International Journal of Latest Research In Engineering and Computing (IJLREC)
Volume 1, Issue 1 : Page No.78-83, September-October 2013
www.ijlrec.com

Efficient deployment of heterogeneous sensors for tracking moving objects: An algorithmic approach

Pankaj Bhambri[1], Dr. O.P. Gupta[2]
[1]Department of Information Technology, Guru Nanak Dev Engineering College, Ludhiana
[2]Department of Information Technology, Punjab Agriculture University, Ludhiana

Abstract : Detecting a moving object inside an irregular region is one of the most fundamental challenges of Wireless Sensor Networks. The performance of an effective and efficient sensor network for detecting moving object is highly related to the proper deployment of the sensors. In this paper we have addressed the problem of deploying heterogeneous sensors in a regular space with a grid-based routing model which may further be extended to an irregular one. We have also considered clustered energy model to detect and replace of a dead node if exist in the network. The simulation shows that with the increase number of deploying nodes for larger space, this model has more than 50% gain with guaranteed shortest path than that of the existing broadcast techniques. More over, the worst case of this deployment algorithm is compare to the average case with existing one.

Keywords- wireless sensor networks, deployment algorithm, routing algorithm

INTRODUCTION

With the exponential growth of technology, the impact of the development of sensor networks is reviewed and new applications are gradually emerging with new thoughts and challenges. Each node needs to know the identity and location of its neighbors to support processing and collaboration. When self-location by GPS is not feasible or too expensive, relative positioning algorithms, diffusion algorithms [1], approximation algorithms [2], have to be provided. The deployment of sensor nodes in the physical environment may take several forms. Nodes may be deployed at random (e.g., by dropping them from an aircraft) or installed at deliberately chosen spots. Deployment may be a one-time activity, where the installation and use of a sensor network are strictly separate activities. The deployment of sensor networks varies with the application considered. It can be predetermined when the environment is sufficiently known and under control, in which case the sensors can be strategically hand placed. The deployment can also be a priori undetermined when the environment is unknown or hostile in which case the sensors may be air-dropped from an aircraft or deployed by other means, generally resulting in a random placement [3]. Early sensor network visions anticipated that sensor networks would typically consist of homogeneous devices that were mostly identical from a hardware and software point of view. However, in many prototypical systems available today, sensor networks consist of a variety of different devices. Nodes may differ in the type and number of attached sensors; some sensor nodes may be equipped with special hardware such as a GPS; some nodes may act as gateways to long-range data communication networks (e.g., GSM networks, satellite networks, or the Internet). The degree of heterogeneity in a sensor network is an important factor since it affects the complexity of the software executed on the sensor nodes and also the management of the whole system [4]. This paper investigates deployment strategies for heterogeneous sensor networks over a region of interest. The focus of this paper is to minimize the number of sensors to be deployed to carry out target detection in a region of interest. The tradeoffs lie between the network performance, the cost of the sensors deployed, and the cost of deploying the sensors. The rest of the paper is organized as follows. In section 2, the definition of the problem is formulated. In section 3, we briefly discuss and analyze the related work in deployment of sensors and routing models. Section 4 is our model of topology for efficient node deployment and section 5 is connectivity and routing technique among the deployed nodes. An analytical study of this solution is given in section 6. Finally we conclude in section 7.

PROBLEM DEFINITION

Most of the existing systems are based on query-reply model where a considerable amount of energy is consumed when the network scale is large or when the query rate is high. Moreover, such models also suffer for flooding with high broadcast-storm [5] phenomenon. Alternatively, if all location information is stored at a specific sensor (e.g., the sink or called Fusion Point (FP)), no flooding is needed. But, whenever a movement is detected of a moving object to sense, update messages have to be sent. One drawback is that when objects move frequently with accelerated or decelerated velocity, abundant update messages will be generated whose cost is not justified when the query rate is low. Clearly, these are trade-offs. If the target’s movement patterns are entirely known (known trajectory), sensors could be deployed to known selected places and programmed to activate as and when required and energy consumption can be controlled also by categorizing the sensors in different states with different energy depending upon the internal processing of aggregated data. But in case of unknown trajectory, we have to ensure 100% sensing coverage. Here we are trying to address the problem of deploying heterogeneous sensors with ensuring 100% sensing coverage in a geographic sensing zone with desired level of accuracy which can applied to track randomly moving objects with uneven velocity in unknown trajectory. Our objective is to deploy sensors with heterogeneous sensing capacity and to build one effective topology so that the sensors can route the information from one sensor to the other. This single node-to-node handoff may suffer information loss when the current node or links incur a failure. Moreover, simultaneous observation of more than one sensor may cause network flooding with redundant information.

