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Design Optimization of Energy and Time Delay Efficient Wireless Sensor Network by Least Spanning Tree Algorithm

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Abstract

In this paper we propose different type of topology and techniques for making an energy efficient WSN with least time delay approach .WSNs are used in defence field where least time delay and life of sensors are most important because the life of soldier depends on fast information transmission. Hence energy and time delay are very scarce resources for such sensor systems and has to be managed wisely in order to extend the life of the sensors and minimizing time delay for the duration of a particular mission. In past a lot of cluster based algorithm and techniques were used. In this paper we also find out all type of algorithm, their application and limitation and present techniques to overcome the problems of low energy and time delay of sensor and compare them with least spanning tree based algorithms and techniques.

Keyword: WSN, Least Spanning tree, clustering

I. INTRODUCTION

Advances in sensor technology, low-power electronics, and low-power radio frequency (RF) design have enabled the development of small, relatively inexpensive and low-power sensors, called micro sensors[1] The emerging of low power, light weight, small size and wireless enabled sensors has encouraged tremendous growth of wireless sensors for different application in diverse and inaccessible areas, such as military, petroleum and weather monitoring. These inexpensive sensors are equipped with limited battery power and therefore constrained in energy [4]. One of the fundamental problems in wireless sensor network is to maximize network lifetime and time delay in data transmission. Network lifetime is defined as the time when the first node is unable to send its data to base station. Data aggregation reduces data traffic and saves energy by combining multiple incoming packets to single packet when sensed data are highly correlated. In a typical data gathering application, each node sends its data to the base station, that can be connected via a wireless network. These constraints require innovative design techniques to use the available bandwidth and energy efficiently. Energy usage is an important issue in the design of WSNs which typically depends on portable energy sources like batteries for power .WSNs is large scale networks of small embedded devices, each with sensing, computation and communication capabilities. They have been widely discussed in recent years.

Coverage is one of the most important challenges in the area of sensor networks. Since the energy of sensors are limited, it is vital to cover the area with fewer sensors. Generally, coverage in sensor networks is divided into area coverage, point coverage, and boundary coverage subareas. Coverage does not ensure connectivity of nodes. In WSNs the sensor nodes are often grouped into individual disjoint sets called a cluster, clustering is used in WSNs, as it provides network scalability, resource sharing and efficient use of constrained resources that gives network topology stability and energy saving attributes. Clustering schemes offer reduced communication overheads, and efficient resource allocations thus decreasing the overall energy consumption and reducing the interferences among sensor nodes. A large number of clusters will congest the area with small size clusters and a very small number of clusters will exhaust the cluster head with large amount of messages transmitted from cluster members.

II. BACKGROUND

There are various algorithms which are used for the energy efficiency of wireless sensor network which are improved time to time by different authors; some important and useful algorithms are shown in figure 1.1.

III. SYSTEM MODEL

For the construction of an energy and delay efficient WSN we make a system model. In this model have a radio power model, energy consumption distribution with respect to node to node distance, traffic and number of hopes.

