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Maduri Chopde
Department of Computer Science PICT, Pune Pune University, India, madhurichopde@gmail.com

Kimi Ramteke
Department of Computer Science PICT, Pune Pune University, India, kimiramteke16@gmail.com

Satish Kamble
Department of Computer Science PICT, Pune Pune University, India, satishkamble53@gmail.com

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Probabilistic model for Intrusion Detection in Wireless Sensor Network

Maduri Chopde, Kimi Ramteke and Satish Kamble
Department of Computer Science
PICT, Pune
Pune University, India
madhurichopde@gmail.com, kimiramteke16@gmail.com and satishkamble53@gmail.com

Abstract— **Intrusion detection in Wireless Sensor Network (WSN) is important through the view of security in WSN. Sensor Deployment Strategy gives an extent to security in WSNs. This paper compares the probability of intrusion detection in both the Poisson as well as Gaussian deployment strategies. It focuses on maximizing intrusion detection probability by assuming the combination of these two deployment strategies and it gives theoretical proposal with respect to intrusion detection.**

Keywords: Wireless sensor networks, Intrusion detection, Poisson distribution, Gaussian distribution, Sensing range, Network deployment

I. INTRODUCTION

Wireless sensor network is the collection of no. of sensors deployed in the special fashion so as to monitor or sense particular area. The Wireless sensor network (WSN) has Military applications, Environmental applications, Health applications, Home applications, Commercial applications, etc. Since WSN has wide diversity application requirements, a general purpose WSN design cannot fulfill the need of all applications. The network parameters like sensing range and node density need to be studied carefully for the specific applications.

Intrusion detection is the technique for a WSN to detect the existence of inappropriate, incorrect, or anomalous moving attackers. This intrusion detection is important for military applications to detect an intruder in the battlefield. The intruder can take straight or curved path in the WSN. Hence to detect an intruder moving towards the target in WSN, sensors need to be deployed in the random way.

In this paper, two deployment strategies have been discussed i.e. through Poisson distribution and Gaussian distribution. In the Poisson distribution, all sensors are deployed uniformly and randomly. And in the Gaussian distribution, some sensors are concentrated at the target area and remaining get rare towards the boundary of the network. Here we propose the combined probabilistic model of Poisson and Gaussian distribution in WSN for intruder detection.

The remainder of this paper is organized as follows: Section 2 presents the Related Work. Section 3 gives the Network Model for WSN. Section 4 presents Comparison Model for intrusion detection. Section 5 illustrates the theoretical results. Finally, this paper is concluded in Section 6.

II. RELATED WORK

For the security purpose, the intrusion detection found to be the most challenging field in WSN. Some research says the node density and sensing range plays an important role in it. Deployment by Poisson distribution gives increased Probability of Intrusion Detection (PID) with increase in the sensing range and has shown detecting with the sensors is better than with the power management [1], [6].

In heterogeneous WSN with the Gaussian deployment, there is increase in PID with the increase in number of type I sensors which help in selecting the right no. of heterogeneous sensors for WSN deployment [7]. [8] Compares both [6] and [7] distributed WSN's for intrusion detection; and it explore the relation between them. [2] Gives a range free algorithm for expected hop progress i.e. LEAP algorithm to find the no. of sensors in the location. The actual time for intrusion detection according to the distance travelled by it and crossing the field of interest [4], [5] respectively. [3] shows that sensor mobility can be exploited to compensate for the lack of sensors and improve network coverage effect of mobile sensors in network . The idea of surreptitious wireless communication has been proposed [10], [11]. The issue of curved path followed by an intruder in WSN rose by [9].

This work combines the strategies of Poisson and Gaussian distribution for homogeneous WSN. It considers the intruder is taking straight path in the network. We are discussing the 1-sensing and k-sensing model to affect the PID.

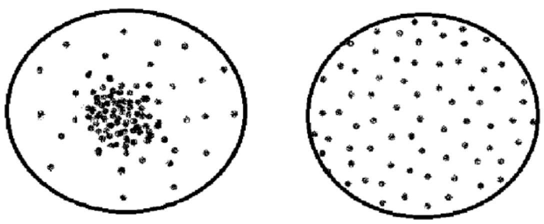

Figure 1: showing the sensors deployment in WSN using Gaussian distribution and Poisson distribution respectively.

