Framework for Fault Revoking and Homogeneous Distribution of Randomly Deployed Sensor Nodes in Wireless Sensor Networks

D. Prasad[1], Manik Gupta[2] and R. B. Patel[3]

[1,2] Department of Computer Science
Maharishi Markandeshwar University
Mullana (Ambala),133207, Haryana, India.

[3] Department of Computer Science and Engineering
Deenbandhu Chhotu Ram University of Science & Technology
Murthal (Sonepat)-131039, India

Abstract

Wireless sensor networks (WSNs) are one of the most exciting and challenging research areas. Sensor nodes (SNs) are generally deployed randomly from some flying base station (BS) in the deployment area, which may result uneven distribution of these static SNs. Besides these, they may be damaged because of natural calamities. In order to obtain the homogeneous distribution it is necessary to provide external kinetic to these static SNs until they acquire the appropriate position in the deployment area.

In this paper, we propose a framework for fault revoking and homogeneous distribution of randomly deployed SNs in the deployment area, so that the sink node within various clusters consumes equal amount of energy. The external kinetic to these static SNs for their homogeneous distribution is provided by the MSNs which are rich in energy. However, if any node gets damaged due to some environmental activity, then the framework makes provision for fault revoking with the help of Fault Revoking Mobile Sensor Node (FRN) in the deployment area.

Keywords: *Sensor Node (SN), Base Station (BS), Mobile Sensor Node (MSN), Fault Revoking Mobile Sensor Node (FRN), Location ID (LID).*

1. Introduction

A Wireless sensor networks (WSNs) is composed of a large number of low-cost Sensor nodes SNs and one or several sink nodes or BS [5]. SNs are typically small wireless devices with limited computational power, radio transmission range, storage size and battery power that co-operatively perform the task of collecting relevant data and monitor its surrounding for some change or event to occur [6]. Sink nodes are distinguishing devices with powerful computation capacity, large memory size, high power energy and long communication range. Sink nodes act as the gateway between WSNs and the end user. WSNs has its own features that not only differentiate it from other wireless networks but also craft the scope of wireless application to disaster relief, military surveillance, habitat monitoring, target tracking and in many civic, medical and security applications [7-10]. SNs may be left unattended in any hostile environment such as battlefields, volcanoes etc., which makes it difficult or sometimes impossible to recharge or replace their batteries. Thus, efforts must be employed to remove this deficiency of WSNs. Many protocols existing in the literature minimize energy consumption on routing paths [7-10]. Even though these approaches increase energy efficiency, they do not always prolong network lifetime; if certain nodes become popular, commonly termed as "hot spots" and present on most of the forwarding paths towards sink in the network. Some of the common characteristics of WSNs that were kept in mind before developing the framework are discussed in [11].

Some of the major issues in the node deployment strategies are: the coverage area of the nodes, finding the dead nodes in the coverage area, as well as the nodes on the boundary of the other nodes coverage area. Beside this the SNs are fault prone devices due to battery loss or some physical damage etc., and during their random distribution from the BS they are deployed unevenly within the network [2-4]. To avoid such problems, the researchers tried to identify the feasible node deployment strategies. However, if ample amount of energy is present to provide mobility to the SNs in the network, the fault revoking can be handled easily and randomly deploy SNs can be distributed evenly in the network.

Rest of the paper is organized as follows. Section 2 summarizes the motivation factors and related works. In section 3 System Model is presented followed by implementation of framework in section 4. Finally simulation, results and discussion of the work are concluded in section 5 and section 6 respectively.

2. Motivation Factors and Related Work

There are three main motivation factors that force us to think about a better solution over the existing WSN technologies and are discussed below:

2.1. Energy Efficiency

A large number of energy efficient algorithms like [12-15] are developed so far to make WSNs long lasting. But, it sounds much better to make WSNs efficient enough to provide continuous energy to the network throughout the lifetime of the network instead of bothering much about making it energy efficient, which still gets disposed at the deployment end after some period of time. It seems to be difficult, but does it really so if one thinks about the concept of wireless electricity [16] or supplying power to space vehicles or solar power satellites (SPS) [17-18] to recharge batteries of satellites in geo-stationary orbits as in [19]. Though the concept of SPS is capable enough to provide unlimited power to the sensor nodes in the deployment area as well as to the flying BS over it, but a large burden of extra cost is involved in it. Besides this the BS may be charged through the satellites, which are governed by any third party, but the involvement of third party arise security issues. So, it would be more cost effective and secured, if we are able to apply the same principle from the land itself rather than space at the deployment area by the first party itself with a very negligible cost difference than the existing setup cost and that too with increased lifetime of the network to almost infinite [1].

2.2. Fault Revoking

In most of the research articles published so far in the domain of WSNs, efforts are involved in fault tolerance and faults due to physical damage or natural calamities are considered ideal stage that can happen any time and not many solutions are provided in such cases. In such cases, the major drawback is that the amount of dead node gets increased if new nodes are deployed at their places causing damaged nodes pollution within the deployment area. However, if mobility is provided to either all or some of the SNs in the deployment area, they can be programmed to replace the damaged SNs without causing much pollution in the deployment area, which are usually hostile in nature; hence can be used for fault revoking as in [1].