A) Radio Power Model and Characteristic Distance

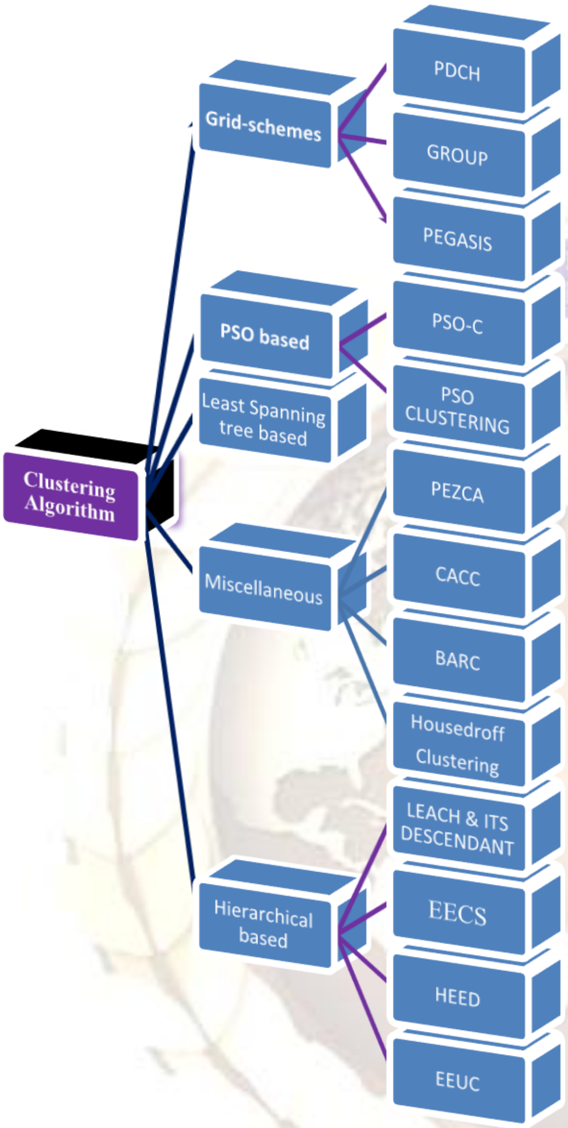

Fig.1.1 Different types of algorithm

For a simplified power model of radio communication, the energy consumed per second in Transmission is:

$$E_t = (e_t + e_d r^n)B \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where e_t is the energy/bit consumed by the transmitter electronics (including energy costs of imperfect duty cycling due to finite startup time), and e_d accounts for energy dissipated in the transmit op-amp (including op-amp inefficiencies). Both e_t and e_d are properties of the transceiver used by the nodes, r is the transmission range used. The parameter n is the power index for the channel path loss of the antenna. This factor depends on the RF environment and is generally between 2 and 4. *B* is the bit rate of the radio and is a fixed parameter in our study.

On the receiving side, a fixed amount of power is required to capture the incoming radio signal

$$E_r = e_r B \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

For currently available radio transceivers are e_t=50x10-9 J/bit, e_r=50x10-9 J/bit, e_d=100x10-12 J/bit/m2 (for n=2) and *B*=1Mbit/s. Since the path loss of radio transmission scales with distance in a greater-than-linear fashion, the transmission energy can be reduced by dividing a long path into several shorter ones. However, if the number of intermediate nodes is very large then the energy consumption per node is dominated by the term e_t in equation (1) and the receiving energy consumption hence an optimum exists. Intermediate nodes between a data source and destination can serve as relays that receive and rebroadcast data. Let us consider multi-hop communication in a finite one dimensional network from the source to the base station across a distance *d* using *k* hops. The source at *x*=*d* will generate traffic of *A* Erlang, so that each intermediate node receives and transmits the same traffic, *A*. The routing nodes are assumed to be regularly spaced and to consume no energy while idle. The power consumed by this communication is then simply the sum of the transmit and receive energies multiplied by the effective bit rate, *BA*, and is given by

$$P = \sum_{i=1}^{k} (e_t + e_d r_i^n + e_r)BA \ldots\ldots\ldots\ldots\ldots (3)$$

$$d = \sum_{i=1}^{k} r_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In order to minimize *P* we note that it is strictly convex and use Jensen's inequality. Given *d* and *k* then *P* is minimized when all the hop distances r_i are made equal to *d/k.* The minimum energy consumption for a given distance *d* has either no intervening hops or k_{opt} equidistant hops where k_{opt} is always of,

$$k_{opt} = \left(\frac{d}{d_{char}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The distanced_{char}, called the characteristic distance, is independent of *d* and is given by,

$$d_{char} = \sqrt[n]{\frac{e_t+e_r}{e_d(n-1)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The characteristic distance depends only on the energy consumption of the hardware and the path loss coefficient (i.e. it is independent of the traffic); d_{char} alone determines the optimal number of hops. For typical COTS (commercial, off-the-shelf)-based sensor nodes, d_{char} is about 35 meters. The introductions of relay nodes are clearly a balancing act between reduced transmission energy and increased receive energy. Hops that are too short lead to excessive receive energy. Hops that are too long lead to excessive path loss. In between these extremes is an optimum transmission distance that is the characteristic distance.