III. NETWORK MODEL

Let, 'S' be the system to find the probability of intrusion detection in WSN of a circular area A.

$$S = \{WSN, PID, F\}$$

1] Let, 'WSN' be the system input consists of sensors N in the area A, which gives the density €.

$$WSN = \{N, A, €\}$$

Where,

'N' be the set of sensors in the WSN,

$$N = \{n_1, n_2, \ldots, n_k\}$$

'A' be the circular area of the WSN,

$$A = \pi r^2$$

'€' be the density showing the no. of sensors in the area A,

$$€ = \text{——}$$

2] Let, 'PID' be the system output consist of detection probability of intrusion travelling the distance 'd', before getting detected in WSN.

$$PID = \{x \mid x \; \square \; PID \text{ and } 0 \leq x \leq 1\}$$

3] Let, 'F' be the set of formulas for getting PID in the given WSN.

$$F = \{f_1, f_2\}$$

Where,'f_1' be the combined PID in the area $A_{[d]}$ and $A_{[\xi\text{-}d]}$ for the Poisson distribution consists of the formulas for the probability in single sensing detection and multiple sensing detection ,

$$f_1 = \{ \; , \; \}$$

Let, 'f_2' be the combined PID in the area $A_{[d]}$ and $A_{[\xi\text{-}d]}$ for the Gaussian distribution consists of the formulas for the probability in single sensing detection and multiple sensing detection ,

$$f_2 = \{ \; , \; \}$$

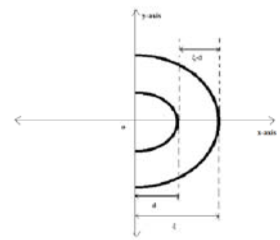

Figure 2: showing the proposed combined model for sensors deployment in WSN

IV. COMPARISON MODEL

Consider, the intruder starts from the boundary of distance 'ξ' to the distance of 'ξ-d'. Let, $A_{[\xi\text{-}d]}$ be the area for intrusion travelling distance (ξ-d) given by[7],

$$A_{[\xi\text{-}d]} = 2(\xi\text{-}d)\, r + \pi r^2 \quad (1)$$

Consider, the intruder starts from the distance 'ξ-d' to the center of WSN. Let, $A_{[d]}$ be the rectangular area for intrusion travelling distance (d),

$$A_{[d]} = 2(d)\, r + \pi r^2 \quad (2)$$

Following the Gaussian distribution, the probability density function (PDF) that sensor located at the point (x, y) is given by,

$$f(x, y, \sigma_x, \sigma_y) = \text{———}$$

This can be simply denoted by,

$$f_{xy}(\sigma) = \text{———} \quad (3)$$

where,

σ_x& σ_y be the deployment deviation of sensors along x-axis and y-axis respectively.

A. *Single –sensing Detecion for area $A_{[\xi\text{-}d]}$*

1) *For the Poisson Distribution*

Let, ' ' be the probability that sensors are located within the area $A_{[\xi\text{-}d]}$, therefore from ….(1)

$p'_{0\,[\xi\text{-}d]} = \frac{(\epsilon A_{[\xi-d]})^n}{n!} e^{-\epsilon A_{[\xi-d]}}$

Probability that there are no sensors within the area $A_{[\xi\text{-}d]}$,

$p'_{0\,[\xi\text{-}d]} = e^{-\epsilon A_{[\xi-d]}}$

Probability that there is at least one sensor located within the area $A_{[\xi\text{-}d]}$,

$p'_{0\,[\xi\text{-}d]} = 1 - e^{-\epsilon A_{[\xi-d]}}$

2) *For the Gaussian Distribution*

Let, 'p_0' be the probability that sensors are located within the area $A_{[\xi\text{-}d]}$, therefore from ….(1) & (3)

$p_{0\,[\xi-d]} = \int_d^{\xi}\int_{-r}^{r} f_{xy}(\sigma)\, dy\, dx$

Let, 'p_1' be the probability that no sensors are located within the area $A_{[\xi\text{-}d]}$,

