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Fault Tolerant Coverage and Connectivity Model for Wireless Sensor Networks in Real time Environment

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Abstract: ***Both connectivity and coverage are considered as the basic performance standards of the service yielded through a Wireless Sensor Network (WSN). Sensing field's monitoring quality is represented through coverage. So, coverage represents the quality of tracking of the sensing field through the sensors. Connectivity exhibits the quality of the information delivery along with the sensor nodes, or to the base station. This paper aims for pre-estimation for the sensor numbers that are to be placed in an adverse situation for achieving required coverage. This paper promotes K-coverage and K-connectivity models that focuses on multipath effects as well as shadowing fading's combined effect. The value of K differs for different types of applications. For measuring the coverage and connectivity probabilities, in shadowing as well as multipath fading presence, a mathematical model is obtained. Moreover, the coverage and connectivity probability derivations which are derived with the help of lognormal shadowing fading as well as Rayleigh fading are approved through the deployments of nodes utilizing Poisson distribution. The simulation section of this paper clearly shows that coverage and connectivity are dependent on the density of node, fading parameters like the standard deviation, and path loss exponent. The sensing model proposed by us is proved to be more appropriate for realistic environment as sensor's ideal quantity necessary in order to attain desirable coverage in fading conditions.***

Keywords: ***Shadowing, Multipath Fading, Coverage, Connectivity, Wireless Sensor Networks***

I. INTRODUCTION

The production of limited power, low cost, and tiny size sensors has been recently enabled by Wireless Sensor Networks (WSNs). The sensor comprises limited resources such as communication bandwidth, battery, memory, CPU. WSNs involve a large amount of sensors. The sensors are positioned either stochastically or deterministically and sense the object and send data from one sink to another. The voluminous use of WSNs is for various applications like habitat monitoring, military surveillances, environment monitoring, etc. [1, 2]. In a warlike or averse situation where the human intrusion is difficult or impossible, then the sensors are dropped randomly by airplanes. In such hostile environment, we cannot get the same node density in the whole area. There may be the areas where less number of sensors are deployed, so the node density may be very less. In such scenario, some areas may remain uncovered and some nodes may become secluded. For maintaining quality of coverage and connectivity, it is necessary to deploy sensors in large number. By deploying sensors in a large number we enhance connectivity along with coverage, however it also increases network cost as well as energy consumption that gradually decreases network lifetime.

It is a basic issue in many applications to maintain the monitoring quality of a specific region that is used to measure how effectively the target region is being monitored by the sensors. So, the coverage is considered among the primary aspects to maintain the WSNs' quality of services [3]. The sensing coverage is defined by considering the ratio of sensing region to the interested area. This gives the area fraction that the sensor network covers. The sensing coverage problem is manifested as point coverage and area coverage. The degrees of sensing coverage differ in different applications; for instance, in few applications only one sensor is needed to monitor the specific area in a region whereas some applications need a notably maximum amount of sensors for the same [4]. Connectivity in WSNs can be defined as the probability that each sensor pair in the networks may have at least one path connecting to the nodes. It is the sensor nodes' function to collect the data as well as to transmit it to the sink node. This is why the connectivity is a crucial issue to be examined [5]. To find out whether a network is reliable or not, it is dependent on the degree to which it is connected. The standard that determines the quantity of information which can be transmitted over the links without any loss is termed as the connectivity of the network. If each and every node communicates to at least one other node, such network is considered to be fully connected.

Nowadays, several researches are focused on deterministic sensing models which usually accept that a sensor has uniform sensing ability in every direction. A regular disk is used to exhibit this [6]. However, when it comes to realistic environments, these models are not suitable.

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Particular signals like magnetic field, thermal energy, light waves, radio waves, seismic signal, or acoustic signals in a given sensing area are detected by the several sensor networks [7]. Furthermore, various environmental factors such as reflection of signals, other objects'movement, propagation path's barriers, noise, and interferences affectthese signals.

