International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

PERFORMANCE ANALYSIS OF PATH LOSS EXPONENT FOR LOCALIZATION OF SENSORS IN INDOOR ENVIRONMENT

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ABSTRACT

Rapid growth in demand for accuracy in location estimation necessitates the analysis of path loss exponent in deployment of wireless sensor networks. Received signal strength is most widely used method that uses path loss exponent (PLE) for distance estimation.

PLE accounts to mitigate fluctuations in wireless channel parameters, which improves the accuracy for distance estimation.

This work tries to provide Performance analysis of PLE which includes consideration of sensor array, number of elements, directivity, frequency of operation in ISM band and distance from transmitter to receiver.

The range of obtained stimulation results for PLE in indoor environment is about 1.42 to 3.31 which falls under theoretical range 2 to 4 in wireless environment.

1. INTRODUCTION

With the growing demand in Wireless Sensor Network (WSN) (Figure 1, for illustration) for tracking, mapping places and locating sensor nodes, achieving more accuracy is a challenge to deal with. Node's current location must be identified without using any extra hardware such as GPS with minimal human intervention. Localization is performed in several ways in which measurement of the distance with the help of PLE and Received Signal Strength [5] is one such approach.

The RSSI approach for wireless sensor node location is analysed using a radio propagation model, which is in generally affected by environmental conditions. Signal propagation in a wireless channel suffer delay due to reflections, refraction, interference, diffraction, fading and so on. The path loss exponent value accommodates for such differences in wireless channel characteristics and has varying values for different environmental circumstances.

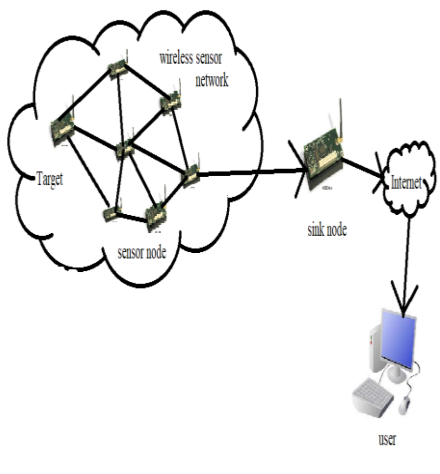


Figure (1): WSN network

2. WIRELESS COMMUNICATION

Due to the increased demand in sensor nodes, wireless communication plays an important role. Wireless communication includes infrastructure based as well as infrastructure less networks. Ad-hoc and sensor network are example of such network which is in demand to be taken care of.

PATH LOSS EXPONENT (PLE):

Physical layer:

The PLE plays an important role for quality of the signal received which in turn affect SINR. Hence PLE is said to be an important parameter to be taken care of for design of Physical Layer.

Network lifetime:

The energy resources of the wireless node have a significant impact on network lifetime(Table-1). PLE is a measure of path loss and hence help in the management of the amount of power to be sent for each successful conversation.

Table-1 Network lifetime

Environment	Path Loss Exponent
Free space	**2**
Obstructed in factories	**2 - 3**
Urban area cellular	**3 – 5**
Urban area cellular radio	**2.7 - 3.5**
Obstructed in building	**4 – 6**
In-building line of sight	**1.6 – 1.8**

3. RELATED WORK

Chuan Chin Pu and his colleagues have investigated the underestimation and overestimation of path loss exponents [9], using two radio wave propagation models:

The basic log distance path loss model and its extension The lognormal path loss model, it was determined that over-estimated path loss occurred.

The log-normal noise effect is mitigated by the loss exponent.

Delft University of Technology in the Netherlands [3] proposes a two-directional maximum likelihood model (ML) PLE self-estimators in wireless networks.

Ali Golestani and his colleagues have worked on enhancing the precision of RSSI-based low energy localization utilising path loss exponent estimates [8] employing a unique technique in which the anchor nodes are separated into two groups and the PLE values are assigned independently.

Chuan Chin Pu, Soo Yong Lim, and Pei Cheng Ooi focus on the measurement arrangement of transmitters and receivers [1] rather than the calculation method for path loss exponent estimate and offer a more appropriate arrangement plan for PLE estimation.

Researchers in Canada [4] have presented a technique for estimating the PLE based on the connection of sensors distributed in a defined region.

4. SOFTWARE SPECIFICATIONS AND REQUIREMENTS

MATLAB (version-2019) software is used to estimate the Path loss exponent. In MATLAB, sensor array analyser app is used to estimate the half power beam width, with this parameter PLE can be estimated.

Parameters Used:

Figure – 3 Uniform Linear Array

Sensor array analyser app screen is visible as shown in above Figure-3.

In this app, array type, element type, number of elements, element spacing, signal frequencies can be selected according to the requirement.

Initially, select the model that will give more directivity by increasing number of elements. Then select the frequency by comparing all the ISM bands frequencies. Performance of PLE can be found by using the above selected model and the frequency.

The mathematical representation for estimation of PLE id given below :

$$P_r(d) = P(d_0) - 10\, n \log(\frac{d}{d_0}) \quad \rightarrow (1)$$

Where,

PL(d)= Path loss incurred by the RF signal at a distance d,

d0 = Reference distance which is taken as 1m

PL(d0)= Path loss at the reference distance

n = Path loss exponent for the modelled wireless channel.