$p_{1\,[\xi-d]} = (1 - p_{0\,[\xi-d]})^N$

Now, p_2 be the probability that there is at least one sensor located within the area specified by the distance (ξ-d) and area $A_{[\xi\text{-}d]}$,

$p_{2\,[\xi-d]} = 1 - p_1$

B. *Single –sensing Detecion for area $A_{[d]}$*

1) *For the Poisson Distribution*

Let, 'p'_0' be the probability that there are n sensors located within the area $A_{[d]}$, therefore from ….(2)

$p'_{0\,[d]} = \frac{(\epsilon A_{[d]})^n}{n!} e^{-\epsilon A_{[d]}}$

Probability that there are no sensors within the area $A_{[\xi\text{-}d]}$,

$p'_{1\,[d]} = e^{-\epsilon A_{[d]}}$

Probability that there is at least one sensor located within the area $A_{[d]}$,

$p'_{2\,[d]} = 1 - p'_{1[d]}$

2) *For the Gaussian Distribution*

Let, 'p_0' be the probability that sensors are located within the area $A_{[d]}$, therefore from ….(1)

$p_{0\,[d]} = \int_d^{\xi}\int_{-r}^{r} f_{xy}(\sigma)\, dy\, dx$

Let, 'p_1' be the probability that no sensors are located within the area $A_{[d]}$,

$P_1 = (1 - p_{0[d]})^N$

Now, p_2 be the probability that there is at least one sensor located within the area specified by the distance (d),

$p_{2[d]} = 1 - p_{1[d]}$

C. *Multiple –sensing Detection for area $A_{[\xi\text{-}d]}$*

1) *For the Poisson Distribution*

Let, p'_k be the probability that there are less than k sensors within the intrusion detection area $A_{[\xi\text{-}d]}$ with respect to the intrusion distance (ξ-d),

$p'_{k\,[\xi\text{-}d]} = \sum_{i=0}^{k-1} \frac{(\epsilon A_{[\xi-d]})^n}{n!} e^{-\epsilon A_{[\xi-d]}}$

Therefore, the probability that there are at least k sensors within the intrusion detection area $A_{[\xi\text{-}d]}$,

$p'_{k1\,[\xi\text{-}d]} = 1 - \sum_{i=0}^{k-1} \frac{(\epsilon A_{[\xi-d]})^n}{n!} e^{-\epsilon A_{[\xi-d]}}$

2) *For the Gaussian Distribution*

Let, P_k be the probability that k no. of sensors reside in the intrusion detection area $A_{[\xi\text{-}d]}$ with respect to the intrusion distance (ξ-d),

$P_{k\,[\xi\text{-}d]} = \sum_{i=0}^{k-1} \binom{N}{k} (p_{0[\xi-d]})^k (1 - p_{0[\xi\text{-}d]})^{(N\text{-}k)}$

Therefore, probability of at least k sensors in the area $A_{[\xi\text{-}d]}$ is given by,

$P_{k1[\xi\text{-}d]} = 1 - \sum_{i=0}^{k-1} \binom{N}{k} (p_{0[\xi-d]})^k (1 - p_{0[\xi\text{-}d]})^{(N\text{-}k)}$

D. *Multiple –sensing Detection for area $A_{[d]}$*

1) *For the Poisson Distribution*

Let, p'_k be the probability that there are less than k sensors within the intrusion detection area $A_{[d]}$ with respect to the intrusion distance (d),

$$P'_{k[d]} = \sum_{i=0}^{k-1} \frac{(€\, A_{[d]})^n}{n!}\; e^{-€\, A_{[d]}}$$

Therefore, the probability that there are at least k sensors within the intrusion detection area $A_{[\xi\text{-}d]}$,

$$P'_{k1[d]} = 1- \sum_{i=0}^{k-1} \frac{(€\, A_{[d]})^n}{n!}\; e^{-€\, A_{[d]}}$$

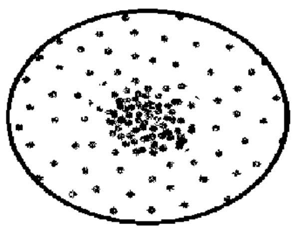

Figure 3: showing the proposed combined model for sensors deployment in WSN using Gaussian distribution at the central area and Poisson distribution at the remaining area