2.3. Homogeneous distribution of SNs in the Deployment Area

While the bulk of published work envisioned sensors to be stationary, some investigated the possibility of attaching sensors to moveable entities such as robots [26, 27]. Sensor's mobility has been exploited to boost the dependability of WSNs. For example, sensors can re-spread in the area to ensure uniform coverage, move closer to loaded nodes in order to prevent bottlenecks, increase bandwidth by carrying data to the base station, and so on [28–30]. Dynamic sensors positioning in the literature can be categorized into two groups based on when relocation is exploited: (1) post-deployment and (2) on-demand relocation.

2.3.1 Post-Deployment Sensor Relocation

This type of relocation is pursued at the conclusion of the sensor deployment phase when the sensor nodes are being positioned in the area. In the WSN applications, sensor deployment is performed randomly due to the inaccessibility of the monitored areas. However, this random configuration usually does not provide an adequate coverage of the area without deploying an excessive number of nodes. Alternatively, the coverage quality can be improved by moving the sensor nodes if they are able to do so. In that case, the sensor nodes can be relocated to the regions that do not have the desired level of coverage or even are not covered at all. Wang et al. [25] utilizes sensor's ability to move to distribute the sensor nodes as evenly as possible in the region. The goal is to maximize the area coverage within the least time duration and with minimal overhead in terms of travel distances and inter-sensor message traffic. The main idea is that each sensor assesses the coverage in its vicinity after deployment and decides on whether it should move to boost the coverage. Nonetheless, this process still can be very slow and hence prolong the deployment time. With the objective of reducing the overall deployment time, Wu and Yang [30] proposed another solution to the same problem based on two-dimensional scan of a clustered network, called SMART.

2.3.2. On-Demand Repositioning of Sensors

Instead of relocating the nodes at the deployment phase, sensor relocation can be used on demand to improve certain performance metrics such as coverage, network lifetime, and so on. This can be decided during the network operation based on the changes in either application-level needs or the network state. For instance, in some applications, there can be an increasing number of dysfunctional nodes in a particular part of the area necessitating the redistribution of available sensors. In addition to improving coverage, the energy consumption can be reduced through on-demand relocation of sensors in order to reach the best efficient topology. The approach presented in [24] performs sensor relocation to counter holes in coverage caused by sensors failure.

3. System Model

This framework consist all the three motivation factors discussed and hence, demand of hybrid WSN arises i.e. to provide external kinetic to static SNs, MSNs are required. The framework procedure is described as below:

1. Supply continuous wireless power to the BS [1].
2. Randomly deploy the static SNs with initially fully charged batteries from the BS in the deployment area.
3. Deployment area is divided into the logical clusters of equal size. Here, the number of clusters is directly proportional to the number of SNs deployed in the deployment area and the size of each cluster is same which is defined by the LIDs of its vertices. However, it is not always necessary that the deployment area is in regular geometrical shape; it can be in any irregular or polygon shape. In such cases, the deployment area is divided into segments having equal area rather than grid structure segments.
4. The BS generates the LID of each SN in the deployment area with its own reference [23].
5. Supply wireless power to each of the cluster and thereby its sink node in the deployment area.
6. Deploy MSNs in the deployment area with the help of parachutes as in [1]. Here, each of the MSN is embedded with additional static SNs that can be used to replace the dead SNs in the network. The total number of MSNs is equal to (c + α); where, 'c' is the total number of clusters and 'α' be number of MSNs which may be required for fault revoking purposes. The value of 'α' vary and depends on the value of 'c' and size of the deployment area. Initially each MSN contains a packet with following format, containing 'k' number of co-ordinate points of the deployment area. Based on these co-ordinate points, the BS divides the deployment area into various clusters corresponding to their LID limits at its own end:

LID – X_1, Y_1	LID– X_2, Y_2	: : : : : :	LID– X_k, Y_k

7. After landing, MSNs finds themselves whether they are within the given X and Y co-ordinate of the net LID limits of the deployment area or not. If the MSN is within the deployment area then it finds the appropriate vacant cluster in the deployment area, established itself in that cluster and sends a "Hello" packet to the BS in the following format, so that no other MSN should establish itself in the same cluster.

NODE ID	LID – X_1, Y_1	LID – X_2, Y_2	HELLO

Here, LID – X_1, Y_1 and LID – X_2, Y_2 are the diagonal co-ordinate points of any segment in the deployment area. Now, the responsibility of that particular MSN is to act as mobile sink node for that particular cluster and aggregate all the data within the cluster and send to the BS. Beside this, the MSNs are also involved in fault revoking of the static SNs in the corresponding clusters.

However, if the MSN is not within the net GPS limits of the deployment area then that particular MSN l approaches towards the net GPS limits of the deployment area and hence eliminating the drawback of the wastage of MSN, which happens in regular SNs distribution technique during the deployment phase.

Figure 1 demonstrate the procedure, here c=36 and α = 2. The 'α' number of MSNs will help both in fault revoking of MSNs and homogeneous distribution of SNs in each cluster. Because of homogeneous distribution of SNs any mobile sink nodes don't suffer from hot sink problem while others are in sleep mode.