Equation (1) can be written as :

$$P_r(d) = -10\, n \log(\frac{d}{d_0})$$

$$\text{Therefore. } n = \frac{10^{\left(-P_r(d)/_{10}\right)}}{d}$$

Comparison table

Table- 2 Comparison of different related works

S.No	Year of publication	Author	Abstract	Tools used	Conclusion
1.	2018	Vaishnavi Dharmadhikari, Neha Pusalkar, Pradnya Ghare	A practical approach for PLE using RSSI model.	MATLAB and hardware setup	Practically PLE they got is 4.2, which lies in the indoor environment PLE range of 4 to 6.
2.	2021	Mohamed K. Elmezughi, Thomas J. Afullo, and Nicholas O. Oyie.	Study of PLE models at different frequencies.	MATLAB	Parameters of path loss models exhibit symmetrical behaviour around 180° AoA.
3.	2012	Gang Wang, H. Chen, Youming Li, and Ming	Estimation of RSS based localization using	Unknown PLE and unknown	In the absence of unknown power or unknown PLE and

		Jin	unknown power and unknown PLE.	power.	both are unknown, WLS method is proposed for localization based on RSS.

Comparisons of works related to our work are present in Table-2.

5. RESULTSAND ANALYSIS

Parameters that are to be considered for simulating in MATLAB are:

No of elements Placed for analysis:

- URA (3×3, 4×4, 5×5) .
- Spacing: (1 meter).
- Parameter taken into consideration (Directivity)
- Propagation speed: ($3x10^8$ m/s)
- Signal Frequency: ($3x10^8$ m/s)

Let's consider the array size - [3 3] :

Table-3 Comparison between number of elements and directivity.

Number of elements VS Directivity

S.No	Array size	Number of elements	Directivity (dBi)
1.	[3 3]	9	8.73
2.	[4 4]	16	13.50
3.	[5 5]	25	15.28

Comparison between number of elements and directivity of array sizes 3*3, 4*4, 5*5 are noted in Table-3 and the graph plotted for the data is in Figure-5.

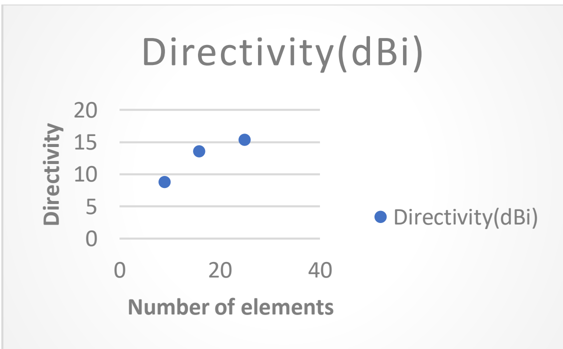


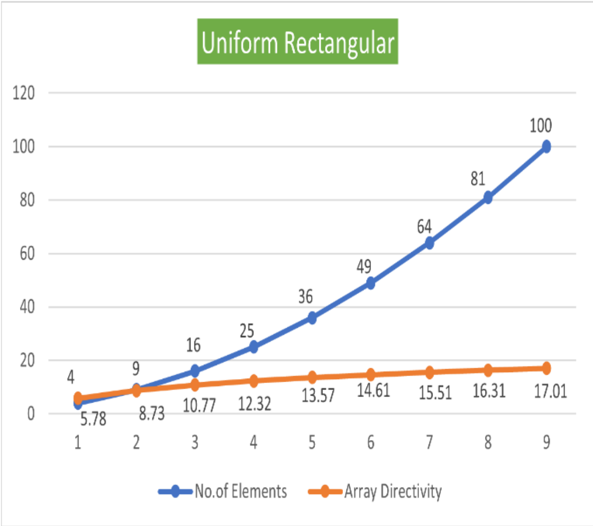
Figure – 5 Number of elements VS Directivity

By observing the above plotted graph, we came to know that as we increase the number of elements in the array, the directivity is also increasing.

6. DIRECTIVITY

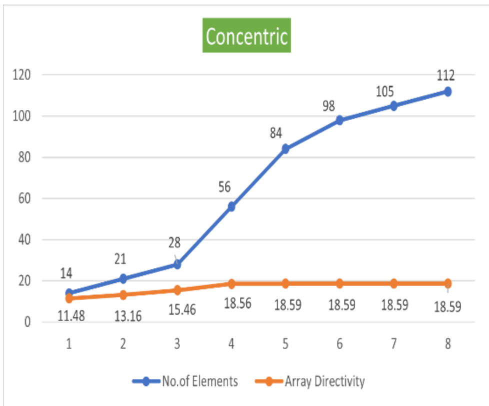
Directivity is a property of an antenna or optical system in electromagnetics that quantifies the degree to which the radiation emitted is focused on a single direction.

Initially we compared the uniform rectangular array and uniform concentric array, as we increase the number of elements in uniform rectangular array the directivity is also increasing gradually. Whereas in uniform concentric array, the directivity becomes Constant after certain increase in number of elements.



