Asian Journal of Information Technology 15 (16): 2750-2755, 2016
ISSN: 1682-3915

A Modified Virtual Approach to Deploy Border Line Sensors

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Abstract: Theuse of Wireless Sensor Network (WSN) has turned into effective applications in the last years. Countries borders reliable protection and security are being one of the essential research problems in these years. WSNs can be utilized in improvingthe borders security in a smart manner. It can be used as an on-line virtual fence to control and prevent any intruder tries to penetrate certain protected areas. Deploying WSNs will support barrier coverage to improve the process of border surveillance and intrusion detection. Collected data by sensors contains rotational and displacement information. There are many deployment techniques with various optimizing goals for each environment. Deploymentor "sensor placement model"represents an awkward mission requires serious effort. It isaffected by the sensors types, process goals, communication channels, coverage area and the areatopology.WSN must have good ability to sense and collect enough data with a participatory sensing property.WSN deployment is one of main problems in wireless sensor network researches. It heavily affects the cost and the network performance. A good deployment strategy can reduce cost of network, save the energy for communication and increase robustness of the network. In this study, a mathematical model is suggested depending on markov property. A simulation model is also proposed using Net Lego. A simulation can be used as a virtual environment to analyse, observe and test this deployment approach. A suggested mathematical model can be used in estimating the accurate location of the deployed sensorsin a sequential manner. This process depends on the previous sensor location, sensing area and the surface area shape. This model will arrange all the deployed sensors in the area of interest to cover and observe all the sensing area and prevent any closing intruder. The developed model is suitable to deploy sensors along border line deployment.

Key words: WSN, nodes deployment, border surveillance, intruder, Iraq

INTRODUCTION

Border detection and control systems are becoming an important and vital issue for many countries. WSN represents a suitable and intelligent technique that can be utilized in border surveillance applications for there quired control and monitor purposes. It combines various properties such as;low power consumption, good sensing level, wireless data transmission ability, low cost andhaving compact devices (Bellazreg *et al*., 2013).

Most countries are searching for an automated surveillance system to offeran effective border continuous monitoring system.WSNs can be utilized as efficient monitoring systems. Deploying sensors close to the border line will detect the intruders and transmit the collected data to the Base Station (BS). This approachrepresents a real time border surveillance system (Sun *et al*., 2011).

The deployment process of WSN affects all its performance metrics such as the network lifetime, data routing andnetwork's coverage area. Selecting the deployment locations, the required sensors number, the coverage area, region of Interest and the deployment costs are representing the main decision problems. Optimizing some of these factors is the essential challenge.

The WSNs can be utilized in different application fields to help in building specific surveillance systems. These applications are either civilian applications or border surveillance. WSNscan be used for border tracking and surveillance applications to provide appropriate solutions for many intruders' problems. The deployment strategies for the sensor nodes can be categorized in to either "controlled deployment" or" random deployment" (Seema and Goyal, 2013).

Border monitoring problems represents one of the main military applications of the WSNs. Manyexisting techniques can be utilized toobserver and advicethe decision makers about any intruders approaching to certain area or crossingcertain line. Sensor nodes with a "high-level technology" were designed and produced in an economical manner. These wireless sensors with "cognitive radio technology"can be usedin "data traffic processes" for a long distance monitoring (Abbasi *et al*., 2014).

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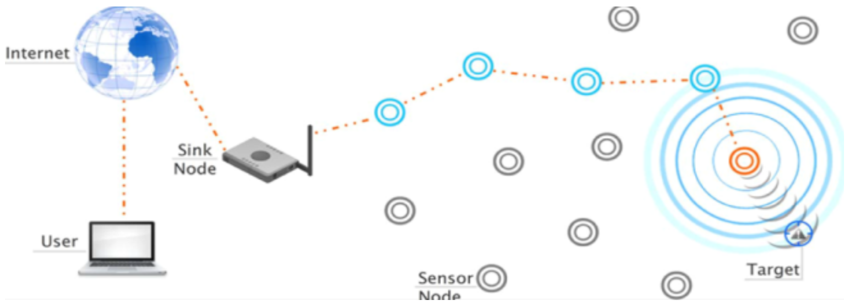


Fig. 1: WSN architecture sample (Abbasi *et al*., 2014)

WSN applications: WSN composed of a wide number of sensors designed to monitorcertain physical area.It can use to sense object movement, sound and temperature.WSN can collect information through the system and transmit it to the Base Station (BS). In military applications, WSNs can be used to observe and control the front line. Figure 1 presents a view of some WSN architecture (Abbasi *et al*., 2014).

