American Journal of Engineering Research (AJER) 2015
American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-5, pp-245-249
www.ajer.org
Research Paper Open Access

# Network Dimensionality Estimation of Wireless Sensor Network Using Cross Correlation Function

Nadia Afrin[1], Md. Shamim Anower[2], Md. Ismail Haque[3]
[1]*Dept. of EEE, Pabna University of Science & Technology (PUST), Bangladesh*
[2]*Dept. of EEE, Rajshahi University of Engineering & Technology (RUET), Bangladesh*
[3]*Dept. of EEE, International Islamic University Chittagong (IIUC), Bangladesh*

***Abstract-*** *Dimensionality estimation of a deployed network is very important for proper operation of Wireless Sensor Network (WSN). In this paper a process with Cross Correlation Function (CCF) is considered as a parameter for estimating dimensionality. The dirac delta functions, output of CCF mainly estimates network's dimensionality. Here underwater environment is considered but it can also be applied to any other WSN. At last a comparison between analytical and simulated result of CCF is done which leads to know the suitability of this process in finding the network dimensionality.*

***Keywords-*** *Wireless Sensor Network (WSN), Network dimensionality, Cross Correlation Function (CCF), Dirac delta function.*

## I. INTRODUCTION

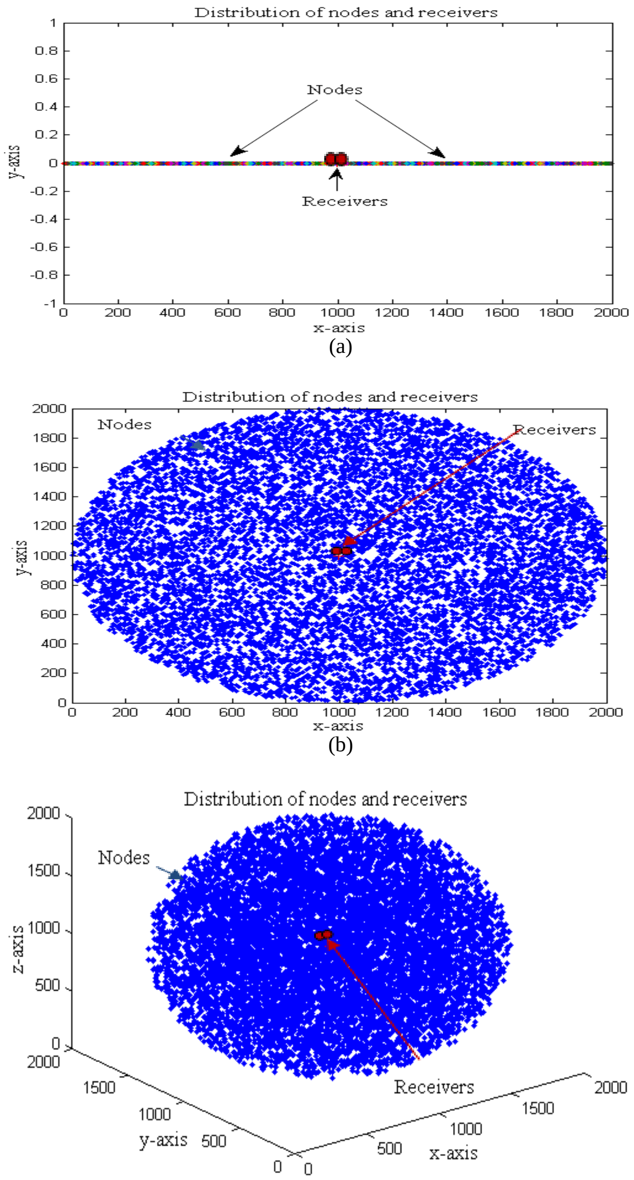
Nowadays WSN is widely used for weather forecasting (Tsunami, Earthquake, and Climate change detection); enemy detection in border area, communication in remote area etc. and in recent years research on applying WSN in underwater has become a great concern. Underwater Wireless Sensor Network (UWSN) is keeping a great contribution in disaster alleviation [1], pollution detection [2], security concern etc. In WSN the number of the active nodes can vary during operation which has a great impact on network analysis. The number of these active nodes can be estimated by using CCF [3] [4], where the CCF depends on the position of the nodes or the dimensionality of the network. Therefore, the main concern of this paper is to determine the dimensionality of WSN.

The formation of CCF has significant dependency on the network dimensionality. By analysing the CCF formation a decision can be made about the dimensionality of the network that is, whether the nodes are oriented in one dimension (1D), two dimension (2D) or three dimension (3D) in space. This process is applied for determining the dimensionality of deployed unknown network. A deployment strategy for 2D and 3D underwater acoustic network is proposed in [5] to determine the minimum number of sensors to be deployed to achieve optimal sensing and communication coverage.

