Boolean Directional Sensor Orientation Solution for K-Coverage in Wireless Sensor Network

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***Abstract*—In wireless sensors networks (WSNs), omnidirectional sensors often uses in k-coverage solution provided to region of interest (ROI). Some application areas seek the directional sensors due to its geographical and deployment advantages. In this paper, a systematic model has given to present the workability of directional sensors. The parameters used to describe the modelling of the directional sensors are further applied to estimate the coverage probability. Moreover, the ratio of omnidirectional to directional sensors is being estimate. Further suggestion has been made about the orientation of the sensors and simulation result has given to investigate the effect of sensor radius and offset angle value on network performance.**

***Index Terms*—Wireless Sensor Network; Omni directional; Coverage.**

I. Introduction

Wireless sensor networks are one of the fastest growing research area in past decade and achieved significant popularity due to is necessitate of application [1, 2]. Invention and growth in micro electrical mechanical system (MEMS) has open the new era of development of low cost efficient multifunctional sensors. Moreover, the data sensing and processing capability of sensors depend upon the specific application. Most of the time, the geographical region of interest (ROI) is not easily accessible which present significant amount of hurdle in is maintains. In this context, the wireless sensors have already resource constraint such as energy, limited memory, battery power, sensing range and many more. Each node of this network communicates with each other through base station within the range [3, 4]. In wireless sensors network, accumulation of many sensors has participated to achieve significant task, specifically in this paper, providing the coverage of ROI.

Coverage of ROI is one of the many potential application provided by WSNs, and it depends upon the characteristics of ROI. Many locations is not accessible easily and sensors is being deployed randomly. Littlie amount of tuning in the orientation of sensors is possible but at the same it is quite energy consuming. In the other hand, mobile sensors have shown significant improvement in such limitation offered by location. In other hand, many building blocks such as nuclear reactors site or chemical plants can possess the opportunity of initial deployment of the sensors based on our own suitable orientation.

In k-coverage, the each point of ROI is fall at least sensing range of k-sensors nodes. Moreover, the degree of coverage provided by the network to each and every point is being defined as k-coverage [5]. A well-structured survey has been provided in [6], in which they covered the individual issues in sensor network with the past proposed solution. Apart from resources in coverage problem, there is solution incompetency also occurs and some point is not being cover and its called void in the ROI. Some work has been proposed in such a way that, the void in the ROI can reduces or minimize [7]. In our work, we propose the two layer mechanism in which the both layer act simultaneously and individually. In this way, two set of sensors can provide the 2-coverage solution and depending upon the delicacy of the application individual layer can add at any time instances. Moreover, adding individual layers can increase the reliability at the same the network lifetime can be reduce significantly, if the set of sensors is from another set of sensors which scheduled to sleep.

The paper proceeds as Section 2 explain the related work on the area, section 3 contain the proposed the work which followed by result and discussion in section 4.

II. Related Works

In [8], directional sensor has been used to provide coverage in target oriented ROI. The advantage of directional sensors is that it have switching capability of angle of focus unlike traditional sensor and the same property has been exploited. In target oriented ROI, the active period of the sensors is depend upon the activity at each time instance. Moreover, they address the multiple directional cover sets problem (MDCS) in such a way that it can be able to provide non-disjoint cover set. In this way the sleep period of the sensors is being increase which further helps in the improvement in the network lifetime. The complexity of the proposed algorithm is exponential and np-complete for which the three heuristics approach has been given and the simulation result shown has given prominent improvement in the NL.

In the recent year, many promising research [9, 10, 11, 12] has been done by many researchers to address the coverage problem of wireless sensor networks. In [10], the heuristics algorithm based on the concept of mutual exclusiveness of sensors to provide the k-coverage for independent region has been given. Moreover the maximum number of sensing area overlapping is depending upon the value of "k". Moreover, the optimality for the sensors placement through the linear programing has been study in [11] for covering the ROI without the hole. In this context, reliability of the network with high probability constraint for covering the region has been given in [13]. The extension of same for k-covering been also given in [14] with the help of for well-known $\in -$ nets technique.

In [15], the greedy approach has been proposed for the estimation of sensors cover within logarithmic factor which further extended [16] for generalized k-coverage optimal solution.

In [15], is extension of [16] for generalization of k-coverage solution provided in [16] with comprehensive complexity analysis. In this simple greedy algorithm has been given to solve the k-cover np-complete problem and np-hard estimation. The complexity analysis has justifies trough the extensive modelling with simulation result. It claims that, for covering the maximum number of targets "T" with "N" of sensors for k-cover is estimated as Tlog(k—N—). The give n result has been claim that it will hold for almost any of the arbitrary ROI.