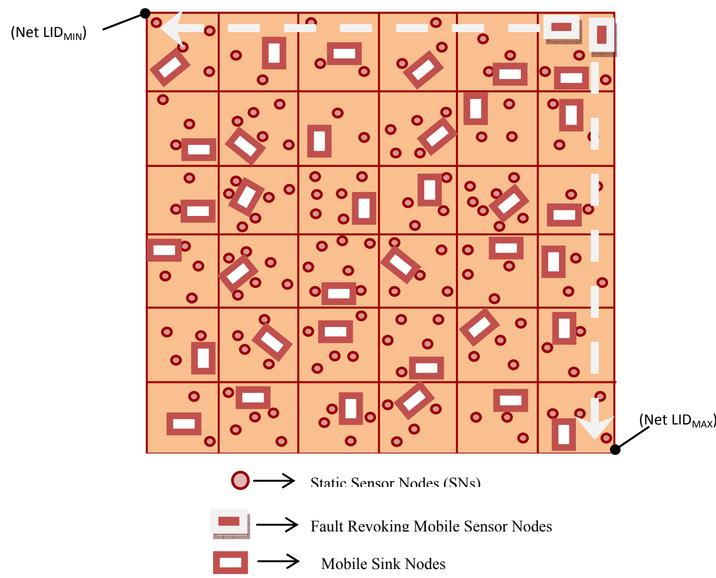

Fig. 1 Establishment of MSNs within the appropriate cluster.

After the successful placement of the SNs within the deployment area, the network enters into the post deployment phase. In the post-deployment phase, the network comes into action for which it was supposed to be deployed. But, the positive edge of this framework is that the SNs in the network can continuously sense the data rather than event driven sensing, due to high power at their disposal. Good security and fault tolerant techniques can now be applied due to the availability of network which is rich in energy; however to handle natural calamities, fault revoking techniques are available, as already discussed.

After the successful deployment of the MSNs in the deployment area, the power supply phase come in to action as in [1]. The laser is directed to all the MSNs in the deployment area on rotation basis by one or more number of directors present in the power supply model in some ratio to the MSNs in the deployment area.

Figure 2 shows a view of the power supply model among various clusters in the deployment area. Here, the deployment area divided into two clusters; where a continuous power beam is provided to each cluster unit and a laser beam is provided to the each mobile sink node among the cluster unit for δ duration of time. Since all the sink nodes are homogeneous and all of them are involved with equal number of SNs, hence the energy consumed by all of them will be approximately same. Thus, the laser beam can be provided to all the mobile sink nodes from a single beam director on round-robin fashion.

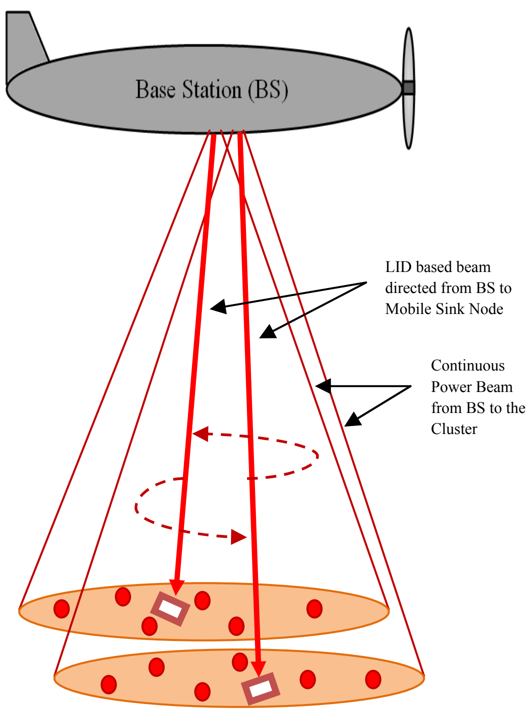

Fig. 2 Closer View of Power Supply Model from the BS to each Cluster Unit within Deployment Area [1]

3.1 Homogeneous distribution of SNs in the Deployment Area

The SNs are generally deployed randomly in the deployment area from some flying BS, due to which it is not possible to obtain the specified position for SNs in the deployment area. Hence, a better solution is to maintain their position within the targeted area by providing external kinetic to each of the static SNs by the mobile sink node within the cluster.

In this framework, we use MSNs and FRNs for equal distribution of the SNs within each cluster. First of all each MSNs communicates with its neighboring MSNs and collects the information about the number of SNs associated with each one of them. If a particular MSN, acting as sink node of a cluster, is associated with less than the average number of SNs within the deployment area then it listens to its physical sink neighbors. If the physical sink neighbors contains more than the average of SNs then they will provide external kinetic energy to extra number of SNs to move into that cluster. But, if that particular mobile sink node is associated with more than the average of the total number of SNs within the deployment area and the physical sink neighbor is associated with less number of SNs then it will provide external kinetic energy to the local SNs to move into the neighbor cluster. However, if both the neighbors in comparison contain less number of sensors than the average of SNs in the total targeted area then they seek help for FRN for extra number of SNs and if both of the neighbors contain more than the average of total SNs then they will send the signal to FRNs, so that FRNs came to know from where to get sensor nodes for the less populated cluster units.