In this paper, network with different dimensionality (1D, 2D, 3D) is analysed. As the shape of the dirac delta function, output of CCF varies with the variation of the network dimensionality, so by determining the CCF for a network, dimensionality of it can be determined.

## II. Networks with Different Dimension

In this paper, three types of network- 1D, 2D, 3D is analysed. Each of the networks has been designed with ten thousand (10,000) transmitting nodes which are distributed through a linear line for 1D network, along a circle and a sphere for 2D network and 3D network respectively. In addition, two probing nodes or two receivers are placed at the centre position of each network. The receivers placed at centre will measure the CCF for the signals coming from the transmitters. The distribution of nodes (10,000) are shown in fig (1).It can clearly be seen that the uniform node distribution for 1D, 2D and 3D network is a straight line, a circle and a sphere respectively.




(a)

(b)

(c)

Figure1: Distributions of (10,000) nodes in (a) 1D; (b) 2D; and (c) 3D

## III. Formation of CCF

In order to determine the CCF for a network at first from receivers (probing nodes) probe request is send to the transmitting nodes and as a response the transmitting nodes send back Gaussian signals to the receivers [6]. Then the Gaussian signals from all transmitting nodes are summed at the receivers and cross correlates the summed signals to find the CCF.

Two sensors with location at $x_1$ and $x_2$ for 1D, $(x_1, y_1)$ and $(x_2, y_2)$ for 2D, $(x_1, y_1, z_1)$ and $(x_2, y_2, z_2)$ for 3D are placed. Probe request from these sensors is given to the 10000 transmitting nodes and they give back Gaussian signal. The Gaussian Signal $s(t)$ is the response of a transmitter, which will reach to the two sensors with different time delay $\tau_1$and $\tau_2$, therefore, the signals at two sensors are as follows:

$$s_1(t) = s(t - \tau_1) \quad (1)$$

$$s_2(t) = s(t - \tau_2) \quad (2)$$

Total signals received by two sensors are:

$$s_1(t) = \sum_{n=1}^{N} s_n(t - \tau_{n1}) \quad (3)$$

$$s_2(t) = \sum_{n=1}^{N} s_n(t - \tau_{n2}) \quad (4)$$

Where N= Transmitting nodes number=10000.

The Cross Correlation of these signals is:

$$C(T) = \int_{-\infty}^{+\infty} s_1(t) s_2(t - \tau) dt \quad (5)$$

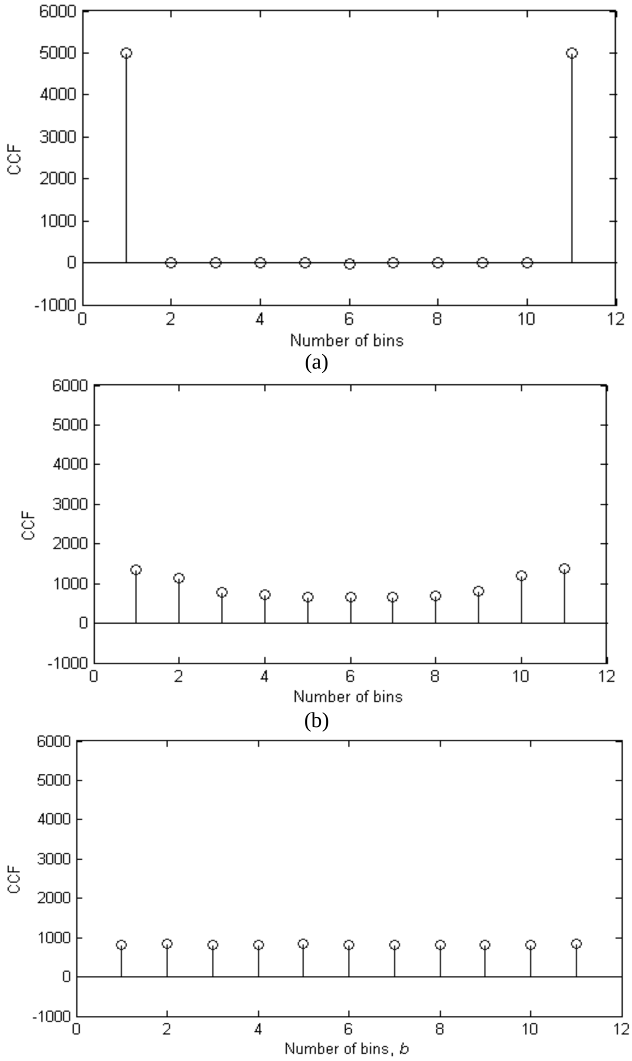
The output of the CCF takes a form of series of deltas. The possible positions of those deltas define by bins, b:

$$b = \frac{2 \times d_{DBS} \times S_R}{S_p} - 1 \tag{6}$$

From equation (6) it is clear that bins can vary by varying distance between sensors, $d_{DBS}$and sampling rate, $S_R$ for a fixed medium for which velocity of propagation, $S_p$ is fixed. In this case there are 11 bins that means the possible positions of delta functions are 11.