In [17], the solution for smart surveillances is given based on mobile sensors to ensure that each region in the ROI is covered by more than one camera. The directional k-coverage (DKC) solution has exploited the limitation of angle of view an on directional sensors. Effectiveness of the model has been study based on simulation result.

In [18], maximum coverage with minimum sensors (MCMS) problem is considered for random deployment of sensors. In this the orientation of sensors is tunable and the Linear programming (LP) formulation and solution is given which able to provide computationally efficient algorithm. The simulation results has been compared with the exiting solution and given better feedback in term of coverage and NL.

In [19], 2-cover solution for ROI has been proposed for heterogeneous mobile sensor. It ensure maximum utilization with minimizing the travelling distance of mobile sensors.

III. Proposed Work

In this section, we will discuss the property directional sensors as well as sensor placement approach for rectangular region of interest (ROI).

A. Directional Sensors model and variables

In WSN area sensing, the sensing unit is typically the Omni-directional and sensor placed at the point "P" is able to cover the area $\pi * R$. where R is equal to the maximum line of sight (LOS_m). Here we are modelling the directional sensors and its resemblance can be found in the model given for field of view in cameras in [20]. We consider here 2D-model of sensing area of sensors and it can be represented with 4-variables (LOC, R, LOS_m, α). Where

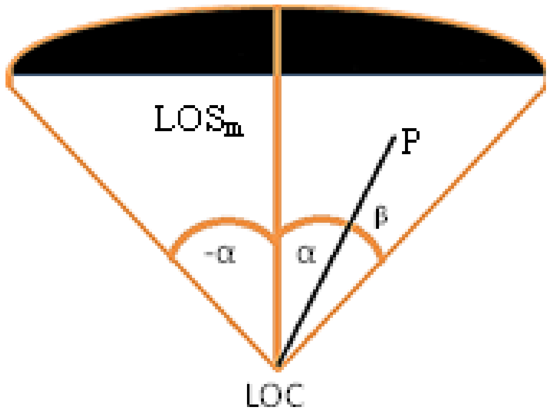

Fig. 1: Directional Sensor Model.

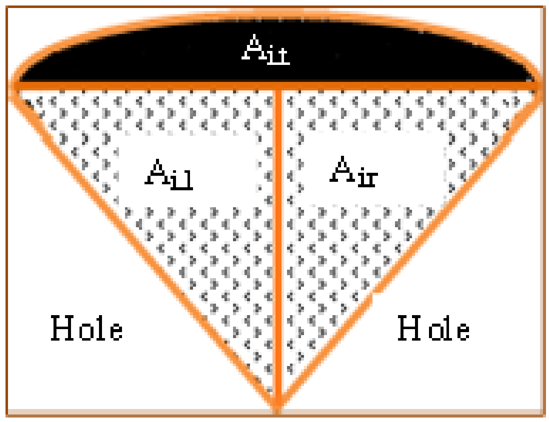

Fig. 2: Directional sensing region in shaded and black region.

In our model, the point "P" is covered at time instance "t", if the following condition is being filled:

(a) $E\_dist(LOC, P) \leq R$, where $E_dist(LOC, P)$ is Euclidean distance between location of any sensors Si where $i \epsilon N$ and point "P" in the ROI.
(b) The angle between LOS_m and line segment of P and LOC should in between $[\alpha-, \alpha]$. In this context, the point P is covered by directional sensor available if the length of line segment $|PLOC| \leq R$ and angle between line segment $|PLOC|$ to offset LOS_m is always less than $abs(\alpha)$.

B. Coverage probability estimation (CPE) of directional sensor

Sensor deployment in WSN in ROI is proceeds in two way and it either manual or random [6] and it depends upon the

TABLE I: Notations

Notation	Description
AOI	Area of interest or active region
LOC	Location of the sensors
R	Radius of sensors
$R_{B,O}$	Ratio of Bidirectional and Omnidirertional
LOS_m	Maximum line of sight
α	Offset angle with LOS_m
S_i	Sensor with arbitrary numbering "i"
E_i	Energy of sensor "i" at initial deployment
E_{it}	Energy of sensor "t" at time instance "t" Note: time is being estimated in unit.
$E_{dist^{(a,b)}}$	Euclidean distance between point "a" and "b"
N	Number of sensors available
$A_{i,t}$	Area covered by sensor "i" with its top notch
$A_{i,l}$	Area covered by sensor "i" with its left sensing portion
$A_{i,r}$	Area covered by sensor i with its right sensing portion

arrangements of ROI. In this context, when the specific place is not easily accessible then random deployment with the help of aeroplane or another vehicle can be helpful while in closed area such as building block which can easily accessible initially for instalment. In closed site such as nuclear power plant or industry the sensor with omnidirectional is underutilization due to obstacle such as concrete wall and so on. Moreover, direction antenna can be cost effective as well as the purpose of covering the ROI.