RELATED WORK

Research on deployment of nodes for centralized target tracking has been carried on for many years, originating from early work on target tracking by radar during World War II. The unique constraints of wireless sensor networks like limited energy, limited storage capacity, scalability, distributed sensing and data processing are the main focused challenging area for every researcher. Chih-Yu Lin, Wen-Chih Peng and Yu-Chee Tseng [6] have proposed a new tree structure where they divide the sensing area into square-like zones, and recursively combine these zones into a tree named as Zone-based Deviation-Avoidance Tree (Z-DAT). Here, the entire sensing field is partitioned into a Voronoi graph, such that every point in a polygon is closer to its corresponding sensor in that polygon than to any other. A Voronoi diagram, however, is not a true sub-division for doubly-connected edge list [7]. It has edges that are half-lines or full lines and these can not be represented in a doubly-connected edge list and to do so, we need to add a big bounding area to our space concerned which is large enough so that it contains all vertices of the Voronoi graph. The final sub-division will then be the bounding box plus the part of the Voronoi graph inside it which take a large computational overhead. The accuracy of device placement may be subject to various errors. To overcome the negative impacts of these errors, the grid resolution and the number of devices to be deployed should be re-evaluated. Kenan Xu, Glen Takahara and Hossam Hassanein [8], in their paper, identified two deployment errors namely, misalignment and random errors. They derived the minimum number of sensors required by a robust grid-based sensor deployment assuming that the errors are bounded. Loukas Lazos, Radha Poovendran and James A. Ritcey [9] address the problem of wireless sensor deployment, for the purpose of detecting mobile targets. They map the target detection problem to a line-set intersection problem and derive analytic expressions for the probability of detecting mobile targets. As the pair-wise distance among the sensors increases with probabilistically measured addresses of the deployed sensors, the difference between two consecutive measurements from a node is too large to be useful for the calculation of the predicted probabilistic approach for sensor measurements. F. Zhao, J. Shin, and J. Reich [10], have addressed the dynamic sensor collaboration problem to determine dynamically which sensor is most appropriate to perform the sensing, what needs to be sensed, and to whom to communicate the information. It is based on the information-driven sensor querying (IDSQ) approach, enabling collaboration, under resource constraints and cost of transmitting information. Here, the next node selection is done by predicting Mahalanobis distance measure technique where the computation from predicted likelihood function may be strongly biased by the prior distribution. Y. Rachlin, R. Negi, and P. Khosla, [11] have addressed the technique of measuring sensing capacity in a sensor network with respect to the maximum ratio of target positions to sensors as achievable within a certain tolerable distortion. As one target is being sensed by more than one sensor, the network will soon get flooded with redundant information. Moreover, sensors lifetime will eventually gets reduced as all the time more than one sensor is sensing one target. J. Faruque, K. Psounis, A. Helmy [12] proposed information-driven routing protocol with consideration of randomly distributed malfunctioning nodes and noise for the cause of failure of transmission. [13], [14] and [15] are based on grid-based Stable Routing Protocol with multi-hop broadcast technique. In [16] several power-efficient routing algorithms are proposed for a sensor network with 2D grid topology.

PROPOSED MODEL

It is obvious that the entire sensing space, (which obviously will be an irregular one) has to be under sensing coverage to track any object moving through any point of the region. We first concentrate on the deployment of the nodes as because, efficient deployment will maximize the sensing space with optimum deployment of the number of sensors with desired level of accuracy

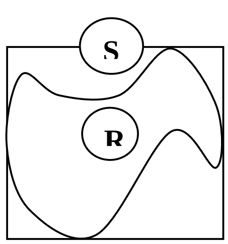

Figure 1: Irregular space [R] and its corresponding regular boundary [S]