MATERIALS AND METHODS

Sensors deployment: A deployment approach in WSN was divided into two groups as "sparse" and "dense deployments". A in the given field of interest while a "sparse deployment" can be used withlittlenumber of nodes deployed while the "dense deployment" can be used in high number of deployed sensors. The "dense deployment"techniquewas used in the case ofevery event wanted to be noticed or there are multiple sensors deployed to cover the same area. When one want to achieve maximum sensing area with minimum number of sensors, then sparse deployment is suitable. Thesensor nodes are either static or mobile so they canchange their positionswith time (Qin *et al*., 2008).

Sensors are deployed in certainfield either by locating them in "predetermined places" or randomly deployed. "Random sensors deployments" approach isone type of the"dense deployments".WSNswith mobile sensors are normallyinitiated with a "random deployment" and by their mobility change their locations to the best suitable location (Guo *et al*., 2012; Zhang *et al*., 2010).

Static deployment: In "static deployment", sensors are static and their locations must be selected due to certain"optimization strategy". Sensors locationswill stay fixed and not changedduring the operation of the network. "Static deployment"strategy can be achieved by deterministic steps and random deployments. This approach (the "deterministic deployment") is started by surveying the area of interests and continuing withthe deployment process (He *et al*., 2010).

Dynamic deployment: One important application of a"dynamic deployment"was used in robots. Mobility helps in attending thesensing goal by letting the sensor move towards amaximum sensing performance. In "random deployment" most of the nodes are tossed in the first step, then a special utilization and reformation estimations to select the next movement (Luo and Pan, 2011). Many developed algorithms were built such as"virtual force oriented particles algorithm" (Wang *et al*., 2007), "simulated annealing algorithm" (Lin and Chin, 2005), "particle swarm optimization algorithm" (Yi, 2011) and "simulated annealing genetic algorithm" (Liao *et al*., 2011).

Sensing areas: The essential aim of any WSN is to have maximum sensing area (maximum coverage area). Coverage or sensing in WSN represents the back bone issue due to its relation with the energy consumption, network reconfiguration and connectivity. A basic problem is how to achieve maximum effective sensing area by deploying the sensors in an optimal manner. A good sensing area is that area in which every point in the area will covered and monitored by at least one sensor (Boukerche *et al*., 2006).

The role of WSN in border surveillance: Each country trying to keep save and secure borders with neighbours. The WSN represents one of the possible tools to keep and build an electronic fence on the borders. WSNs are necessary to reduce the population dense regions where there are some intruders. One of the troubles in an occupied district is that the sensors will have an ability to distinguish the disturbing effects from individuals (Felemban, 2013).

Sensors can be deployed along lines todeliver strength defense along the wanted deployed line.The WSN's plays an essential role in its area of applicationin theborder surveillance application (Karl and Willig, 2005).

Markov models: A "Markov chain" represents one aspects of a "mathematical model". Ithas certain random occurrencedepending on time in a specific style that the future state depends only on the current state. The applied "time" can be described as discrete or continuous. In some mathematical applications, such phenomenon which depends on time and only the present activity will affects the next activitywas called a "dynamical system". For any time t, the upcomingpath (A(x), x = t) can be entirelystated by the current state A(t), without ant need to the past states.In most applicationsthey dealt with random variables rather thanthe deterministic values.

Markov chains represent a very important modelling tool that can be applied for the situations in which the trials do not happen according to an "independent and identically distributed" mechanism. Markovian property means that any stochastic process {xt}must have the following property:

$P\{x_{t1}= j \backslash x_0= k_0, x_1=k_1, \ldots, x_{t-1}=k_{t-1}, x_t=i\} = p\{x_{t+1}=j \backslash x_t=i\}$, for t = 0, 1, . . . and every sequence i, j, k_0, k_1, . . . , k_{t-1}. Markovian property means that "the conditional probability of any upcoming event (any preceding events and the current state $X_t = i$) is independent of the historical events and depends only on the current state" (Hiller and Lieberman, 2001).