In addition to the path loss, these sensing signals suffers from additional power loss due to these environmental factors. This extra power loss results in the large deviation in the strength of received signal. Thus, the propagation path hindrances causes the received signal strength's deviations which is then termed as shadowing while the multipath fading is results due to the deviations caused by reflections. The quality of sensing coverage and connectivity gets severely affected by the phenomena of multipath fading and shadowing [8]. This is why it will be more realistic to use a probabilistic sensing model accounting for both the shadowing and multipath effects so that problems related to the connectivity and coverage can be dealt. Although, for the ideal environment probabilistic sensing model or deterministic sensing model are selected for considering coverage and connectivity problems by the several researches in the literature. The researches till date show that no study has been concerned on the WSNs network coverage and connectivity issues that is resulted due to combined impact of multipath fading as well as large-scale shadowing. This paper promotes K-connectivity and K-coverage models that consider the combined effect of shadowing and multipath fading. In this paper, we have also attempted to explore the effect of shadowing model and multipath fading on K-connectivity and K-coverage of wireless multi hop network where at least K sensors covers the every target region point and from source to destination there are at least K paths. This paper analytically explores the coverage and connectivity issue related to the multipath and shadowing environment with the help of deployment of nodes by utilizing the Poisson distribution.

The rest of the paper is presented as follows: In the second section, we have discussed about earlier works done by various researchers on coverage and connectivity. In the third section, we have presented system model, coverage uniform sensor node deployment. In the fourth section, we have focused on coverage model with and without shadowing and multipath effects. In the fifth section, we have looked into the possibility of connectivity model with and without shadowing and multipath effects. In the sixth section, we have presented simulation result and performance analysis. In the seventh section, we give conclusions and future scope.

II. RELATED WORKS

Over the last decades, many researchers have developed various methods for coverage and connectivity in WSNs. This section gives a brief literature review on these approaches and have summarized their shortcomings. Tsai [7] investigates the effect of shadowing on the coverage. When shadowing environment is randomly distributed over the sensor network on a large scale, then the author finds that standard deviation of shadowing effect increases, and it harshly degrades sensing coverage. Ammari and Das [9] focuses WSNs issue of k-coverage. The authors propose a model dependent on k-coverage problem for a sufficient condition in this paper. Also, for maintain the K-connectivity and K-coverage among all active sensors, a relation among sensor's communication range and sensing is provided by the authors. This model consumes more energy and is not suitable in real world application. Cal et. al. [10] develop a sleep scheduling based protocol which is named as Area-based Collaborative Sleeping (ACOS). This protocol achieves maximum coverage of area while saves energy and extends the network lifetime by keeping an inessential sensor to sleep mode. The sensors in ACOS can be active, semi-active, passive, and semi-passive. When redundant sensor is in sleep mode then some areas are not covered by sensor and then coverage hole problem occurs. Esnaashari [11] propose a strategy for k-coverage with the movement of sensor called "Cellular Learning Automata based Deployment Strategy (CLA-EDS)". CLA-EDS cover every point having different value of k in different areas and it establishes cooperation with its neighbor to find out its best position within area to achieve high coverage. This proposed strategy is an extension of CLA-DS. He, chen et.al. [12] overcome coverage and connectivity problem and promote a new type of network which is called Partitioned Synchronous Network (PSN). In PSN, duty cycled approach is used for saving energy. This network inherits the advantage of both synchronous and asynchronous network. The authors claim that PSN shows good network performance in comparison to synchronous and asynchronous networks. Li et. al. [13] study the problems on target coverage related to maximum energy efficiency and fault tolerance. The authors propose two heuristic algorithm TS and RA for k-connect coverage of target with minimal number of active node. Set cover algorithm based TS algorithm covers all target and some new nodes are added. Another RA algorithm is reverse algorithm. If sensor node has no impact on coverage and k-node-disjoint path is presented among two sensor neighbors then sensors become inactive. Bai [14] analyzes optimal patterns that attain multiple coverage in a region. In this paper, optimal bound based pattern is proposed which is named optimal 2-coverage pattern. This pattern achieves 2-coverage and 1-,2-,3-connectivity. This pattern is not suitable for k-coverage and connectivity. Dhillion and Chakrabarty [15] formulate an optimization problem on placement of the sensor. The authors analyze a unique view of the network where minimal number of sensors are placed to give adequate coverage. The authors have proposed polynomial-time algorithm for minimizing number of node and their placement. In this paper, the authors examine how to determine a sensor location in each step of the algorithm. Bettstetter and Hartmann [16] study on the effect of log-normal shadowing environment on connectivity of Multi-hop network. Here sensors are randomly distributed as per the homogeneous poisson process. In this paper, the authors give minimum node density with tight lower bound. In this bounded region the network is surely connected. The authors also analyze the effect of fading on the topology of multi-hop network.