Besides these basic criteria that can be easily maintained in plain area, there can be many challenges that may arise in case of hilly targeted area. In such environmental conditions, the SNs even with parachutes can't be deployed at some desired position. So, we can make use of specialized MSNs i.e. SNs embedded on spider robots or better which are capable enough to move in uneven hilly surfaces. With spider MSNs, such cases can be handled efficiently as we have ample amount of power at the disposal of deployment area, but the only drawback is deployment time can be comparatively larger than that of even surfaces.

3.2. Fault Revoking

In the proposed framework each of the MSN is embedded with additional some static sensor nodes, used for replacing dead sensor nodes in the network. The total number of MSNs deployed in the targeted area is equal to (c + α); where, 'c' is the total number of clusters and 'α' be number of MSNs which may require for fault revoking purposes. Here, each of the 'c' MSN is responsible for fault revoking within their cluster unit and the remaining 'α' MSNs are responsible for fault revoking of the mobile sink nodes.

In a cluster, if a SN gets damaged or enters into dead stage then the BS sends the LID of the affected SN to the mobile sink node within that cluster unit. The mobile sink node comes into action and physically deploys a SN at the same location by removing the affected SN from there and hence no dump is left behind within the cluster.

On the other hand, the damage to the mobile sink nodes can be handled by the remaining 'α' MSNs, acting as FRN. Here also, if a mobile sink node gets damaged then it will immediately comes onto dead stage at a particular location and the BS will send the concerned LID to one of the FRN based on some priority like nearest FRN to the BS. In this case, if the total number of dead SNs carried by the mobile sink node reaches to its maximum capacity then also the mobile sink node is considered to be in dead stage. Such programming skills can be previously burned within the memory of all MSNs before their deployment and are absolutely application specific. Thus, a good knowledge of robotics need to be explored to efficiently implement fault revoking techniques with the help of MSNs in any kind of wireless sensor networks.

4. Implementation of Framework

There are a number of robots that we can use as MSNs in this framework, depending upon the application and area of usage; like mountains, deserts, plane etc. In our framework we consider the Soldier UGV (SUGV) to simulate the framework. SUGV is a man-packable small robot system, weighing less than 30 lbs, used for Urban Operations environments and subterranean features to remotely investigate the threat obstacles, structures and the structural integrity of facilities and utilities. SUGV systems will be highly mobile for dismounted forces and will be capable of being re-configured for other missions by adding or removing sensors, modules, mission payloads and subsystems.

The entire framework is divided into two phase i.e. pre-deployment phase and post-deployment phase. In the pre-deployment phase, after the successful division of the network into clusters followed by the mobile sink node establishment within each cluster, the power supply phase at the deployment area comes into action. The availability of high power at the deployment end makes MSNs enable for exhaustive actions to do and providing external kinetic to the SNs for their homogeneous distribution among the clusters within the deployment area.

In our network model, we have assumed that the network has the following properties:

1. There exists a unique BS, flying above the network with at the most to the perpendicular distance of 1 mile or hypotenuse distance of 8 miles from beam director [20].
2. Each SN has a unique identity.
3. Network is hybrid but homogeneous i.e. all the static sensor nodes are equivalent, having the same energy, computing and communication capacity and the same holds for the MSNs.
4. Location of nodes is obtained using locations IDs based on virtual co-ordinate system as in [23].
5. The transmitter can adjust its amplifier power based on the transmission distance.
6. The MSNs use laser diode array while SNs use simple photovoltaic cells as in [1] instead of regular batteries for power.

4.1. Algorithm for Homogeneous Distribution of the SNs

Let 'n' be the total number of SNs and 'c' be the total number of clusters formed in the deployment area, then 'avg' be the average number of SNs within each cluster. If LID[i] and LID[j] be the location IDs of the sink nodes in clusters i and j, then they will communicate with each other only if the distance among them is less than β and i and j are said to be physical neighbors. If the number of SNs in any cluster, say i, is less than 'avg' then the corresponding entry in the list maintained at the fault revoking node FR[i] will be set to 1.

1. Calculate the average number of SNs in each cluster at the BS end as below:

$$avg = \frac{n}{c}$$

where, n is the total number of SNs in the deployment area.
c is the total number of clusters within the deployment area.