Markov chain can be generally definedas follows: for a "set of states, $S = \{s_1, s_2, \ldots, s_n\}$". The movementwill be initiated inany one of these states and goessequentially from state to state. Each change is titled as a step. If the chain is found in certain state s_i then, it can go to state s_j at its next step with certain probability equal to p_{ij}. This probability value will dependson statesi and j only.

The transition probability represented by (p_{ij}) means the probability of going from state 1 to state 2 on the upcoming step. The transition matrix collects all the transition probabilities from state to state (Wong *et al*., 2007).

Probability distributions: There are many useful probability distributions with random behaviors can be used in real application. Most useful distributions may help in this study are the uniform, exponential and normal distributions (Howard and Pao, 1998).

For a uniform distribution, any random variable lies between b and a, the uniform density function of a random variable x is:

$$f_X(x) = \begin{cases} 0, & \text{if} x < a \\ \frac{1}{b-a}, & \text{if} a \le x \le b \\ 0, & \text{if} x > b \end{cases}$$

A uniform random variable can take any value between its upper limit and lower limit. P(c ≤ X ≤ d) was used to represent the area "under" the line between any two points (d and c). It can be estimated by the following equation:

$$P(c \le X \le d) = \frac{d-c}{b-a}$$

For the exponential distribution, usually the exponential distribution depends on one parameter (λ). And its probability density function is:

$$f(x) = \lambda e^{-\lambda x}$$

And for the case of the normal distribution, it depends on two parameters its random variable mean and variance (called μ andσ). The "probability density function of a normal distribution" is:

$$f_X(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{(x-\mu)}{\sigma}\right)^2}$$

RESULTS AND DISCUSSION

Model assumptions: The sensors deployment process can be modeled and analyzed according to markov chain property. Sensors deployment can be started by locating the first sensor node on the initial or the started position. This started point represents the location (x, y) of the first sensor. The location of the second neighbor sensor must be chosen carefully depending on the location of the first sensor. Its location must be within the coverage area (the sensor sensing range). The distance between any two sensors must be estimated to ensure good connectivity, good sensing and covering the interested area. A real distance must be measured from the deployed sensor to the next one. This real distance must be less or equal the sensor coverage area. If there is a certain elevated area, Low area or Valley, the distance must be measured on the surface area. The following model is suggested to be applied:

Assume that the first sensor location is f (x_0, y_0) and equal to d_0; then

$$d_0 = f(x_0, y_0)$$

The location of the next sensor is:

$$d_1 = d_0 + f(c, s)$$

Where:

c = Coverage range and

s = Surface area line

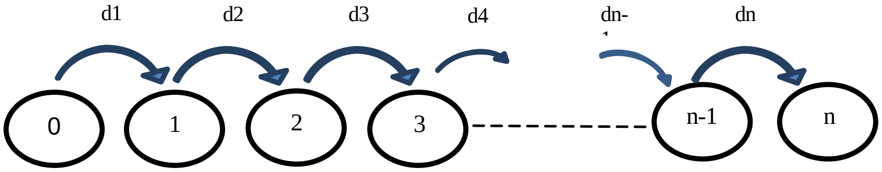
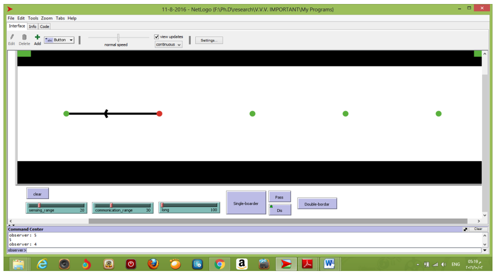


Fig. 2: The border deployment transition rate diagram



```
sensing_range 20
commonication_range 30
long 100
```

```
observer: 5
5
observer: 4
observer>
```

Fig. 3: Program snapshot for single layer

If s is flat → f (c, s) = c otherwise:

f(c, s) = RR :is random distance calculate as random variable. R = 0 for flat area

$$R = \begin{cases} r1 - c & \\ & \text{for lower area} \end{cases}$$

$$R = \begin{cases} r2 - c & \\ & \text{for lower area} \\ 0 & \end{cases}$$

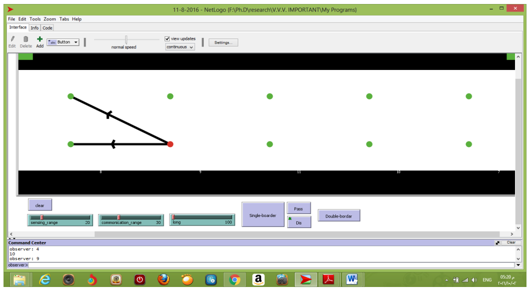
$$p_{ij} = P(d_{i+1} = R_{i+1} \mid d_i = R_i)$$

