THINK INDIA JOURNAL

ISSN:0971-1260
Vol-22- Issue-12-November-2019

Deployment Schemes for Mobile Sensor Nodes: A Review

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Abstract:

Wireless Sensor Network (WSN) over the years came out as an essential system for monitoring the distant, unreachable geographical locations. WSN is a collection of sensor nodes (SNs) deployed within a target area in order to keep an eye over the changes that occur in the target region. SNs can be mobile or static depending on the application.

In this article we will discuss several existing models which are used for the deployment of MSNs within a target region and their comparative study.

Keywords: Mobile sensor, Sensor Network, Sensor Node, WSN, MSN, SN.

1. Introduction:

Wireless Sensors has diverse application and implementation in the field of remote monitoring and disaster management [1] [2]. Sensor Nodes (SNs) are cost-efficient small devices designed to be installed over the unreachable and hostile target region [3] [4]. This region may be a territory of enemy, disaster prone region, Marshy, Forest region, agriculture fields, etc. [5] [6]. SNs are deployed in such regions so that the physical, chemical or biological changes occurring within those regions can be tracked [7] [8]. Once some suspicious change is figured out by the SN, the information regarding the same is propagated to the Base Station (BS) [9]. A number of models have been proposed for the deployment of SNs. Few of the common deployment schemes are as follows:

- Manual Deployment.
- Robot assisted deployment
- Aerial deployment [10]

In this article we will discuss several existing models which are used for the deployment of MSNs within a target region and their comparative study.

ISSN:0971-1260
Vol-22- Issue-12-November-2019

2. Mobile Sensor Deployment Schemes

Mobile sensor have an additional advantage that in comparison to the static sensor they have a mobility module which facilitates them to change their position after the initial deployment. Mobile Sensor deployment techniques are described as follows:

2.1. FLOOR Based Technique

FLOOR based technique of SN deployment improved form of CPVF [11]. In this method candidate area is plotted into Floor Lines (FLs) parted by a $d = 2 * r_S$ as given in Figure 1. Alike CPVF, FLOOR model make use of BUG2 (algorithm) and Lazy Movement (algorithm) to reduce the movement of MSN while dealing with the obstacles.

After the stochastic spreading of the MSNs within target region, they start relocating to the closest FLs. As shown in Figure 1 MSN_1 and MSN_2 shift to FLs F_1 and F_2, after approaching FLs, MSN_1 and MSN_2 follow their respective FLs in order to reach axis-Y, which is then followed by MSN_1 and MSN_2 to shift in the direction of the *BS*, they halt at position PS_1 and PS_2 when they get linked with the BS.

BS send the IDs of all the ancestors MSNs to the newly connected MSNs. This stage aims at finding which of the MSNs can be relocated in order to increase the coverage of the network without dividing the network. In order to move the MSNs attempt to find new parents for their child MSNs, so that they remain in connection with the BS.

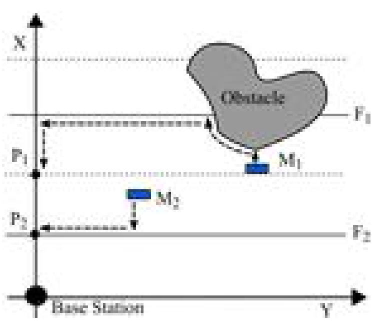

Figure 1. MSNs movement in direction of BS(redrawn from [11]).

After all the MSNs which can move are figured out, they are relocated to increase the area covered. Placed MSNs determines the uncovered patches at their vicinity and then computes the position where the unplaced MSN can be relocated in order to efficiently cover the target region.

ISSN:0971-1260
Vol-22- Issue-12-November-2019

The uncovered spaces between the r_s of MSNs on either FLs restricts the model from attaining maximum coverage but it significantly reduces the movements of MSN.

2.2. Distributed Deployment Model

Kumar et. al. in [12] suggested a distributed deployment model (DDM) for uniform dispersal of MSNs in the target region. DDM uses BS to splits target region into number of concentric circular regions centred at it, each circular region is parted by 1/2 of r_{com} (Figure 2).

BS calculate entire target locations for positioning the stochastically dispersed MSNs. Target locations are calculated by splitting the target region in hexagonal sub-regions (with each edge = r_{sns}) and centre of the hexagons form the target locations. The derivation of r_{sns} and r_{com} is specified by Equation (1).

$$r_{com} = r_{sns} * \sqrt{3} \tag{1}$$

BS calls the stochastically dispersed MSNs region after (circular region represented by R_1, R_2, R_3, R_4, …) after region (starting from the innermost region) in order to occupy the pre-computed target locations, thus getting connected. If any circular region don't have MSNs then the BS waits for definite time t ($t \geq$ utmost time taken by the MSN in present circular region in order to relocate up to last occupied circular region) and calls the MSNs in next circular region to relocate in direction of the connected MSNs to get connected.

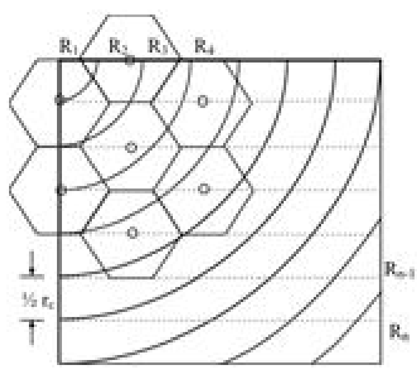

Figure 2. Division of target region ([12]).