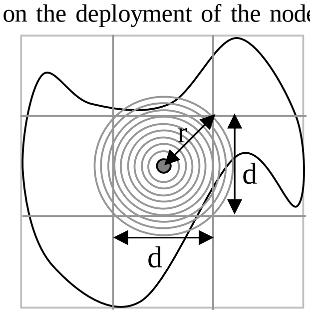

Fig. 2: Deployment

and also can track the object efficiently with more accuracy. Here we make the boundary of the irregular space by square in shape as shown in the figure 1. Let the random area to be sensed is denoted by R and the Square area that cover R is S where $R \leq S$. As we are considering sensors of heterogeneous in nature, their individual cover-areas also vary. Each sensor is deployed with respect to their coverage area and with each deployment a logical grid is created which as shown in the figure 2. We have started deployment from the center of the zone so that maximum coverage is achieved. Next node will be deployed to any of the four sides (left, right, up and down) of the previously deployed node in descending order of their coverage area that can cover the maximum. Repeating this we can cover optimally the entire sensing zone *S*. We can now define the problem as: Given *n* number of heterogeneous nodes n_0, n_1, n_2, ..., n_{n-1} having coverage area r_0, r_1, r_2, ..., r_{n-1} respectively, whether the optimum coverage exists for a given sensing space *S*.

Algorithm NodeDeploy() {
Assumptions:
1. *Nodes are heterogeneous with different cover-capacity.*
2. *Nodes are sorted with their respective coverage in descending order (i.e.* $r_0 \geq r_1 \geq r_2 \ldots \geq r_{n-1}$*).*
3. *Sensing zone R is random in nature*
4. *Zone is covered by a logical square area S.*

Let every node is free;
Deploy n_0 *at the center of S;*
Update free node list;
CREATEGRID ();
Calculate (ld_{n0}, rd_{n0}, ud_{n0} *and* dd_{n0}*) and store in sorted distance list;*
[ld_{n0} → *distance to left boundary*]
[rd_{n0} → *distance to right boundary*]
[ud_{n0} → *distance to upper boundary*]
[dd_{n0} → *distance to down boundary*]
For node i = n_1 *to* n_{n-1} *{*
BESTFIT (n_i*);*
CREATEGRID ();
If (entire sensing space is covered) then{
Return the co-ordinates of nodes;
Terminate ;}}}

Algorithm BESTFIT (n) {
Input: sorted node list ($r0 \geq r_1 \geq r_2 \ldots \geq r_{n-1}$*).*
sorted distance list (ld_{n0}*, rdn0,* ud_{n0}*,* dd_{n0}*).*
Compare d_{max} *(maximum distance) with* r_{max} *(maximum range)*
If ($d_{max} \geq r_{max}$*) {*
Deploy node n at derived co-ordinate (at grid-boundary).
Update distance list;
Update free node list ;}
Else {
Find minimum difference (d,r) for all free node
Deploy relevant node;
Update distance list;
Update free node list ;}}

Analysis of algorithm

We can redefine the problem as: Given *s* number of heterogeneous static sensors in specified sensing area *S*, is it possible to partition *S* in *x* X *y* grid (for square grid *x = y*) where $s \geq xy$. The algorithm works through a series of assignment where every time a free node is assigned in a partition-grid satisfying the condition $d_{max} \geq r_{max}$. If a node is temporarily assigned and satisfies optimum coverage, it is called engaged. Once a node becomes engaged, it will be engaged forever. This guarantees termination after at most *O(sd)* deployment [Hoftcroft and Karp, 1973, perfect matching problem for 1:1 matching combination.]. But considering application in real world, where incomplete-coverage for non-suitable reference node exists with overlapped redundant of deployment, it will become NP-Hard and it is obvious that if we consider optimum coverage the algorithm will become NP-Complete (3-DM is NP-Complete [17].

CONNECTIVITY AND ROUTING

In this model, all the nodes in grid are connected with Fusion Center either by single hop or by multi-hops. Since all the nodes have their co-ordinates known, this will ensure shortest path with minimum-flooding for wireless and zero-flooding for wired communication. All the nodes will follow horizontal or vertical direction towards the fusion center for hop size $(h) \geq 1$ which guarantees the movement towards shortest path. For the matrix [mXn] where $m \neq n$, the value of *h* will be $[(\max[m,n]-1)/2]$ which implies that for symmetric or non-symmetric grid unit, the total hop size for static nodes is fixed and follows the shortest path with for the entire network space message movement.