This bounded approach is used only for fixed connectivity network but not for dynamic connectivity. Hekmant and Van Mieghem [17] analyze undirected geometric random graph model based connectivity in ad-hoc network. In this paper, the authors use the radio model. This model uses statistical variations of signal power within mean value for finding the link probability. The authors reduce the amount of correlation between link and raise the long links probability and therefore enhance the connectivity probability of network by using more realistic log-normal shadowing environment. Miorandi et al. [18] analyze the process for computing the coverage as well as node isolation probability on an ad hoc network, with applications to fading and shadowing effect, in channel randomness presence. The authors use stochastic ordering to demostrate the beneficial effect of log normal shadowing as well as the Rayleith fading's negative impact. Sagar and Lobiyal [19] propose k-coverage and k-connectivity model according to poission distribution in sensor network. The authors utilises log-normal shadowing path loss model as well as analyze its connectivity and coverage impact. The authors have also analyzed that k-coverage model faces the node failure problem.

III. SYSTEM MODEL

Let's assume that N sensors are deployed which are static and with homogeneous energy in the respective sensing area. These sensors are deployed according to Poisson distribution densely and randomly and having densityλ. The $\pi {R_s}^2$ area is sensed by the every sensors that is having sensing radius R_s. The sensing area is monitored if the area lies within the range of at least one of the sensors deployed. Each sensor will forward the sensed information to sink either through single or multi-hop communication. It is presumed that each and every sensor is having the similar transmission range and sensing range and every sensor will get equally affected by the distance and environment. In table 1, network parameters and their symbols are given.

Table I:Parameter definitions for Coverage and Connectivity

Parameter	Definition
N	Number of Sensors
ρ_s	Transmission power of a Sensor nodes
σ	Standard deviation for Shadowing
τ	Standard deviation for Rayleigh fading
A	Area of interest
P_{detect}	Probability of event detection
η	Pathloss exponent

A. Sensing Channel Model

Sensors are the sensing devices that are applications-oriented and consists of extensively dissimilar features. Different sensing models based on a particular application environment and sensor device can be made to signify the sensor's sensing characteristics. Moreover, a real channel model cannot be captured by the circular disk model. Hence, we have assumed non-uniform sensing range for a sensor so as a sensing channel model is developed for capturing real sensing characteristics. It is also assumed that *N* sensors are placed in a uniform manner in area *A* of sensing field. In this work homogenous sensors are used, which means, the sensing threshold power is same δ (in dB) for all. Furthermore, sensing threshold is described as the received signal's minimum strength which sensor decodes appropriety. We can determine the power attenuation along the propagation path, sensing signal's transmit power, and sensing threshold power is used for calculating the sensing range. The ρ_s (in dB) represents the sensing signal power which is event generated. For developing the proposed sensing channel model, we have used the popular propagation fading models, i.e., multipath fading model as well as log-normal shadowing fading model, in our work. Multipath fading and log-normal shadowing model is used to express received signal power $\rho_{rs}\ (d)$ (in dB) as [20]

$$\begin{gathered}\rho_{rs}(d) = \rho_g(d) + \omega \\ \rho_g(d) = \rho_{am}(d) + \chi \\ \rho_{am}(d) = \rho_s - \bar{L}(d) - 10\eta \log_{10}\frac{r}{d}\end{gathered} \tag{3}$$