The procedure iterated is until every MSN is placed on target locations. DDS achieves the multipath connectivity, with lowest overlap and 100% coverage with optimum number of MSN movement, but it is not scalable as the MSNs are deployed in sequential manner (circular-region after another) due to which the time of deployment increases with the

ISSN:0971-1260
Vol-22- Issue-12-November-2019

increase in the size of the target region. Moreover, the MSNs can effectively move in the plain surfaces, which makes the DDS ineffective for real scenarios.

2.3. Energy Efficient Scalable Deployment Scheme

MSN based SN deployment model was offered by Gupta et. al. [13]. It intends to achieve maximum coverage with help of optimum count of MSNs and achieve full connectivity with least movement of MSNs. It resembles with DDS [12] on a fact that both of these models use the same relation between r_s and r_c (Equation (1)) and the method for computing target locations for the placing the MSNs by splitting the target region in hexagons of regular size, is also similar. Both the schemes however targets in achieving the blanket coverage over the wide open-area target region where MSNs are stochastically dispersed from the air in the initial stage of deployment. However it is dissimilar to DDS in terms of scalability and distributed mechanism used by it to concurrently relocate the MSNs to most preferred target locations within a target region. It also contains a mechanism for dealing with the obstacles encountered during the movement of MSNs. BS broadcasts the entire list of pre-computed target locations to the stochastically dispersed MSNs, which is then sorted by the individual MSN based on its distance from every target location. MSNs then start moving towards each target location in the order stated by the sorted list until unoccupied target location is achieved. After reaching the target locations the MSNs periodically broadcast the STOP message in order to intimate the MSNs heading towards that target location. Thus the MSNs stopped by the placed MSNs again sort the list of target location based on their current locations and repeat the process for further placement. The obstacles are handled with the help of Bug2 algorithm [14].

The major inadequacy of SEEDS is that, the list of target location increases with the increase in area of the target region, which in turn increase the length of packet o be broadcasted.

2.4. Distributed Self Spreading Model (DSSA)

DSSA proposed a technique for the positioning the MSNs homogenously in a target region by iteratively repositioning them in order to attain the desired density of MSN within a target region [15]. DSSA is inspired from the molecular arrangement (i.e., equilibrium)of any

ISSN:0971-1260
Vol-22- Issue-12-November-2019

compound terms of intermolecular spacing and density. Every MSN individually make decisions in context to the direction and distance of relocation. Decisions for the relocation of MSNs are taken based on the collective power applied by neighbouring MSNs and variation among local density D_l and expected density D_{ex} levels. D_{ex} for any area A_r of target region with N MSN is explained by equation (2).

$$D_{ex} = \frac{2 * N * \pi}{A_r} \tag{2}$$

$$F_n^{i,j} = \frac{D_l}{(D_{ex})^2}\left(r_c - \left|p_n^i - p_n^j\right|\right)\frac{p_n^j - p_n^i}{\left|p_n^j - p_n^i\right|} \tag{3}$$

Force applied on i[th] MSN by the neighbouring j[th] MSN is denoted by $f_n^{i,j}$ in Equation (5). Where, p_n^i depicts the location of i^{th} MSN at time-step n. The resulting force F on i by virtue of all its neighbouring MSNs is given by merging all the forces applied on i. The MSN is assumed to be still in the given situations:

1. If MSN don't have displacement more than d_{min} (minimum relocation distance) for time interval T (because of deficient battery or letdown of the MSN).
2. If the sum of oscillations (to & fro motion of MSN) by MSN surpasses definite oscillating limit.

DSSA efficiently reduced the travels of MSN by regulating the oscillations, but fails to assure the linkage with the BS.

2.5. Neighbour Assisted Deployment Scheme (NADS):

Sharma et. al. [7] proposed a neighbour assisted scheme (NADS) which uses a collaborative effort of neighbouring SNs for deployment. It uses a 3-Step improvement method to ideally place the MSNs within a target region. Resultant of every step makes a set-up to support the relocation for ideal positioning of residual unplaced MSNs. It can be applied to deploy the MSNs in the target region of every size and shape. The complete target region is visualized like a union of square shaped sub regions of equal size, which are again divided into various regular hexagons and the centre of every hexagon is made the Preferred Locations (PLs) for the positioning of MSNs. After random scattering of MSNs, they perform communication locally to decide the most suitable MSN (MSN nearest to the DL) for specific DL. Elements such as, speed of wind, height of dropping, size of parachute, capacity of battery and weight

ISSN:0971-1260
Vol-22- Issue-12-November-2019

of MSN are taken care to determine all the plausible locations of landing of any MSN aerially dropped and geographical region which can be reached by it.

3. Comparative analysis

Table 1 represents the comparative analysis of various schemes used for the deployment of MSNs. It is observed that none of the mentioned scheme of sensor deployment is capable of operating in all the terrains, however they are restricted to specific type of terrains.

Table 1. Comparative analysis

Models	SN Type	Connectivity Assurance	Obstacle handling	Scalable	Independent of terrain
FLOOR	Mobile	Yes	Yes	Yes	No
DDM	Mobile	Yes	No	No	No
SEEDS	Mobile	Yes	Yes	No	No
DSSA	Mobile	No	No	Yes	No
NADS	Mobile	Yes	Yes	Yes	No

4. Conclusion:

Wireless Sensor Network (WSN) over the years came out as an essential system for monitoring the distant, unreachable geographical locations. WSN is a collection of sensor nodes (SNs) deployed within a target area in order to keep an eye over the changes that occur in the target region. SNs can be mobile or static depending on the application.

In this article we have discussed the working of various schemes used for the deployment of mobile sensors and then compared their capabilities.

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Vol-22- Issue-12-November-2019

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