2. Establish each of the MSN, containing information about the average number of SNs within the deployment, as the sink node for each cluster in the deployment area, as discussed above.
3. Obtain LIDs for each of the sink node.
4. for k := 1to c

```
    Calculate the total number of SNs (x) in the cluster.
    if (x[k] < avg) then
        Set FR[k] := 1.
    //end if
//end for
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```
5. for i := 1 to c
      for j := 1 to c
         if (i ≠ j)
            if (LID[i] – LID[j] ≤ β) //if the distance among
sink nodes is less than the threshold distance β i.e. i and j
are physical neighbors
               do{
                     if ((x[i]<avg) && (x[j]>avg)) then
                        Call SN_EXCHANGE(i,j).
                  else if ((x[i]>avg) && (x[j]<avg)) then
                        Call SN_EXCHANGE(j,i).
                  else if ((x[i]>avg) && (x[j]>avg)) then
                        Call GET_NODE(i,j).
                  else if ((x[i]<avg) && (x[j]<avg)) then
                        i.  Set FR[i] := 1.
                        ii. Set FR[j] := 1.
                  else if ((x[i]<avg) && (x[j]==avg)) then
                        Set FR[i] := 1.
                  else if ((x[i]==avg) && (x[j]<avg)) then
                        Set FR[j] := 1.
                  } while (x[i] := avg). //end while
            //end if
         //end if
      //end for
//end for
6. for k := 1to c
   i.  Calculate the total number of SNs (x) in the cluster.
   ii. if (x[k] < avg) then
         Set FR[k] := 1.
   //end for

SN_EXCHANGE(a,b) //mobile sink nodes gets SN from the
                                   neighboring cluster

   1. Sink[b] will carry SN[b].
   2. Sink[a] and Sink[b] move towards one of the common
      co-ordinate point of their LID limits.
   3. Sink[b] assign SN[b] to Sink[a].
   4. Add SN[b] to the list of sensor nodes at Sink[a].
   5. Remove SN[b] from the list of sensor nodes at Sink[b].
   6. x[a] = x[a] + 1.
   7. x[b] = x[b] – 1.

GET_NODE(p,q)// cluster obtain extra SNs from the FRN

   1. UPTO_AVG(p).
   2. UPTO_AVG(q).

   UPTO_AVG(y) // FRN supply extra SNs to clusters
                        having total SNs less than average.

   1. do{
         for k := 1 to c
            if FR[k] == 1then
               i.   FRN will carry SN[y] and assign it to
                    Sink[k].
               ii.  Add SN[y] to the list of sensor nodes at
                    Sink[k].
               iii. Remove SN[y] from the list of sensor
                    nodes at Sink[y].
            //end if
         //end for
      } while(x[j]:= avg).
   2. Set FR[k] := 0.
```

5. Simulation

Simulation is done using Matlab as the plotting software, as well as the calculation engine to plot the results. The following parameters are considered for simulation.

1. The distance between the BS and the network is taken as 200m.
2. Size of message is 80 bytes.
3. Free space attenuation coefficient (E_{fs}) is 10 pJ/bit/m^2.
4. Multipath attenuation coefficient (E_{mp}) is 0.0013 pJ/bit/m^4.
5. Electronic power (E_{elec}) is 50 nJ/bit.
6. Size of node ID 4 bytes.
7. Cluster area 10m^2.
8. Deployment area is considered to be plane rather than terrestrial.
9. Soldier Unguided Vehicles (SUGVs) are the MSNs we are using to simulate the framework.

For realistic, our simulation uses the first order radio model as the communication model. Equation (1) and (2) represent the energy dissipation, when a SN sends or receives an l -bit message.

$$E_{recieve} = l \times E_{elec} \qquad (1)$$

$$E_{trans} = \begin{cases} l \times (E_{elec} + E_{fs} \times d^2), if d \le \sqrt{\frac{E_{fa}}{E_{mp}}} \\ l \times (E_{elec} + E_{mp} \times d^4), if d > \sqrt{\frac{E_{fs}}{E_{mp}}} \end{cases} \qquad (2)$$

6. Results & Discussions

The graph is plot between energy level of MSN with respect to time, effect of concentration of FRNs to revoke damaged SNs in the deployment area and time required to