here η represents path loss exponent which manifests the rate in which distance escalates the path loss. $\bar{L}(d)$ represents the mean path loss at d (the distance between a sensor and its target) and r (reference distance). χ represents a Gaussian random variable (in dB) with zero mean and variance σ. σ represents lognormal shadowing effects occurring due to different levels of cutter in the path of propagation. Generally, a Gaussian distribution that has area mean power $\rho_{am}(d)$ (in dB) is manifested by the received signal power $\rho_g(d)$. A random variable (in dB) which is represented by the ω parameter represents the Rayleigh fading effect which is result of wave interference and multipath propagation. The received power $\rho_{rs}(d)$ represents Rayleigh distribution with mean $\rho_g(d)$as the occurrence of multipath fading is noticed as local fluctuations near the local mean power. Therefore, the ω 's normalized pdf is represented as [20]

$$f_\omega(v) = \frac{v}{\tau^2} e^{[-v^2/2\tau^2]} \tag{4}$$

where $\tau = \sqrt{\frac{2}{\pi}}\, 10^{20\log_{10}(m)/20}$, m is mean of Rayleigh fading.

The parameters , $\sigma, and\ \tau$ are responsible for the fading effects. Sensor node's sensing radius is changed if any change has been occurred in any of these parameters. Application environments' as well as particular sensor's sensing characteristics are represented by these parameters. Moreover, for distinct environments average sensing radius can be determined by these parameters.

IV. K-COVERAGE MODEL

Coverage is defined to be where every portion of the target region is monitored at least by one sensor.

The Sensor can be of different varieties, for example, if only one sensor covers the sensed areas, it is called as 1-coverage and if K sensors are used to sense the particular area then it is called as K-coverage. To enhance the accuracy and make the network more fault tolerant, K-coverage is required, for example, in military applications, forest fire detection, intruder detection system. For assumption, the area is considered as obstruction free and sensing radius is considered as equal for all the directions, but in real time scenario, sensing radius of sensor node is blocked by obstacles which cause reflection, refraction and scattering. The sensor will detect the sensing signal only when the threshold value will be lesser than the signal strength. This process is termed as sensing sensitivity.

A. K-Coverage without Lognormal Shadowing and Rayleigh fading

We assume A and Rsas the area of interest and the sensing radius. When coverage without shadowing fading is considered, then $\sigma = 0$. If a target lies in the sensing area, it is said to be covered. Therefore, the probability that a target can be diagnosed by a sensor node is

$$P = \frac{A_{tar}}{A} = \frac{\pi {R_s}^2}{A} \qquad (6)$$

Here, A_{tar} is the sensing area and A is the whole network area

The Probability that a sensor(which is randomly placed) will not sense the target is

$$P_{undetect} = (1 - P)$$

Let N sensor nodes which is not placed uniformly in the concerned areas. Therefore, the probability of target detection at least by one sensor out of N sensor nodes is

$$P_{detect} = 1 - (1 - P_{undetect})^N (7)$$

Using equality approximation $(1 - P)^N \approx e^{-NP}$ is very large, (7) can be rewritten as

$$P_{detect} = 1 - e^{-NP}$$

$$P_{detect} = 1 - \sum_{p=0}^{N} \binom{N}{P} \times e^{-N\frac{\pi {R_s}^2}{A}} (8)$$

B. K-Coverage with Lognormal Shadowing and Rayleigh fading

Both the Rayleigh fading as well as lognormal shadowing fading effects are subjected by the channel. Sensor's receiver signal power is observed to be different in every direction. This is because the different propagation paths are used for receiving the receiver signal power as well as varied multipath fading and shadowing loss affects this. Hence, sensor's sensing radius is not uniform in every direction. By these statements as well as referring to equation (3), we can express the sensor's received sensing power which is situated from a distance r away from the target as

$$\rho_{rs}(d) = \rho_s - \bar{L}(d) - 10\eta \log_{10} \frac{r}{d} + \chi + \omega$$
(9)

