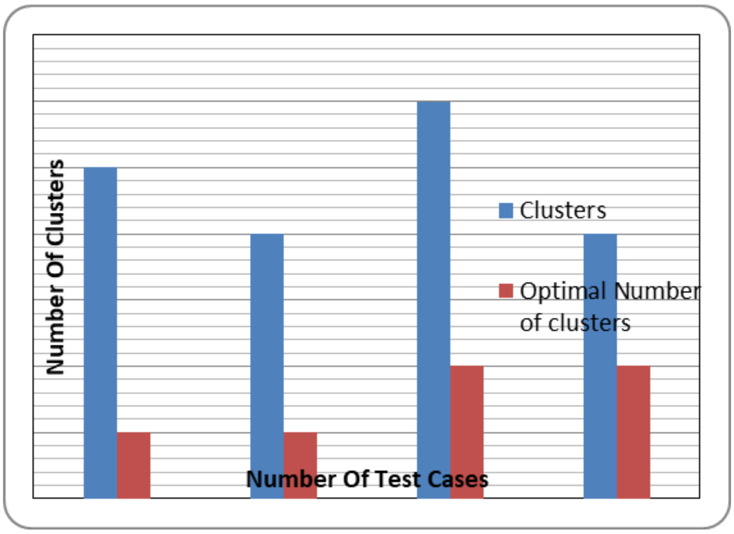


```
Enter the cost matrix:
5
4
3
4
5
6
3
4
5
3
4
5
6
7
6
56
4
5
6
5
7
8
6
4
3

Enter the source matrix:3

Path with least energy wastage:
3->1,cost=20.000000
3->2,cost=20.000000
3->4,cost=20.000000
3->5,cost=20.000000
```





In this program we actually found out the optimal number of clusters for varying number of nodes which were unequally clustered, and from the formulas given in the problem formulation section we actually compute the original wasted energy for each edge connecting the sensor nodes. The first graph demonstrates the results for the lesser amount of energy consumed after using the djkistra's shortest path algorithm in comparison to the amount wasted energy before applying the algorithm. The first bars in every test case represents the energy consumed before in comparison to the second bar which represents the amount of energy consumed after.

This algorithm basically equalizes the amount of wasted energy to the minimum amount of enrgy which remains the for every node from a source node for a particular case. The X-axis in the first graph represents the comparison of the wasted energy during data transmission for a particular node X to node 1,2 ,3…n-1 in a series of n nodes in a WSN. Each of the two bars represent the amount of wasted energy for data transmission from node x to node i(varying from 1 to n-1) before and after apllying the shortest path respectively. In second graph the x-axis represent the test cases and is just a comparsion to the original to optimal number of clusters for various number of clusters.

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