In the above section I have introduced a simple energy model in which no energy was consumed while the node was idle. This led to a characteristic distance that was independent of traffic. We now include the idle state energy and show how the characteristic distance is modified. On one hand a short range is preferred for energy efficient data transmission as a result of the nonlinear path loss ratio. On the other hand more redundant nodes can be put into the sleep state to prolong the network lifetime if a long range is used in the topology management of sensor networks. If the transmission route is divided into *k* grids and only one node wakes up in each grid as relay node, as in the GAF protocol, the total energy consumption per second by *k* hops is

$$P = k\left(e_rBA + e_tBA + e_d\left(2\frac{d}{k}\right)^n BA\right. \\ \left. + ce_r(1-2A)B\right. \ldots\ldots\ldots\ldots.7)$$

The last term $ce_r(1-2A)B$ in the equation (7) represents the energy consumption when the radio neither receives nor transmits, i.e. it is in the idle state. The energy consumption in the idle state is approximately equal to that in the receiving state, so that the parameter *c* is close to 1. Note that we are currently assuming that nodes in the sleep state consume no energy. Also, we assume that the routing node in each grid can be located anywhere within that section and so the radio range is now twice the grid size. The energy efficient optimum size of the virtual grid can now be derived from equation (1.7) and is given by

$$R_{opt} = {}^{r_{opt}}/_{2} = \sqrt[n]{\frac{(e_t + e_r)A + ce_r(1-2A)}{2^n A(n-1)e_d}} \,..(8)$$

We know the energy consumed at the cluster head is much larger than that at individual sensing node. The reason is as follows: (1) the cluster-head needs to relay all the traffic of the cluster; (2) for each data unit, the cluster-head needs to transmit longer distance due to transmission between clusters, while the sensing nodes just transmit data inside the cluster. In view of this, let E_p and E_c be, respectively, the current energy and clustering energy(E_c is fixed), after a period of time, the i^{th} cluster-head has transmits information n_1 times and has receives information n2 times before T_1(suppose the energy of the i^{th} cluster-head is not lower than the threshold and the information unit is A Erlang) .the remainder energy of the i^{th} cluster-head at T_1 is then simply as the equation (9).

$$E_p(i) = E_p(i) - \sum_{k=1}^{n_1} E_r(i,k) \\ - \sum_{i=1}^{n_2} E_r(i,l) - E_c \times n_i \,.. \qquad (9)$$

Where i, j, k respectively denote cluster-head, n_i is the clustering time in cluster i before T_1.

IV. CLUSTERING AND LEAST SPANNING TREE

This is the main process to reduce the participation of all nodes and reduction of communication range.

A) Clustering Model

In this work, we consider the wireless networks where all nodes in the network are homogenous and energy constrained, and each node can vary its transmission range to directly communicate with any node in the network. In this environment, instead of using a flat configuration, adopting the clustering approach can statistically multiplex many connections into a few paths so that the overall interferences can be reduced with well-controlled access.

a. Clustering cluster-head

When sensor nodes are deployed in a network area for communication and data exchange, from node to base station, all nodes of the network take participate for data exchange and loss there energy very soon as shown in the figure. So, for reducing the energy consumption of the network the network is divided in form of many sub networks, called clusters. Now I select a node as a cluster head. Cluster head is a node by which all communications take place to other cluster and sink and all other nodes of the same cluster communicate and the power loss of the node is reduced due to less participation of nodes and reduction of the communication range. All clusters head communicate with sink directly and avoid participation of other node and increase the lifetime of the network. The process of constructing cluster-head is comprised of two phases, as illustrated below:

1. Initial phase*:* First, partitions the multi-hop network and then chooses cluster-heads with the following stages:

i. Partitioning stage: Every node i maintains a triplet: a unique identification ID(i),a cluster identification to which i belongs ,CID(i),and its remaining energy, Crp(i). Such information is exchanged by a MAC layer protocol and thus can be obtained by the neighbors within one-hop distance. By using the first two values, CHEP partitions the multi-hop network into clusters according to some distributed clustering algorithm.

ii. Choosing stage*:* Every node within a cluster sends its remaining energy Crp(i),to the cluster-head to which it belongs. The cluster-head, upon receiving the power information choose the node with the maximum power as the new cluster-head and broadcasts the decision to its member. From now on, the cluster-head become a normal member, which listens to the messages from the new head just like the other members.

2. Re-clustering phase*:* When the energy of a cluster-head is lower than threshold, a cluster-head switches its role back to a node with the most residual power within the cluster. Since the power information is maintained by the cluster-head, this can be done easily with broadcasting message, and none of the distributed algorithms, such as those for the initial phase.

B. Least spanning tree

The minimum spanning tree is a tree of a planar graph. Each edge is labelled with its weight, which here is roughly proportional to its length. Given a connected, undirected graph, a spanning tree of that graph is a sub graph that is a tree and connects all the vertices together. A single graph can have many different spanning trees. We can also assign a weight to each edge, which is a number representing how unfavourable it is, and use this to assign a weight to a spanning tree by computing the sum of the weights of the edges in that spanning tree. A least spanning tree (LST) or minimum weight spanning tree is then a spanning tree with weight less than or equal to the weight of every other spanning tree. More generally, any undirected graph (not necessarily connected) has a minimum spanning forest, which is a union of minimum spanning trees for its connected components.

One example would be a cable TV company laying cable to a new neighbourhood. If it is constrained to bury the cable only along certain paths, then there would be a graph representing which points are connected by those paths. Some of those paths might be more expensive, because they are longer, or require the cable to be buried deeper; these paths would be represented by edges with larger weights. A spanning tree for that graph would be a subset of those paths that has no cycles but still connects to every house. There might be several spanning trees possible. A minimum spanning tree would be one with the lowest total cost