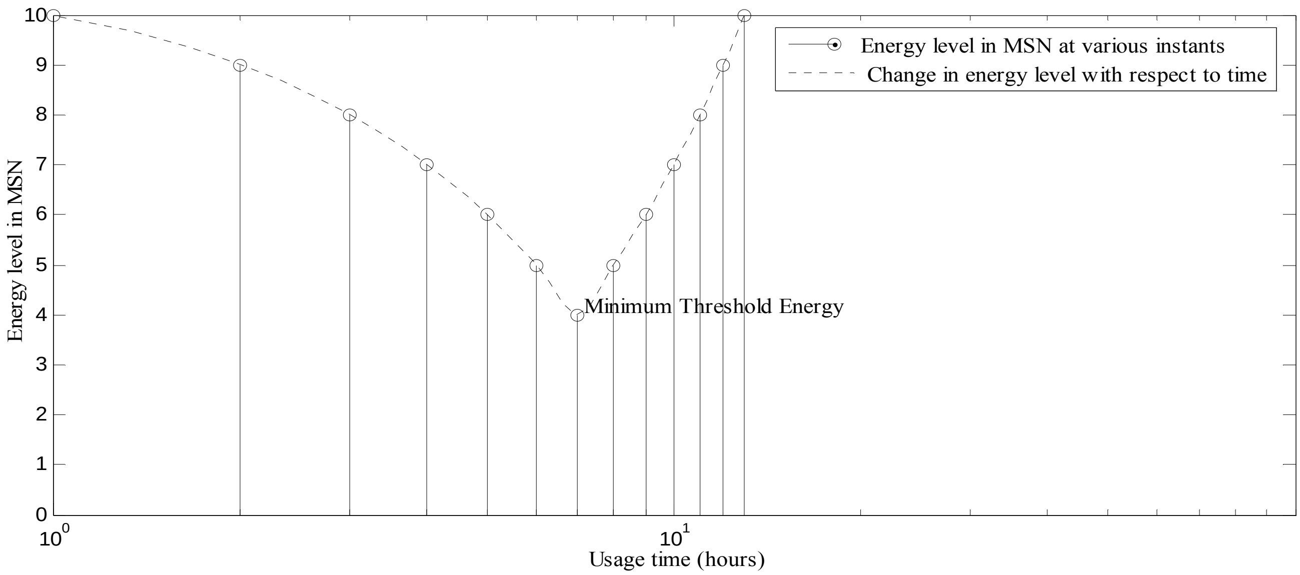

Fig. 3 Energy level in MSN at various instants of time

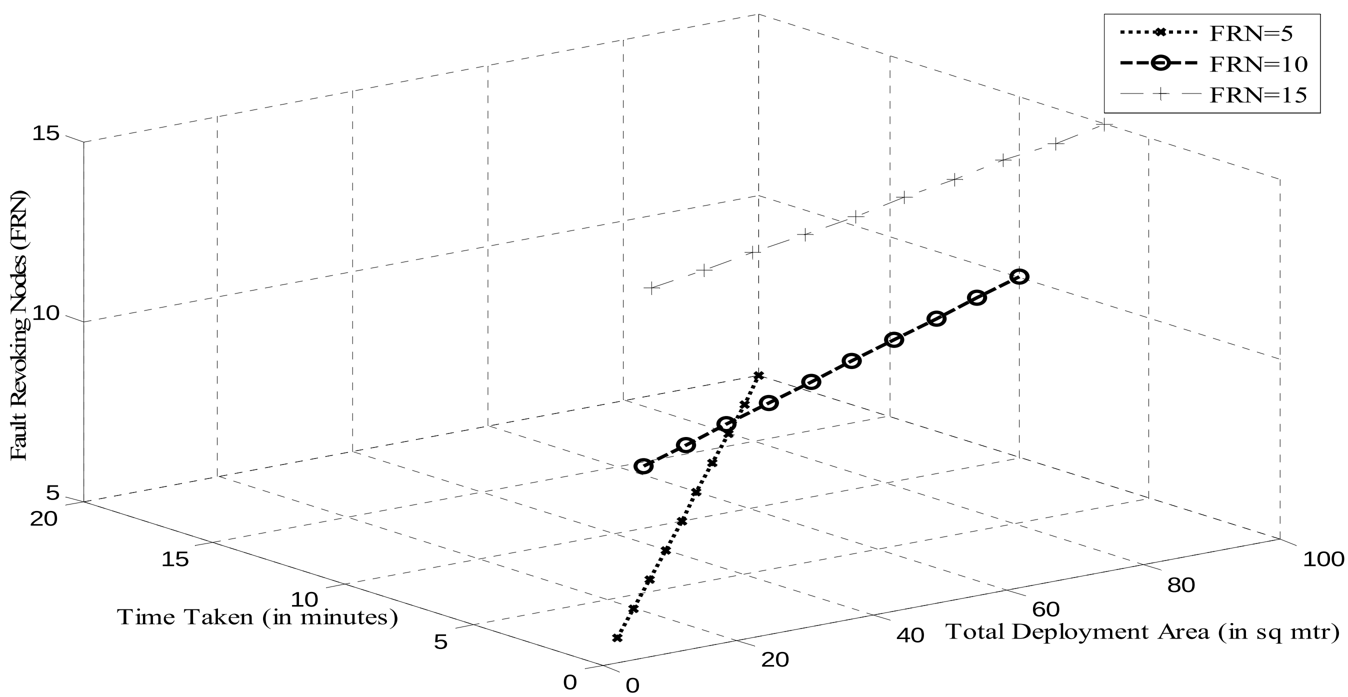

Fig. 4 Effect of concentration of FRNs with respect to time to revoke fault in the Deployment Area

setup the network with respect to variation between SNs and MSNs (i.e. both the sink nodes as well as FRNs). The energy level of MSN decreases with time and when it reaches to the mimimum threshold value then high intensity power beam is directed to the laser diode array [1] to recharge it in least possible time, as shown in Figure 3.

It can be observed in Figure 4 that on increasing the FRNs in the deployment area, the time taken for fault revoking purposes get reduced and finally, in Figure 5, we can see that by increasing the ratio between the SNs and MSNs (including both FRNs and sink nodes) in the deployment area, the network setup increases.