Number of elements

Figure -6(i) Number of elements VS Directivity for Uniform Rectangular array.



Number of elements

Figure -6(ii) Number of elements VS Directivity for concentric array.

Figure-6(i) and Figure-6(ii) are the graphs plotted between number of elements and directivity for URA and concentric array.

Finally, uniform rectangular array that gives higher signal strength based on directivity can be used for finding the path loss exponent.

Frequency:

The number of times a repeated event occurs per unit of time is known as frequency. The unit of frequency is hertz (Hz), which equals one (event) per second. The period is the reciprocal of the frequency since it represents the length of one cycle in a repeated occurrence.

- Firstly, we compared the directivity between rectangular and concentric Array. There we came to know that as the directivity increases with the increase in number of elements in uniform rectangular array as compared to concentric array.

- Initially we used speed of light as speed of frequency but now we are choosing ISM band i.e., 2.4 to 2.48 GHz as the speed of frequency.
- By varying the frequency from 2.4 to 2.48 GHz we find the directivity from 2*2 to 10*10 size.

Comparing different number of elements with different ISM band frequencies

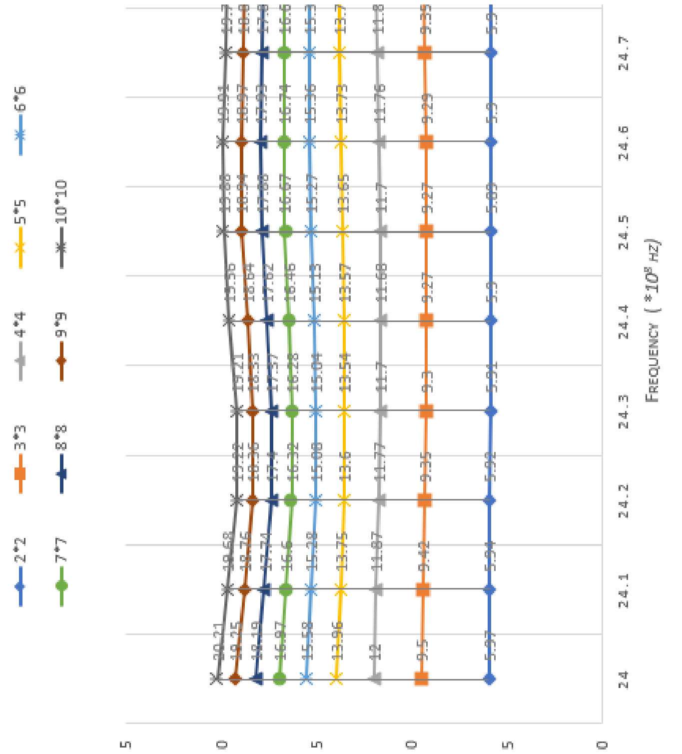


Figure – 7

Directivity Vs ISM band frequency

Figure-7, Illustrates the directivities for different ISM band frequencies.

The directivity is almost constant for the range of 2.43 GHz frequency. So, we can use this range of frequency as the speed of frequency.

Path Loss Exponent:

The path loss exponent (PLE) is a parameter that indicates how quickly the received signal strength (RSS) declines with distance. Its value is determined by the propagation environment. In distance-based wireless sensor network localization, where distance is inferred from RSS data, path loss exponent estimation is critical. Other applications of path loss exponent estimation include sensor network dimensioning. To calibrate the PLE, existing solutions rely on both RSS measurements and distance measurements in the same environment.

However, in some situations, obtaining distance measurements might be difficult and costly.

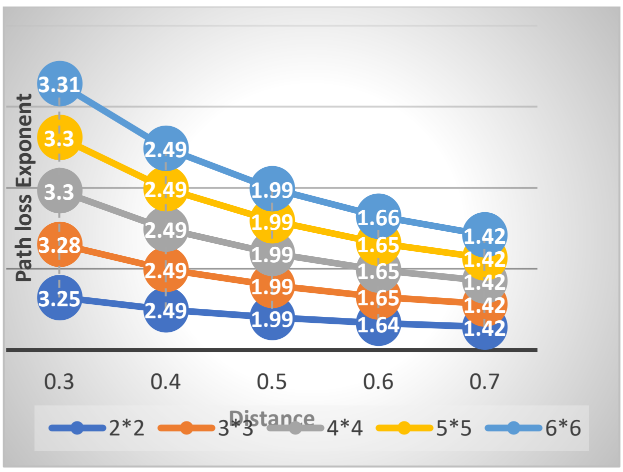


Figure- 8 Distance Vs PLE

By observing the Figure 8, as we increase the distance between elements, path loss exponent will decrease. For indoor environment path loss exponent should be between 2 to 4. So, we can use distance spacing 0.3, 0.4, 0.5 as their path loss exponent is between 2 to 4.

7. CONCLUSION AND FUTURE WORK

Conclusion:

Results and analysis (chapter 4) for PLE in indoor environment is found to be nearly 1.42 to 3.31 which is approximately equal to the hypothetical range of 2 to 4 in wireless environment.

Further, this work will be extended for distance estimation and Localization of sensors

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