2) *For the Gaussian Distribution*

Let, P_k be the probability that k no. of sensors reside in the intrusion detection area $A_{[d]}$ with respect to the intrusion distance (d),

$$P_{k\,[d]} = \sum_{i=0}^{k-1} \binom{N}{k} \left(p_{k[d]}\right)^k (1- p_{k[d]})^{(N-k)}$$

Therefore, probability of at least k sensors in the area $A_{[d]}$ is given by,

$$P_{k1[d]} = 1- \sum_{i=0}^{k-1} \binom{N}{k} \left(p_{k[d]}\right)^k (1- p_{k[d]})^{(N-k)}$$

V. COMBINED MODEL

As shown in the figure 2, 3, we consider the WSN of the circular area A. Now, we measure the PID from boundary to the center of the WSN. Let, ξ be the distance from the boundary to the center of the WSN.

Let, A be the system representing the total area of the WSN,

$$A = A[d] + A[\xi\text{-}d]$$

Where,

A_1 be the area for distance d where the PID for Poisson is equal to the PID for Gaussian given by,

$$A[d] = \pi d^2$$

A_2 be the area for distance (ξ-d) given by,

$$A[\xi\text{-}d] = \pi(\xi^2\text{-}d^2)$$

Our idea is to apply Gaussian distribution in the area A[d] and Poisson distribution in the area A[ξ-d].

VI. EXPLAINATION OF THE RESULT

We set the networking parameters as follows:
The deployment area is set as $A= \pi\, \xi^2$ from the figure 2, where ξ =50. The sensing range of a sensor is set as r=5. The no. of deployed sensors in the area A is taken as 100.The deployment deviation is set as $\sigma_x = \sigma_y = 25$ in the Gaussian distribution.

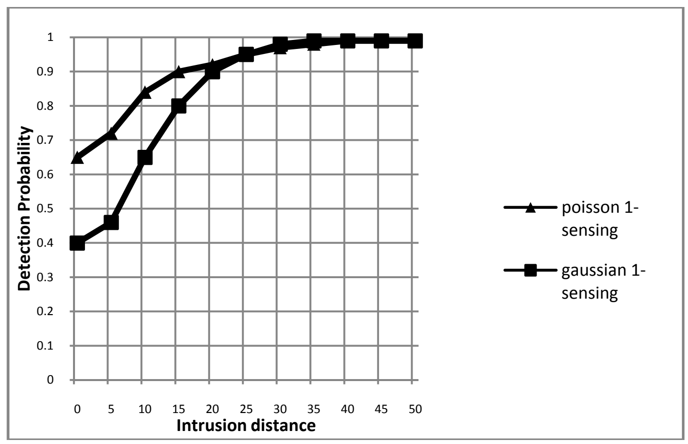

Figure 4: 1-sensing detection probability for Poisson and Gaussian distribution along the path from boundary towards the center of the WSN

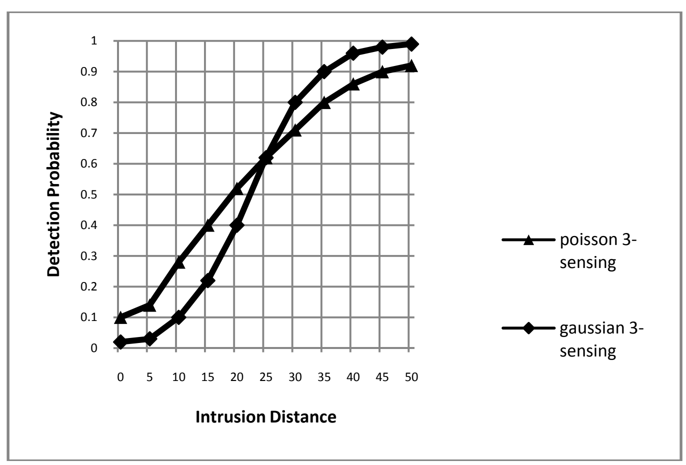

Figure 5: 3-sensing detection probability for Poisson and Gaussian distribution along the path from boundary towards the center of the WSN

We are considering the starting point (ξ,0). Figure 4 shows the detection probability of the intrusion for single sensing Poisson and Gaussian distribution.