Routing Algorithm

Algorithm routing {

1. *Compare the coordinates of source node (transmitting node) and destination node (fusion center) to determine direction.*
2. *Select Source*
3. *Flood the message in all four directions for wireless communication / send the message to the next effective node for wired communication.*
4. *Store selected nodes in PATH and ignore other nodes*
5. *If destination reached then EXIT*
6. *Transmit the message to the neighbor node which is closer to fusion Center. //shortest path guaranteed//*
7. *Update message if status modified.*
8. *Repeat step 1 to 3 till the message reach to fusion center*
9. *Finally compile the message with other received information about the tracking object*
10. *end*

}

Dead node replacement

Due to variable consumption, the nodes life time varies from one node to another and finding a dead node from a heterogeneous sensor networks is quite difficult and as its replacement too. To overcome this

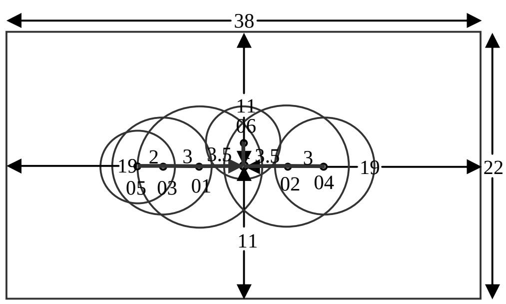

Figure 3: Coverage and connectivity for heterogeneous deployment

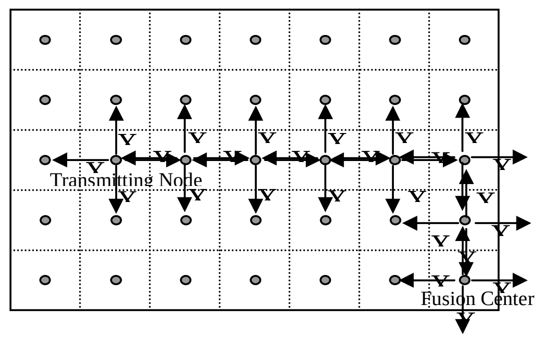

Figure 4: Routing path with shortest distance

problem, we observe the total cluster energy (E_c) of a grid. When this energy will become less than pre-calculated threshold energy (E_{th}) i.e. when $(E_c \le E_{th})$ we need to re-deploy new node within that cluster.

Let all the static nodes have the same energy, say, (e_s) and all the fusion nodes have the same energy (e_f). Assuming each cluster has one fusion node i.e. sink node, the total no. of cluster i.e. grid unit = (N_c) = number of total fusion nodes (N_f). Let total number of static nodes = (N_s). Therefore, average no. of nodes in a grid-unit / cluster = $1 + N_s / N_c$. So, total energy of the entire sensing zone will be $E_S \approx (N_s \times e_s + N_f \times e_f)$. After a certain time, say *t*, the energy used by the nodes will not be the same due to different operations. By obvious reason, Total work down of a node, say, (w) = total no. of bits transmitted (N_{BT}) + amount of sensing + amount of computing [assuming hazard-free transmission] and for both fusion and static nodes $E_f \;\infty\; {}^{1}\!/_{W_f}$ and $E_s \;\infty\; {}^{1}\!/_{W_s}$ respectively, so, with constant as K_f *and* K_s ,