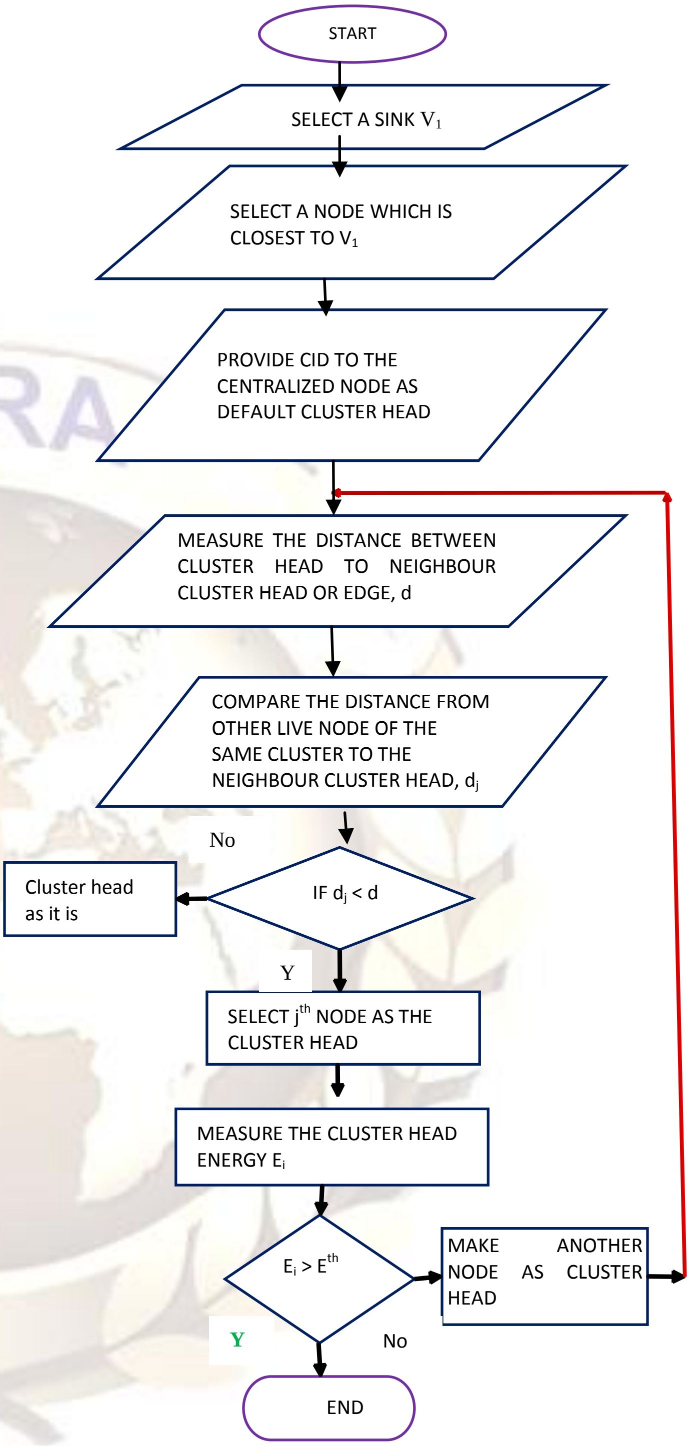

Figure-1.2;Flowchart

a. Constructing least spanning tree

By Eq(9),we can compute the remainder energy, if $E_p(i)$ is lower than E_v, then modify the information table of the i^{th} cluster-head: set flag=0; broadcast information to its children, also inform the neighbour j^{th} cluster-head doesn't transmits information to it, and let i^{th} cluster-head i is in the sleeping state; else the i^{th} cluster-head may go along the next clustering or transmitting or receiving. According to Prim algorithm, suppose undirected graph G (V, E, D), where V is the set of cluster-heads and the number is N, E is the set of connections of cluster-head, and D is the distance of cluster-heads, the process of constructing least spanning tree as illustrated below:

- Initialization: V_1=Sink, E′=null, and V_2=V-V_1.

- Select a edge: which has minimum distance from Sink to one cluster-head (suppose is V_i), where V_i is connected with Sink, then set, V_1= {Sink, V_i}, E ′= {(Sink, V_i)}, V_2=V_2-V_1.
- For each cluster-head V_k in V_1 do :select a minimum distance d(k,j),which $V_k \in V_1$,$V_j \in V_2$ and E′=(V_k, V_j) ∈ E ,but V_k is not ∈ E′, then V_1=V_1 ∈ V_j, E′={(V_k, V_j)} ∈ E′, V_2=V_2-V_j.
- If V_2 is empty then end, else go to above.

Flowchart of above algorithm is shown in figure 1.2.

The deployment of node by least spanning tree is shown in the figure 1.3(a & b).

In this deployment we take one cluster which is nearer to the sink. Now by MAC protocol we find out the weightage of different edge (path distance). And make an incident matrix which shows the direction of data flow from node to node.