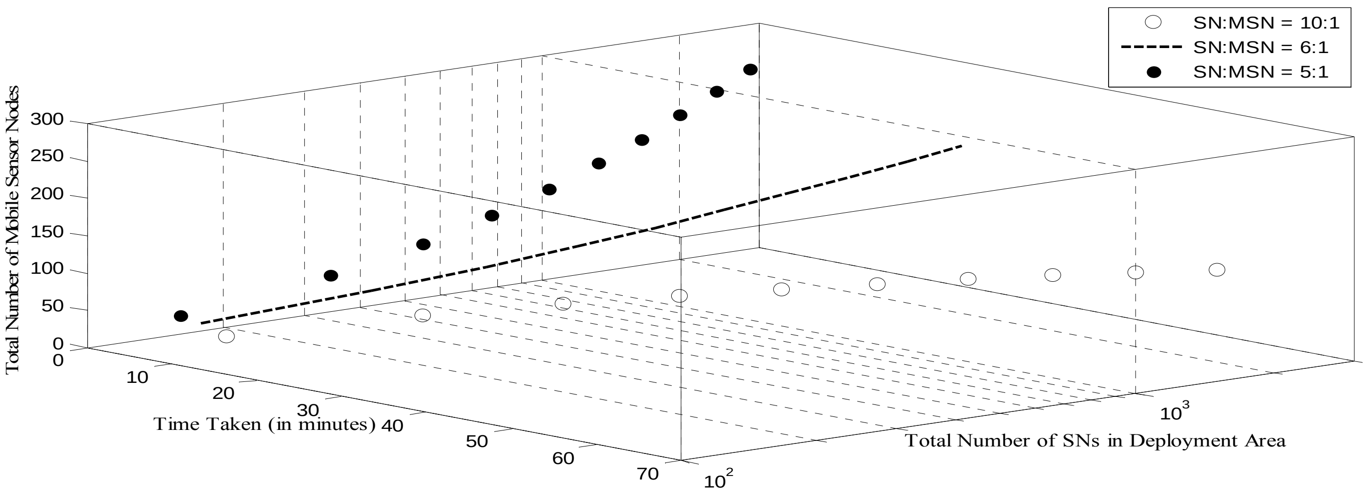

Fig. 5 Effect of ratio between SNs and MSNs with respect to time to setup the Network

References

[1] Manik Gupta, D. Prasad, R.B. Patel, "FREEDOM: Fault Revoking and Energy Efficient Protocol for the Deployment of Mobile Sensor Nodes in Wireless Sensor Networks", International Journal of Advanced Engineering Sciences and Technologies (IJAEST), Vol No. 1, Issue No. 1, 001 – 009, ISSN: 2230-7818, Page. 1-9.

[2] H. Zhang and J. C. Hou. Maintaining sensing coverage and connectivity in large sensor networks. Intl. Journal of Wireless Ad Hoc and Sensor Networks, 1(1-2):89-124, 2005.

[3] F. Ye, G. Zhong, S. Lu, and L. Zhang, "Peas: A robust energy conserving protocol for long-lived sensor networks," in Proceedings of the 10th IEEE International Conference on Network Protocols, Washington, DC, USA, 2002. pp. 200-201.

[4] Siqueira, M. Fiqueiredo, A. Loureiro, J. Nogueira, and L. Ruiz, "An integrated approach for density control and routing in wireless sensor networks", in Proceedings of Parallel and Distributed Processing Symposium, Greece, April 2006, pp. 10-19.

[5] D. P. Agrawal and Q-A. Zeng, "*Introduction to Wireless and Mobile Systems"*, Brooks/Cole publisher,2003.

[6] F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey", Computer Networks Journal, Elsevier Science, Vol. 38(4):393-422, No. 4 pp 393–422, March 2002.

[7] Matt Welsh, Dan Myung, Mark Gaynor, and Steve Moulton. "Resuscitation monitoring with a wireless sensor network". In Supplement to Circulation: Journal of the American Heart Association, October 2003.

[8] G.L. Duckworth, D.C. Gilbert, and J.E. Barger. "Acoustic counter-sniper system", In SPIE International Symposium on Enabling Technologies for Law Enforcement and Security, 1996.

[9] Alan Mainwaring, Joseph Polastre, Robert Szewczyk, and David Culler. "Wireless sensor networks for habitat monitoring", In First ACM International Workshop on Wireless Sensor Networks and Applications, 2002.

[10] Robert Szewczyk, Joseph Polastre, Alan Mainwaring, and David Culler. "Lessons from a sensor network expedition", In First European Workshop on Wireless Sensor Networks (EWSN'04), January 2004.

[11] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey", Computer Networks Journal, Elsevier Science, Vol. 38, No. 4 ,pp 393–422, March 2002.

[12] S. Bandyopadhyay, E. Coyle, "An energy-efficient hierarchical clustering algorithm for wireless sensor networks," in Proceedings of the IEEE INFOCOM 2003, San Francisco, IEEE Computer Press, July 2003, pp. 1713 -1723.

[13] HO. Tan, "Power efficient data gathering and aggregation in wireless sensor networks," SIGMOD Record, 2003, 32(4): 66 -71

[14] Y. Tang, M. Zhou, X. Zhang, "Overview of Routing Protocols in Wireless Sensor Networks," Journal of Software, 2006, 17(3):410-421

[15] 0. Younis, S. Fahmy, "Distributed clustering in Ad hoc sensor networks: A hybrid, energy-efficient approach," in Proceedings of the IEEE INFOCOM 2004. Hong Kong: IEEE Computer Press, 2004, pp. 630-640.

[16] K. Ramasamy,T. Shanmuganantham, S. Sheik Mohammed "Wireless Power Transmission – A Next Generation Power Transmission System"2010 International Journal of Computer Applications (0975 – 8887) Volume 1 – No. 13.