The sensing area is explained as the area which is interested for sensing and also defined as ROI [7]. In table 1, the area of interest is denoted by AOI. Assume there is no exactly two sensors is located at the same region. In addition, each point P is being at least 1-coveage and the overlapping of the sensing range by either the top, left and right sensing portion of sensors is supposed to minimize. In this context, the directional sensors with offset angle is able to provide sensing capability in region αR^2 and for omnidirectional the sensing region value is πR^2. The number of sensors deployed in the area is equal to N as mention in the table 1. With the help of N-directional sensors deployed, the probability of covering the targeted region can be given as:

$$p = 1 - \left(1 - \frac{\alpha R^2}{AOI}\right)^N \tag{1}$$

For Omni-sensing sensors =, then the coverage probability once the N sensors is deployed can express as given in equation.2

$$p = 1 - \left(1 - \frac{\pi R^2}{AOI}\right)^N \tag{2}$$

In the same way, in real time application the network should prove the threshold value and the same value can be used to calculate the reliability of the network. Moreover to achieve the probability "p" (important variable for calculating reliability of the network), the number of deployed directional sensors should be at least N and this can simply calculate with equation.3

$$N \geq \frac{ln(1-p)}{ln(S - \alpha R^2) - lnAOI} \tag{3}$$

Again for Omni-sensing sensors=, the number of sensors required to achieve probability should be

$$N \geq \frac{ln(1-p)}{ln(S - \pi R^2) - lnAOI} \tag{4}$$

From the above equation, the ratio of directional sensors with respect to omnidirectional sensors can express in term of following equation.

$$R_{B,O} = \frac{ln(S - \pi R^2) - -lnAOI}{ln(S - \alpha R^2) - lnAOI} \tag{5}$$

C. Linear formulation for coverage

In this section, the calculated probability estimated earlier is being used as threshold value. Moreover the coverage of the area as maximize by following the estimated probability as well as other constraint. The similar work has been done in our previous work on translucent optical network for routing and wavelength assignment [21]. In equation 6 the area coverage is being maximize by dividing the coverage capability of the sensors into three categories as defied in table 1. Equation 1 define to maximize the shaded region fall within the ROI and so the constraint to allow it and make sure that request is being full field by keeping the constraint.

$$maximize \sum_i^N A_{i,t} + \sum_i^N A_{i,l} + \sum_i^N A_{i,r} \tag{6}$$

In equations (7-11), the required constraint has given. In equation 7, sensing range limitation is given so that the sensing range of the sensors can not exceeds from certain threshold, which in our case is ROI. By controlling the sensing range, the depletion of energy can reduce as sensing range decrease.

$$\begin{aligned} &subject\ to, \\ &AOI \leq ROI \end{aligned} \tag{7}$$

In equation 8, the maximum available sensing unit is given and as earlier the threshold probability has been estimated. Therefore, number of sensors used to maximize the coverage should be always less than or equal to availability of sensors.

$$N \leq N_{max} \tag{8}$$

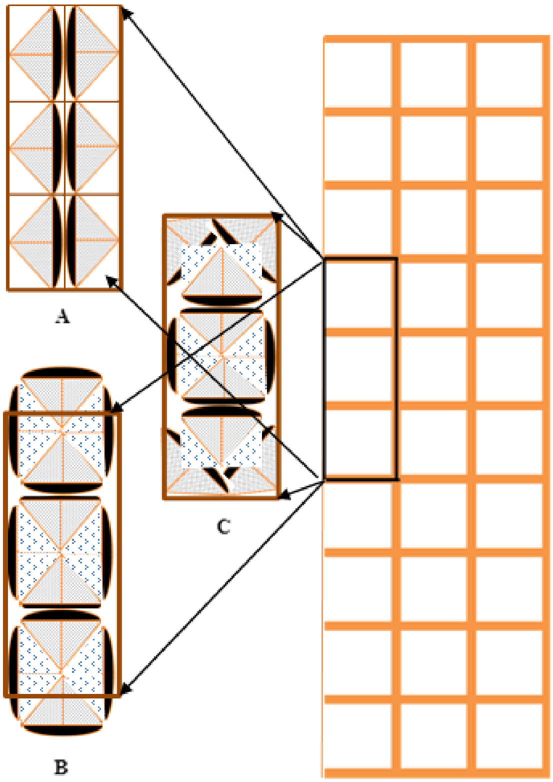

Fig. 3: Directional sensor orientation in any of 3-block.