## IV. CCF by Simulation

The constructed CCF from the simulation shows different results for different dimensionality which is shown in fig (2).CCF for 1D network contains only two dirac deltas at 1st and 11th bin with equal strength shown in fig 2(a),CCF for 2D network is a series of dirac which contains a variation in the magnitude with a width of bin having centered at 6th bin of 11th bins shown in fig 2(b),CCF for 3D network is a series of dirac deltas of uniform magnitude through the width $2d_{DBS}$ having centered at 0 shown in fig 2(c).




(a)

(b)

(c)

Figure2: CCFs versus *b*: (a) 1D; (b) 2D; and (c) 3D

## V. CCF by Analytical Analysis

In this section, the theory regarding this phenomenon will be discussed. By Cross Correlating two time delayed signals of a Gaussian signal will cause an output of dirac delta function. For Several Gaussian signals there will be dirac delta functions spread over a distance of $2d_{DBS}$(which is divided equally into several bins).The location of the dirac delta function is determine by the delay difference between the two signals,($\tau_1 \sim \tau_2$).

In [5], it is shown that the deployment of nodes of equal delay difference follows a hyperbola. The dirac deltas for all the transmitting inside a hyperbola will be placed at the edge of that hyperbola.

For 1D network there are only two hyperbolas with equal area so the dirac deltas will be placed at only two points (edges of two hyperbola). Shown in the figure 3(a).For both 2D network and 3D network there are 11 hyperbolas.

There is same area of each hyperbola in 3D network so the dirac delta functions in 3D network will have a uniform strength. But in 2D network area of hyperbolas are not same and maintain a difference shown in figure 3(b) so the dirac deltas will also maintain a difference between their strength.

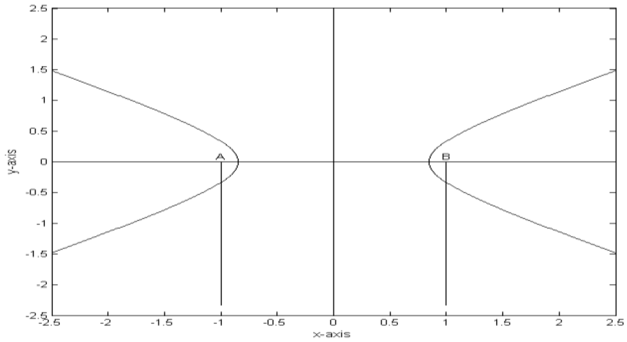
The area of two hyperbolas shown in fig (4) is calculated using the trapezoidal rule of numerical integration.

From fig (4) the area inside hyperbola is:

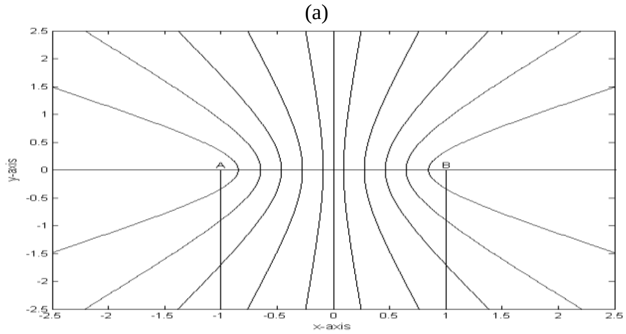
$$\text{Area, } A_1 = \text{Area, } A_3 - \text{Area, } A_2 = 1.7\text{m}^2 \tag{7}$$

The number of deltas at the bin at location A is:

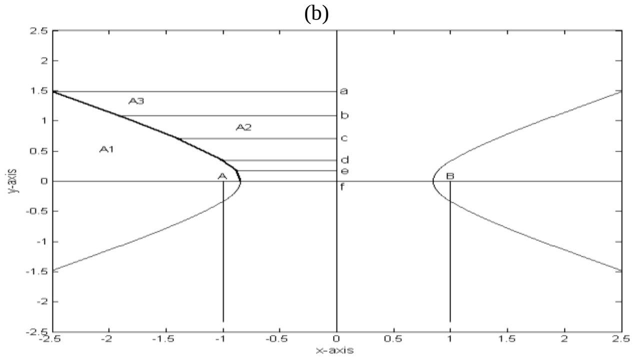
$$\frac{2 \times Area, A_1}{Total\ Area} \times 100\% \approx 13.6\% \tag{8}$$




(a)




(b)