When the received signal power is more than threshold value δ, then only sensor node can sense the target. Hence, the probability that threshold value is less than the received power is represented as

$$P_{detect}(d) = [\rho_{rs} > \delta]$$
(10)

χ is a Gaussian random variable with variance σ^2 and zero mean as well as the propagation path is given some shadowing impacts. For modelling the multipath effects in propagation path Rayleigh fading is used and is represented by a random variable ω. Thus, the detection probability $P_{detect}(t)$ can be manifested as:

$$P_{detect}(t) = \int_0^{\infty} \int_{z-u}^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{u^2}{2\sigma^2}} \frac{v}{\tau^2} e^{-\frac{v^2}{2\tau^2}} du\, dv$$
(11)

where $z = 10\eta \log_{10} \frac{t}{r}$

$$P_{detect}(t) = Q\left(\frac{z - \tau\sqrt{2}}{\sigma}\right)$$

Therefore, probability is discovered with the help of Q Function when threshold value is exceeded by the received signal. Where$Q$function is given by

$$Q(n) = \frac{1}{\sqrt{2\pi}} \int_n^{\infty} e^{-\frac{x^2}{2}} dx$$

The probability with which a sensor is randomly placed at distance t over an area A to the event of interest, is $\frac{2\pi t\, dt}{A}$, where dt represents distance's least variation. Thus, the probability of sensor node to sense the targeted area is

$$P_{detect} = \frac{1}{A} \int_{t=0}^{R_m} Q\left(\frac{z - \tau\sqrt{2}}{\sigma}\right) 2\pi t\, dt \qquad (12)$$

According to (7), the coverage probability P_{cov} that a target is sensed by P sensors out of N sensors in sensing field of area A is

$$P_{cov}(P) = \binom{N}{P} (P_{detect})^P (1 - P_{detect})^{N-P}$$

Substituting the value of P_{detect} from (12),

$$P_{cov}(P) = \binom{N}{P} \left(\frac{1}{A} \int_{t=0}^{R_m} Q\left(\frac{10\eta \log_{10} \frac{t}{r} - \tau\sqrt{2}}{\sigma} \right) 2\pi t\, dt \right)^P \times \left(1 - \frac{1}{A} \int_{t=0}^{R_m} Q\left(\frac{10\eta \log_{10} \frac{t}{r} - \tau\sqrt{2}}{\sigma} \right) 2\pi t\, dt \right)^{N-P}$$

Probability that target location is covered by at least K sensor is represented by

$$P_{cov}(K) = 1 - \sum_{P=1}^{K} \binom{N}{P} \left(\frac{1}{A} \int_{t=0}^{R_m} Q\left(\frac{10\eta \log_{10} \frac{t}{r} - \tau\sqrt{2}}{\sigma} \right) 2\pi t\, dt \right)^P \times$$

1−1At=0RmQ10ηlog10tr−τ2σ2πt dtN−P(14)

From (14), the probability of K-coverage can be drawn; i.e., each and every point in the field is detected at least by K sensors so that the network is made fault tolerable. We can also see from the equation that as the shadowing parameter increases, the probability of coverage decreases.

V. K-CONNECTIVITY MODEL

The sensors, in WSN, send the sensed information to the BS either using single or multi-hop communication. As sensors are having limited battery power, therefore as transmission proceeds the nodes will run out of energy and also some sensors will run out of energy long before the other nodes cause network breakdown or hole. Therefore, connectivity is one of the important issues for any application.