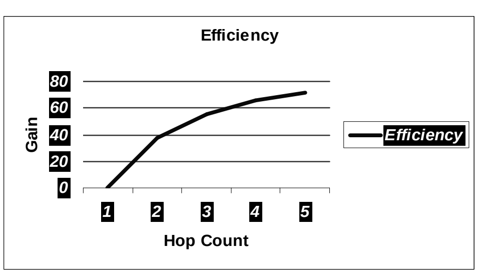

Figure 5: Efficiency graph

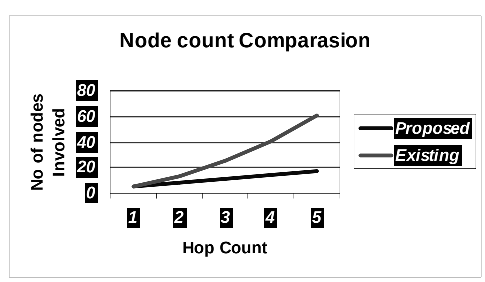

Figure 6: Comparison graph

$E_f = K_f \cdot {}^{1}\!/_{W_f}$ *and* $E_s = K_s \cdot {}^{1}\!/_{W_s}$. Let energy consumed by a fusion node to sense per second be e_{f_s} and that of a static node be e_{s_s} and to compute be e_{f_c} and e_{s_c} respectively. Therefore maximum work done by a grid unit (cluster) after time *t* will be $W_c = W_f + W_s$ where, $W_s = (N_s / N_c) \times (N_{BT_s} + t(e_{s_s} + e_{s_c}))$ and $W_f = N_{BT_f} + t(e_{f_s} + e_{f_c})$, assuming uptime for sensing and computing is negligible. Hence maximum total energy consumed by a cluster after time *t is* $(E_{ct}) = K_f / W_f + K_s / W_s$. So, if $E_{ct} \le E_{th}$ we need to deploy a new node.

Average fusion node capacity

Let *m* = message in bits a node is sending to fusion center. So, the message created by each grid-head/cluster = $(N_s / N_c) \times m$. If *α* is in-grid data reduction for aggregation, the total message volume per grid-head will be of size $(N_s / N_c) \times m \times \alpha$ bits. Let h_a = the average hop distance of the nodes to reach to fusion node in a grid area. Hence maximum message volume per grid-head / fusion node = $(N_s / N_c) \times m \times \alpha \times h_a$ bits.

SIMULATION

For simulation, we have randomly consider a regular rectangular space [38X22] units and deploy Fusion Center (FC) at its centre (19, 11) as shown in figure 3. We have taken the nodes in sorted order descending on their area coverage (5, 5, 4, 4, 3, 3…), So, $d_1 = {}^{r_1}\!/_{\sqrt{2}}$ ≈ 3.5 units and the maximum distance is 19 left to FC. So, first node will be deployed at distance 3.5 left to FC. Recalculating the boundary distances nodes will be deployed as shown in Table I. Here we have shown the simulation of 6 nodes to be deployed with different coverage area as per the table shown. For a grid area [7X5], we have simulated the routing path as shown in figure 4 assuming all nodes are homogeneous for simplicity. Since all nodes co-ordinates are known, the algorithm will follow the shortest path for transmitting data from a transmitting node to Fusion Center. Hence, broad-cast problem is highly minimized with this topology. A comparative study is made respect to the existing broadcast methodology with this topology which is shown in the table II. It is clear that with the increase hop distance the node involvement in transmission is remarkably reduced and in consequence the gain is significantly high as shown in the figure 5 and 6.

Node	L	R	U	D	Deploying Node			
					C_r	No	D_d	B
FC	19	19	11	11	5	01	FC-L-3.5	R
01	15.5	X	11	11	5	02	FC-R-3.5	L
02	X	15.5	11	11	4	03	01-L-3	R
03	12.5	X	11	11	4	04	02-R-3	L
04	X	12.5	11	11	3	05	03-L-2	R
05	10.5	X	11	11	3	06	FC-U-2	D
…	…	…	…	…	…	…	…	.
…	…	…	…	…	…	…	…	.

Table I

[Distances from boundaries: L (Left), R (Right), U (Up), D (Down); C_r = Coverage radius; No = Node no; D_d = Deploying distance (Current node-direction-distance); B = Blocked]

Hop-Size (h)	Total Nodes Involved		Gain (in %)
	Proposed	Existing	
1	5	5	0
2	8	13	38
3	11	25	56
4	14	41	66
5	17	61	72
…	…	…	
h	$5+(h-1)*3$	$2h^2+2h+1$	

Table II

CONCLUSION

In this paper we have introduced the model of topology for a distributed sensor network with heterogeneous nodes deployed in a regular geographic shape. In reality, we have to consider a random shape of the sensing zone and we will further extend this model to an irregular one. We have also calculated the operational energy utilization for effective strength to select the nodes and to re-deploy new node in place of a dead one. With best of current study, no such transmission exits in wireless sensor networks grid-based protocol to transmit messages in a single direction (approaching shortest path with limiting to zero-broadcast) with total sensing coverage.