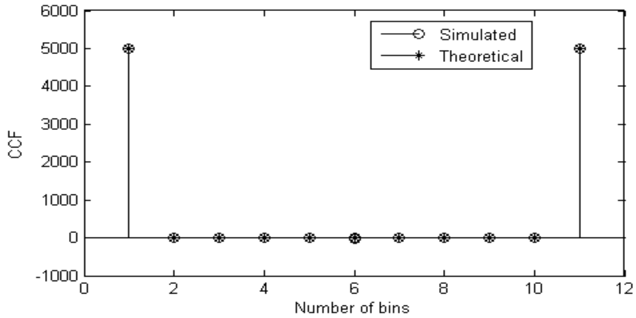



(c)

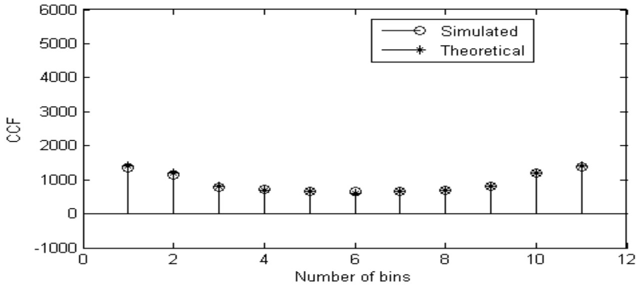
Figure 4: Representation of hyperbolas for theoretical distributions of CCFs:
(a) 1D; (b) 2D; and (c) 3D

## VI. Results

Assuming the deltas and the no. of nodes are of equal strength, the theoretical estimation using equations (7) and (8) plotted in figure (5), with imposing the simulated result on it to find the comparisons between the simulated and theoretical result. It is seen that the theoretical and simulated results matches in every cases.




(a)

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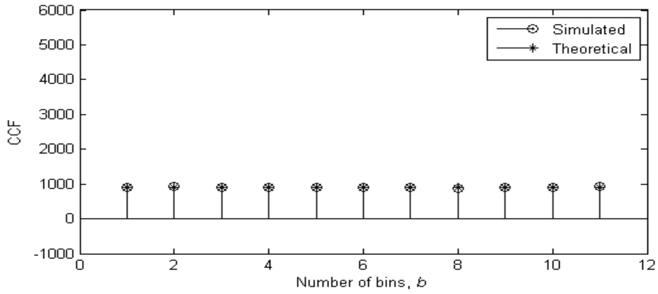


(c)

Figure 5: Simulated and theoretical distributions of CCFs:
(a) 1D; (b) 2D; and (c) 3D

## VII. Conclusion

For determining the dimensionality of Ad-hoc network after deployment here we use Cross Correlation of several Gaussian signals from transmitting nodes. The process is done for a large number of transmitting nodes. The output, dirac delta function contains strength dependent on the transmitting nodes. For differentiating the CCF output results for 2D and 3D it is must to have large number of transmitting node. This is the major drawback of the process for finding the dimensionality of a network using Cross Correlation function. In future, we intend to overcome this limitation and determine the dimensionality for all type of network.

## REFERENCES

[1] N. N. Soreide, C. E. Woody, S. M. Holt, “Overview of ocean basedbuoys and drifters: Present applications and future needs,” 16th International Conference on Interactive Information and ProcessingSystem (IIPS) for Meteorology, Oceanography, Hydrology, LongBeach, California, USA, 2004.

[2] M. S. Anower, S. A. H. Chowdhury,J. E. Giti, A. S. M. Sayem, M. I. Haque, “Underwater network size estimation using crosscorrelation:selection of estimation parameter”,The 9th International Forum on Strategic Technology (IFOST), October 21-23, 2014, Cox’s Bazar, Bangladesh.

[3] M. S. Anower, “Estimation using cross-correlation in a communications network,” Ph.D. dissertation, SEIT, University of NewSouth Wales at Australian Defense Force Academy, Canberra, 2011.

[4] Md. ShamimAnower, Michael R. Frater, Michael J. Ryan, “Estimation by cross-correlation of the number of nodes in underwater networks.”978-1-4244-7322-9/YR/$26.00 ©2009 IEEE.

[5] Pompili, D., Melodia, T., et al, “Three-dimensional and two-dimensional deployment analysis for underwater acoustic sensor networks”, Ad Hoc Networks, Volume 7, Issue 4, June 2009.

[6] M. Islam, S. Mekhilef, and M. Hasan, "Single phase transformerless inverter topologies for grid-tied photovoltaic system: A review," Renewable and Sustainable Energy Reviews, vol. 45, pp. 69-86, 2015.

[7] Roux, P., Sabra, K. G., “Ambient noise cross correlation in free space: Theoretical approach.” The Journal of the Acoustical Society of America 117(1): 79-842,2005.