Connectivity of sensor nodes is defined as a communication link between various sensors in the network. In a network, sensor can communicate if every sensor pair is linked with a path in the network. It is assumed that Poisson point distribution is followed by all the sensors as well as sensors'' positioning is considered as a homogeneous Poisson process. We have not considered mobility in this paper. So, the Probability of N sensors appears in the region A is

$$P(k) = e^{-\lambda A_{tar}} \frac{(\lambda A_{tar})^k}{k!} \quad (15)$$

Here λ represents node density and N represents no. of sensors located in A_{tar}

A. Node isolation probability

Firstly, it is necessary to calculate the sensor's probability of isolation before getting the connectivity of the whole network. Also the node isolation probability P_{NIP} is defined as as the neighbors or a node which is randomly selected and has no neighbors, or a node which has none of the other nodes present in the networks to communicate with. According to the [11] the node speculation probability is expressed as

$$P_{NIP} = e^{-2\pi\lambda \int_0^\infty sf(s)ds} \quad (16)$$

The node isolation probability P_{NIP} in the Presence of Rayleigh Fading and Log-normal Shadowing

$$\int_0^\infty sf(s)ds = \int_0^\infty s e^{-\frac{(s/d)^\eta}{\tau^2}} e^{\frac{\sqrt{2}\sigma}{\eta}} ds \quad (17)$$

Let $z = \frac{(s/d)^\eta}{\tau^2}$, hence $s = d(\tau^2 z)^{\frac{1}{\eta}}$ and $ds = \frac{d\tau^{\frac{2}{\eta}}}{\eta} z^{\frac{1}{\eta}-1} dz$

Substituting z for s into (17)

$$\int_0^\infty sf(s)ds = \int_0^\infty d(\tau^2 z)^{\frac{1}{\eta}} e^{-z} e^{\frac{\sqrt{2}\sigma}{\eta}} \frac{d\tau^{\frac{2}{\eta}}}{\eta} z^{\frac{1}{\eta}-1} dz$$

$$= \int_0^\infty \frac{d^2\tau^{\frac{4}{\eta}}}{\eta} e^{\frac{\sqrt{2}\sigma}{\eta}} e^{-z} z^{\frac{2}{\eta}-1} dz$$

$$\int_0^\infty sf(s)ds = \frac{d^2\tau^{\frac{4}{\eta}}}{\eta} e^{\frac{\sqrt{2}\sigma}{\eta}} \Gamma\left(\frac{2}{\eta}\right) \quad (18)$$

where $\Gamma\left(\frac{2}{\eta}\right) = \int_0^\infty e^{-z} z^{\frac{2}{\eta}-1} dz$ signifies the Gamma function. Substituting (18) into (16), we get

$$P_{NIP} = e^{-2\pi\lambda \frac{d^2\tau^{\frac{4}{\eta}}}{\eta} e^{\frac{\sqrt{2}\sigma}{\eta}} \Gamma\left(\frac{2}{\eta}\right)} \quad (19)$$

B. K- connectivity with Lognormal Shadowing and Rayleigh Fading

Let us assume that in WSN, sensors are not uniformly located in a 2-dimensional area $A = w * l$. where l is the length and w is the width of two dimensional area. According to the Poisson distribution theory, the mean intensity is λ. Thus, the quantity of sensor nodes per unit area is expressed as $\lambda = \frac{N}{A}$. The probability connectivity is expressed as

$$P(k) = e^{-kP_{NIP}} e^{-\lambda A_{tar}} \frac{(\lambda A_{tar})^k}{k!} \quad (20)$$

Target area is $A_{tar} = \pi {R_c}^2$

Where R_c is the effective communication range and k is the degree of the neighbor node such that $k = 1,2,3,4 \ldots \ldots \ldots \ldots \ldots \ldots \ldots ....$

$$P(k) = e^{-kP_{NIP}} e^{-\lambda\pi {R_c}^2} \frac{(\lambda\pi {R_c}^2)^k}{k!} \quad (21)$$

If a sensor node has no neighbors, i.e., $k = 0$ then the probability of connectivity is

$$P(\,0\,) = e^{-\lambda\pi {R_c}^2}$$

$$If\ degree\ of\ neighbors = 0,1,2,3,4 \ldots \ldots \ldots \ldots \ldots \ldots \ldots .k - 1\ then$$

$$P(\,1\,) = e^{-P_{NIP}} e^{-\lambda\pi {R_c}^2} \frac{(\lambda\pi {R_c}^2)}{1!}$$

$$P(\,2\,) = e^{-2P_{NIP}} e^{-\lambda\pi {R_c}^2} \frac{(\lambda\pi {R_c}^2)^2}{2!}$$

$$P(k-1) = e^{-(\,k-1\,)P_{NIP}} e^{-\lambda\pi {R_c}^2} \frac{(\lambda\pi {R_c}^2)^{(k-1)}}{(k-1)!}$$