REFERENCES

1. Jang, Jaeshin "A Study on a Sequenced Directed Diffusion Algorithm for Sensor Networks", Advanced Communication Technology, The 9th International Conference on Publication Date: Feb. 2007 Volume: 1 On page(s): 679 – 683
2. Xu Xiaochun; Sahni Sartaj; "Approximation Algorithms For Wireless Sensor Deployment" IEEE Transactions on Computers Volume PP, Issue 99, 2007 Page(s): 1 – 1
3. T. Clouqueur, V. Phipatanasuphorn, P. Ramanathan and K. K. Saluja "Sensor Deployment Strategy for Target Detection", ww.ece.wisc.edu/~sensit/publications/ Clouqueur_WSNA2002.pdf
4. Romer, K. Mattern, F. "The design space of wireless sensor networks ", Wireless Communications, IEEE Publication Date: Dec. 2004 Volume: 11, Issue: 6 on page(s): 54 - 61
5. Yu-Chee, Tseng Sze-Yao Ni En-Yu Shih, "Adaptive approaches to relieving broadcast storms in a wireless multi-hop mobile ad hoc network" IEEE Transactions on Publication Date: May 2003 Volume: 52, Issue: 5 page(s): 545 – 557
6. Chih-Yu Lin Wen-Chih Peng Yu-Chee Tseng, "Efficient in-network moving object tracking in wireless sensor networks", Mobile Computing, IEEE Transactions on Publication Date: Aug. 2006 Volume: 5 , Issue: 8 On page(s): 1044 – 1056
7. M. de Berg, M. van Kreveld, M. Overmars, O. Schwarzkopf, "Computational Geometry, Algorithm and application" second edition, Springer, 2000, ISBN 3-540-65620-0.
8. Kenan Xu, Glen Takahara and Hossam Hassanein," On the robustness of grid-based deployment in wireless sensor networks", International Conference On communications And Mobile Computing, Proceedings of the 2006 international conference on Wireless communications and mobile computing, Pages: 1183 - 1188 Year of Publication: 2006
9. Loukas Lazos, Radha Poovendran and James A. Ritcey, "On the Deployment of Heterogeneous Sensor Networks for Detection of Mobile Targets", www.ee.washington.edu / research / nsl / home/papers / LAZOS_IPSN07.pdf
10. F. Zhao, J. Shin, and J. Reich, "Information-driven dynamic sensor collaboration for tracking applications," Signal Processing Magazine, IEEE Publication, Mar 2002 Volume: 19, Issue: 2 On page(s): 61-72
11. Y. Rachlin, R. Negi, and P. Khosla, "Sensing capacity for target detection," Information Theory Workshop, 2004. IEEE Publication Date: 24-29 Oct. 2004 On page(s): 147- 152
12. J. Faruque, K. Psounis, A. Helmy, "Analysis of Gradient-based Routing Protocols in Sensor Networks", IEEE/ACM Int'l Conference on Distributed Computing in Sensor Systems (DCOSS), June 2005.
13. Wu, Zhengyu Song, Hantao Jiang, Shaofeng Xu, Xiaomei, "A Grid-Based Stable Routing Algorithm in Mobile Ad Hoc Networks", Modelling & Simulation, 2007 AMS '07 First Asia International Conference 27-30 March 2007 On page(s): 181-186, Phuket.
14. Chih-Min Chao, Jang-Ping Sheu, Cheng-Ta Hu, "Energy-conserving grid routing protocol in mobile adhoc networks", Parallel Processing, 2003 Proceedings. 2003 International Conference on Publication Date: 2003 On page(s): 265 - 272 Number of Pages: xvi+647
15. Yuh-Ren Tsai, "Coverage-Preserving Routing Protocols for Randomly Distributed Wireless Sensor Networks", Wireless Communications, IEEE Transactions on Publication Date: April 2007 Volume: 6, Issue: 4 on page(s): 1240 - 1245 Number of Pages: 1240 - 1245
16. Zhang, J. Shi, H., "Energy-efficient routing for 2D grid wireless sensor networks" Information Technology: Research and Education, 2003.Proceedings. ITRE2003. International Conference on Publication Date: 11-13 Aug. 2003 On page(s): 311 - 315 Number of Pages: 649
17. Michael R. Garey, David S. Johnson, "Computers and Intractability: A guide to the theory of NP-Completeness, W. H. Freeman and Company, NY.