In equation 9, ensure that the point which lies inside the ROI is covered as maximum as possible. We had already discussed that in directional sensors deployment, the hole in AOI is always possible. By adding this constraint, the void is being reduced as much as possible.

$$PLOC\ angleLOCLOS_m \geq |PLOC| cos\alpha \tag{9}$$

In equation 10, the covering angle of directional sensors can be control, but at same If it increase the depletion of the energy will be fast. Therefore the covering angle is control by this constraint and in theory if any of the result is giving the=pi, means those sensors can be replace by omnidirectional sensors for better network lifetime and energy management.

$$4.\alpha \leq \pi \tag{10}$$

In equation 11, the energy is being accounted so that the total time of the network alive can be estimate. As we discuss that, in our two separate layer of coverage is being used in which either any of the single layer sensors will be active at time t.

$$5.E_i \geq E_{th} \tag{11}$$

IV. Result and Discussion

In this section, the experimental setup for proposed work is explained through the parameters of the sensors as well as ROI. The area of ROI is assume as $10 * 3unit^2$, in which any of the three vertical block is being consider for placement of the sensors. In figure 3, the building block and placement for k-coverage with orientation of the directional of the sensors has been given. In this orientation, the white part represent the hole if the orientation present is being opt. Moreover, it is here need to understand that, there can be many possible orientation can be possible but the orientation given in Now the angular coverage value here is vary from $\alpha = 30^o$ till $\alpha = \pi$. The computational parameters are being summarized in table 2.

Further on the basic of estimated probability, coverage maximization has been performed on MATLAB version 7.10.0 with computational capability of 2.4 GHz and RAM capacity with 4GB. In figure 4, the experimental result has been shown in the term of coverage rate (probability) vs. offset angle with respect to different sensor radius ratio. It can be observe form graph that as number of sensor is being increases, the probability of coverage is also increases with specific angle of view. As with different angle of view the experiment has been performed and can be observed from figure 4. Moreover, as the comparison of increasing of angle from 0 to 180 with different value of radius of the sensor is presented in graph 5. The number of sensors in this scenario is being fixed based on the data set presented in the table 2.

V. Conclusion

In this paper, we had given the model of directional sensors which has been used in the coverage of ROI. In this context,

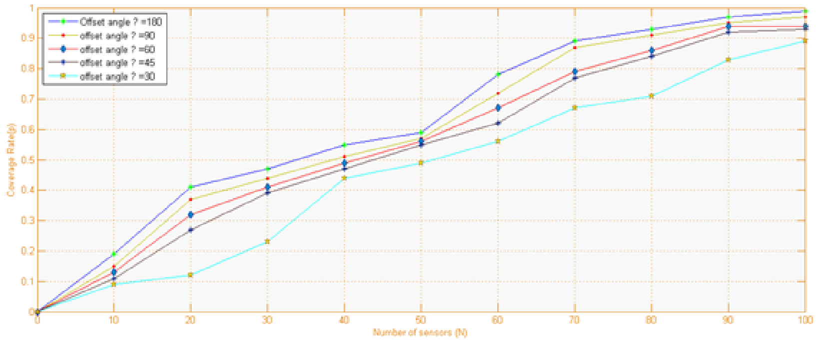

Fig. 4: Effect of offset angle of sensors for threshold coverage.

TABLE II: Notations

Parameter	Default	Variation
Coverage rate (p)	1	0-1
Sensor number N	100	0-100
Offset angle α	180	0-180
Sensor radius	20 unit	0-25 unit
Communication radius	40 unit	0-50 unit
Area (S)	10*3 $unit^2$	10*3 $unit^2$

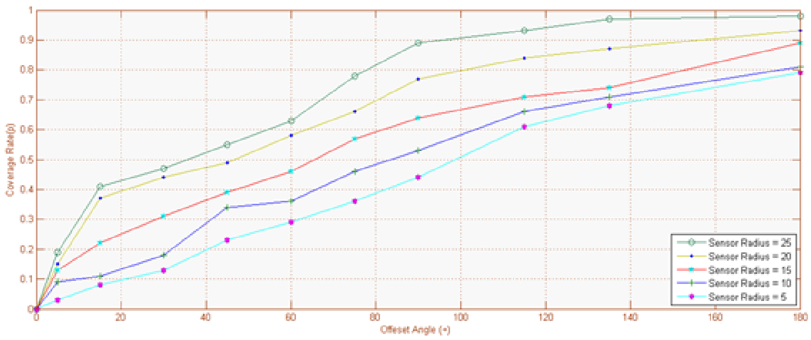

Fig. 5: Effect of sensors radius on threshold coverage and on offset angle time line.

the probability estimation method is being used to calculate the threshold value which further extended to the ratio of directional sensor with respect to omnidirectional sensors. Moreover, LP formulation for maximizing the coverage area with the available resources has been given. In the simulation result effect of offset angle and sensor radius has been presented. With the fixed number of the sensors, different orientation method has been suggested and the future objective is to achieve the coordinated value of the sensors in ROI. Moreover, the energy consumption for achieving the k-coverage solution is further need to study.

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