Figure 5 shows the detection probability of the intrusion for multiple sensing Poisson and Gaussian distribution. These figures are the outputs of the analytical results.

From the figure 5 we observe that, the detection probability of Poisson multiple sensing is greater than the Gaussian multiple sensing for the distance ξ-d. At the point (d,0) both the distributions having near to the equal detection probability. But, as the intruder travels near to the center the Gaussian distribution is having greater detection probability than the Poisson distribution. Same is the case for single sensing distribution probability as shown in the figure 5.

Here, we can choose maximum allowable intrusion distance d=25 as the threshold. We can choose 'd' as the radius and have an area of A[d]. In the combined approach we will deploy sensors in the area A[d] using Gaussian distribution. In the remaining area A[ξ-d], we will use Poisson distribution for deployment of the sensors.

VII. CONCLUSION

The proposed model says that by deploying the sensors at the central area by Gaussian distribution and deploying the sensors in the remaining area by Poisson distribution of the wireless sensor network, the probability of the intrusion detection will not be zero. This matches the intuition of having good probability of intrusion detection.

REFERENCES

[1] *X. Wang, Y. Yoo, Y. Wang, and D.P. Agrawal, "Impact of Node Density and Sensing Range on Intrusion Detection in Wireless Sensor Networks," Proc. 15th Int'l Conf. Computer Comm. and Networks (ICCCN '06), Oct. 2006.*

[2] *Y. Wang, X. Wang, D. Wang, and D.P. Agrawal, "Localization Algorithm Using Expected Hop Progress in Wireless Sensor Networks," Proc. Third IEEE Int'l Conf. Mobile Ad hoc and Sensor Systems (MASS '06), Oct. 2006.*

[3] *B. Liu, P. Brass, O. Dousse, P. Nain, and D. Towsley, "Mobility Improves Coverage of Sensor Networks," Proc. Sixth ACM Int'l Symp. Mobile Ad Hoc Networking and Computing (MobiHoc'05), pp. 300-308, 2005.*

[4] *O. Dousse, C. Tavoularis, P. Thiran "Delay of Intrusion Detection in Wireless Sensor Networks," MobiHoc '06 Proceedings of the 7th ACM international symposium on Mobile ad hoc networking and computing,New York, NY, USA ©2006.*

[5] *L. Lazos, R. Poovendran, and J. A. Ritcey, "Probabilistic detection of mobile targets in heterogeneous sensor networks," in IPSN '07: Proceedings of the 6th international conference on Information processing in sensor networks. New York, NY, USA: ACM, 2007, pp. 519–528.*

[6] *Y. Wang, X. Wang, B. Xie, D. Wang, and D. P. Agrawal, "Intrusion detection in homogeneous and heterogeneous wireless sensor networks," IEEE Transactions on Mobile Computing, vol. 7, no. 6, pp. 698–711, 2008.*

[7] *Y. Wang, W. Fu, and D. P. Agrawal,"Intrusion detection in Gaussian distributed heterogeneous wireless sensor networks," 6th IEEE International Conference on Mobile Ad Hoc and Sensor Systems Oct. 2009.*

[8] *Y. Wang, F. Li, and F. Fang, "Poisson Versus Gaussian Distribution for Object Tracking in Wireless Sensor Networks " 2nd Workshop on International Intelligent Systems and Applications (ISA), May. 2010.*

[9] *Y. Wang, Y. K. Leow, and J. Yin," Is Straight-line Path always the best for Intrusion Detection in Wireless Sensor Networks, " 15th International Conference on Parallel and Distributed Systems (ICPADS), Dec. 2009.*

[10] *Q. Shi, C. Comaniciu," Efficient cooperative detection for wireless sentinel networks" 44th Annual Conference on Information Sciences and Systems (CISS), March 2010*

[11] *D. Turgut, B. U. Turgut, and L. Boloni, "Stealthy dissemination in intruder tracking sensor networks," IEEE 34th Conference on Local Computer Networks LCN, Oct.2009.*