[17] W. Neil Johnson, Keith Akins, James Armstrong, Kwok Cheung, Glen Henshaw , Steven Huynh, Paul Jaffe, Matthew Long, Michael Mook, Michael Osborn, Robert Skalitzky, and Frederick Tasker, Jill Dahlburg, Michael N. Lovelette, David Huber, Mark Dorsey, Donald Gubser, Philip Jenkins, Scott Messenger, John Pasour, Robert Walters, Nathan Smith, Wayne Boncyk, Michael Brown, Robert Bartolo and Keith Williams "Space-based Solar Power: Possible Defense Applications and Opportunities for NRL Contributions" October 23, 2009.

[18] Glaser, P.E., "The Future of Power from the Sun," Intersociety Energy Conversion Engineering Conference

(IECEC), IEEE publication 68C-21- Energy, 1968, pages 98-103.

[19] HerbertW.Friedman, "Near-Term Feasibility Demonstration of Laser Power Beaming" SPIE's International Symposium on Optoelectronic and Microwave Engineering Los Angeles, California January 25-27, 1994.

[20] T.J. Nugent and J.T. Kare "Laser Power for UAVs", Laser Motive White Paper- Power Beaming for UAVs, NWEN, March 2010.

[21] JongGyu Kim, John Paul M. Torregoza, InYeup Kong and WonJoo Hwang "Photovoltaic Cell Battery Model for Wireless Sensor Networks" IJCSNS International Journal of Computer Science and Network Security, VOL.6 No.9B, September 2006.

[22] Meinel A. B., Meinel, M.P., "Applied Solar Energy: An Introduction", Addison-Wesley Publishing Company, Inc. 1976.

[23] Ajay Kr. Gautam (Member IEEE), and Amit Kr. Gautam, "Accurate Localization Technique using Virtual Coordinate System in Wireless Sensor Networks", International Journal of Recent Trends in Engineering, Vol 2, No. 5, November 2009

[24] K. Akkaya, M. Younis and M. Bangad. "Sink repositioning for enhanced performance in wireless sensor networks". *Computer Networks*, 49(1):512–534, 2005.

[25] G. Wang, G. Cao, T. La Porta, and W. Zhang. "Sensor relocation in mobile sensor networks" In *Proceedings of the IEEE Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM'05)*, pp. 2302–2312, Miami, FL, March 2005.

[26] http://www-robotics.usc.edu/robomote/

[27] http://www.symbio.jst.go.jp/symbio/morph.html

[28] G.Wang, G. Cao, and T. La Porta. "Movement-assisted sensor deployment" In *Proceedings of IEEE INFOCOM*, Hong Kong, March 2004.

[29] A. Kansal, E. Yuen, W. J. Kaiser, G. J. Pottie, and M. B. Srivastava. "Sensing uncertainty reduction using low complexity actuation" In *Proceedings of Information Processing in Sensor Networks (IPSN 2004)*, Berkeley, CA, April 2004.

[30] J.Wu and S. Yang. "SMART: A scan-based movement assisted sensor deployment method in wireless sensor networks" In *Proceedings of the IEEE Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM'05)*, Miami, FL, March 2005.

Devendra Prasad is an Associate Professor in the Department of Computer Science and Engineering, M.M. University, Haryana, India. Devendra Prasad is in teaching and Research & Development since 1996. He has supervised several M. Tech, and M. Phil Thesis. Devendra Prasad received his B.E. degree from Kumaon University, Nainital, India in 1995, M.Tech. Degrees from Kurukshetra University, Kurukshetra, India in 2007. He is currently enrolled as a PhD student in the Department of Computer Science and Engineering at M. M. University, Haryana, India. His research area is security, fault tolerance and data dissemination, in wireless sensor networks.

Manik Gupta is a member of IAENG-International Association for Engineers and currently enrolled as a student of Masters of Technology in Computer Science in the Department of Computer Science, Maharishi Markandeshwar University, Mullana, Ambala, India. He had been awarded for Best Research Paper, in December, 2010. He also worked as Software Developer for one year after completing his Bachelors Engineering in Computer Science from University of Jammu. His research area is Security, Energy Efficiency, Fault Tolerance, Fault Revoking and Mobility in Wireless Sensor Networks.

Dr. R. B. Patel received PhD from IIT Roorkee in Computer Science & Engineering, PDF from Highest Institute of Education, Science & Technology (HIEST), Athens, Greece, MS (Software Systems) from BITS Pilani and B. E. in Computer Engineering from M. M. M. Engineering College, Gorakhpur, UP. Dr. Patel is in teaching and Research & Development since 1991. He has supervised 30 M. Tech, 7 M. Phil and 1 PhD Thesis. He is currently supervising 3 M. Tech, and 8 PhD students. He has published more than 100 research papers in International/National Journals and Refereed International Conferences. He had been awarded for Best Research paper many times in India and abroad. He has written numbers books for engineering courses (These are "Fundamentals of Computing and Programming in C", "Theory of Automata and Formal Languages", "Expert Data Structures with C," "Expert Data Structures with C++," "Art and Craft of C" and "Go Through C". His research interests are in Mobile & Distributed Computing, Mobile Agent Security and Fault Tolerance, development infrastructure for mobile & Peer-To-Peer computing, Device and Computation Management, Cluster Computing, Sensor Networks, etc.