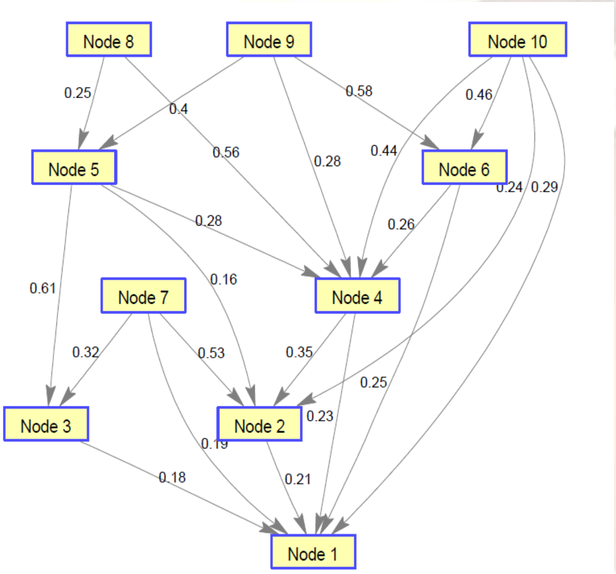

Figure 1.3(a) deployment of sensor node

Now we apply least spanning tree algorithm and we get shortest path from each node to the node 'A', which is the nearest cluster head of the network from the sink. The least spanning tree graph is shown in the figure 1.3 (b).

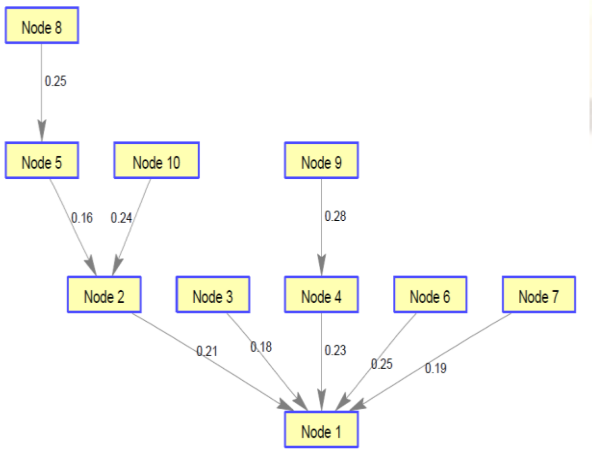

Figure 1.3 (b). Least spanning tree graph.

V. RESULTS

For the simulation of our algorithm we take 50 nodes and take initial power of the node. It consists of 50m×50m area and all nodes are deployed randomly. Now we take measurement for the power consumption per node for the network without clustering and it takes more energy when we increase the range or distance from the sink. But when we apply clustering the power consumption of the node reduced. And after applying least spanning tree power consumption per node per hop is reduced. The performance of the analysis is shown in the figure 1.4.

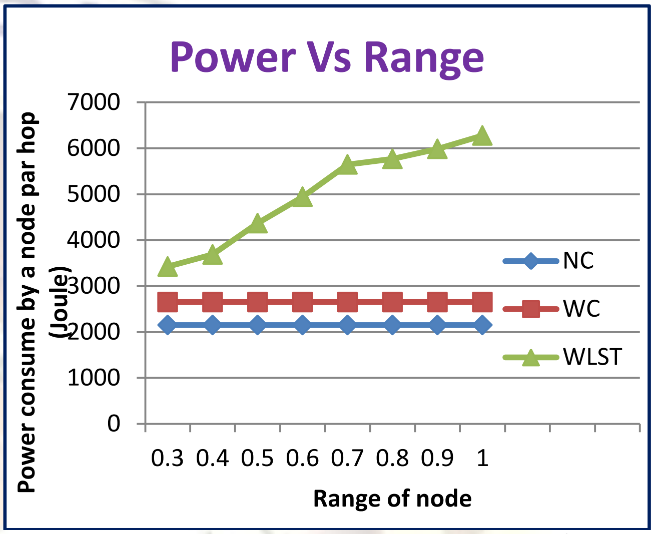

Figure 1.4 power consume by a node in per hop over the range of data transmission

When we take performance of power consumption over the traffic of the network then analysis is shown in the figure 1.5.