r1 = Distance from node i to local maximum for the case of elevation

r2 = Distance from node i to local minimum for the lower area

The resulted Transition matrix is:

$$\begin{array}{c|cccccccccc}
 & 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & \cdots & n \\
\hline
0 & 0 & d1 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & n \\
1 & 0 & 0 & d2 & 0 & 0 & 0 & 0 & 0 & \cdots & n \\
2 & 0 & 0 & 0 & d3 & 0 & 0 & 0 & 0 & \cdots & n \\
3 & 0 & 0 & 0 & 0 & d4 & 0 & 0 & 0 & \cdots & n \\
4 & 0 & 0 & 0 & 0 & 0 & d5 & 0 & 0 & \cdots & n \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots \\
n-1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & dn
\end{array}$$



```
sensing_range 20
commonication_range 30
long 100
```

```
observer: 4
10
observer: 9
observer>
```

Fig. 4: Program snapshot for double layer

Such stochastic transition matrix is convenient and suitable in simulating and studying all the possible probabilities for a sequence of taking place stages before generating or building these sequence steps.

The transition matrix can be transformed into another graphical representation called transition diagram. Figure 2 shows a developed transition rate diagram for this transition matrix.

There are many probability distributions can be utilized to help in estimating the required suitable distances between any two successive deployed sensors. The sensors deployment manner can be represented as a "sequence of discrete states". The input to this model is a distance. The probability, transitions are dealing with time, in this model we suggests that the time is directly proportional with the distance.

A good deploying contribution can be reached if these distributions are utilized with the markov chain fundamentals.The distance between any two successive sensors can be estimated virtually as a random variable with certain probability distribution. The distance can be calculated by finding the new coordinates (x, y) of the position of the next deployed sensor with respect to the previous one. So in each step a (∆x or ∆y) value represent a horizontal move value must be added to the previous x or y value. The selection of the probability distribution will depend on the application and environment types.

A developed simulation program was adapted using Net Logo (5. 3. 1) to model different deployment cases. Figures 3 and 4 shows a program snap shots to represent

Fig. 5: Sensors deployed on a flat area boarder

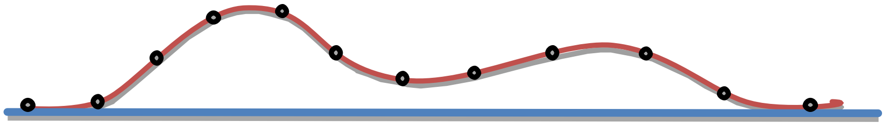


Fig. 6: Sensors deployed on an elevated and lower area boarder line

Table 1: Sensors deployment positions for flat area

Sensor no.	x	y	di	Final location
1	10	15	10	10
2	30	15	20	30
3	50	15	20	50
4	70	15	20	70
5	90	15	20	90

he created environment in two different deployment approaches, namely single and double deployed sensors layers.

Figure 5 shows a sample of deployed sensors on a border segment with flat area while in Fig. 6 presents a sample of elevated and lower areas border line with deployed sensors.

As an example a certain flat area can be selected to indicate the sensors location results. A coverage area of 20 m was suggested for sensors. Table 1 shows a simulation results for each sensor location in short

CONCLUSION

In this study, we have developed a mathematical approach to predict and calculate the next sensor place based on the previous sensor location depending on markov chain and probability distributions. The sensors deployment process was modeled as successive steps. In each step a position of one sensor can be calculated and adjusted. After locating one sensor, the next step will move toward x- axis or y-axis depending on surface area shape and the sensor sensing range.

The proposed model in this study can be utilized to provide an additional useful applicable approach to estimate the value and the direction to the next sensor location.

This study places towards a mathematical model for sensors deployment to insure good connectivity and coverage the area of interest. The integration of the Markov model with probability distribution in sensors deployment approach is novel probabilistic model for the sensors deployment in WSNs. In order to extra improve of the sensors location prediction problem; we are planning to continue this work towards the optimal assigning of the sensors locations taking into accounts most of the effected factors.

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