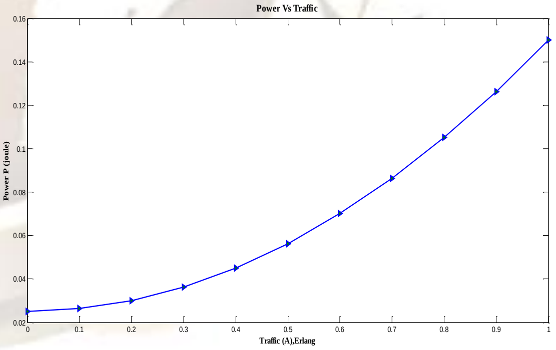

Figure 1.5 Power Vs Traffic

When traffic of the network is approximately zero then the lifetime of the node is very high and when the traffic of network increases the lifetime of the node is reduced. But when we apply clustering and spanning tree the performance of the node improves over the traffic of the network as shown in the figure1.6.

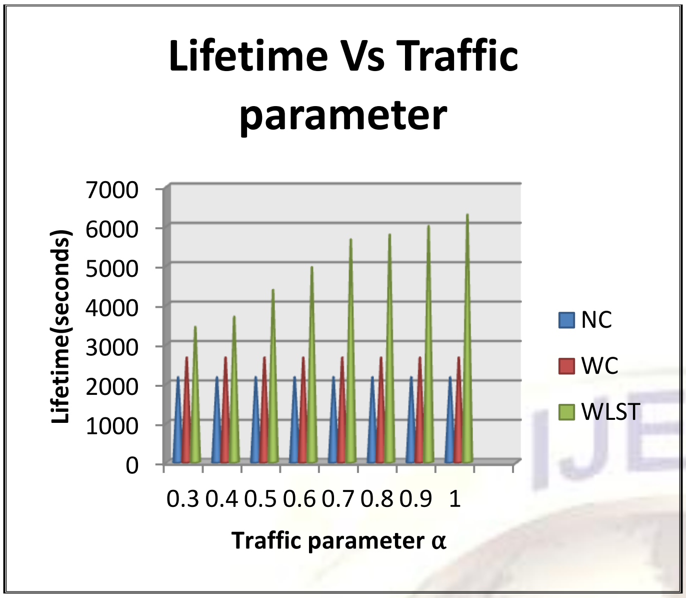

Figure 1.6 Lifetime of Node (sec.) Vs Traffic parameter (α)

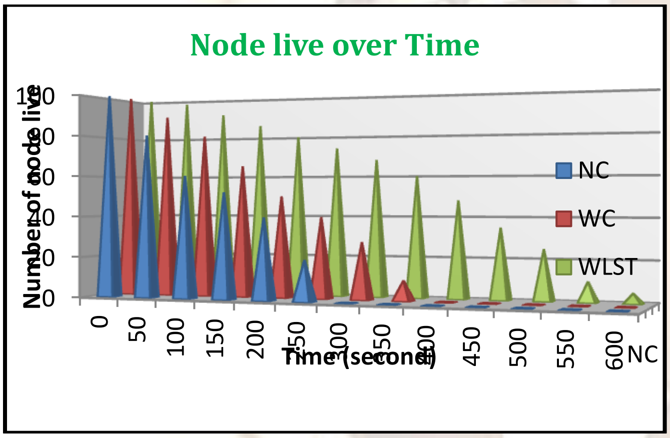

Figure 1.7 number of node live over time

VI. CONCLUSION

It has been concluded that when we take cluster based Minimum Spanning Tree, it gives better life time to the wireless sensor network and also reduce the energy consumption by the node. Since with cluster based Minimum Spanning Tree we can add more application of other algorithm such as power gathering and distributed least spanning tree. By these applications we can improve the efficiency of WSN and also reduce the power delay of the information and increase the range of sensor nodes. Further we can improve efficiency of energy, time delay as well as data transmission security using other application.

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