If the minimum node degree is not lesser than or is equal to k then the probability of connectivity for each sensor node is

$$P(d_{min} \geq k) = \left(1 - e^{-\lambda\pi {R_c}^2}\left(1 + e^{-P_{NIP}} \frac{(\lambda\pi {R_c}^2)}{1!} + e^{-2P_{NIP}} \frac{(\lambda\pi {R_c}^2)^2}{2!} + \cdots \ldots + e^{-(k-1)P_{NIP}} \frac{(\lambda\pi {R_c}^2)^{(\,k-1\,)}}{(k-1)!}\right)\right)$$

$$P(d_{min} \geq k) = \left(1 - e^{-\lambda\pi {R_c}^2} \sum_{i=0}^{k-1} e^{-kP_{NIP}} \frac{(\lambda\pi {R_c}^2)^i}{i!}\right)$$

If N represents the number of sensors then connectivity probability is

$$P(d_{min} \geq k) = \left(1 - e^{-\lambda \pi {R_c}^2} \sum_{i=0}^{k-1} e^{-kP_{NIP}} \frac{(\lambda \pi {R_c}^2)^i}{i!}\right)^N \quad (22)$$

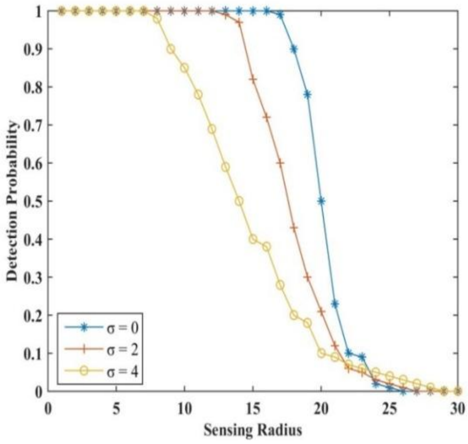
VI. SIMULATION RESULTS

The simulation results for producing the effect of sensing channel model on the network coverage under multipath and shadowing fading environments are represented in this section. We perform simulations with the help of MATLAB for investigating the K-Connectivity and K-Coverage results. the sensing field is presumed to be a square with area $A = 1000m \times 1000m$, in the simulation results. The maximum sensing radius R_m is presumed to be $20m$. Table 2 represented the parameters used for obtaining the simulation results. The assumption is made that log-normal shadowing χ's standard deviation σ is greatly linked with the path loss exponent. For non-shadowing and non-multipath environment, ($\eta = 3, \sigma = 0, \tau = 0$), as well as the maximum value is attained by the sensing radius. The small regular changes in η can be exhibited as the τ (multipath) and σ (shadowing)'s combined effect whereas η is kept constant for a specific environment.

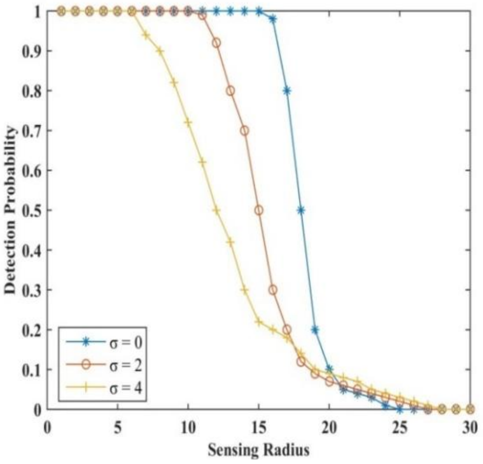
Table II. Simulation Parameter

Parameter	**Value**
Number of Sensor Node (N)	250-2500
Area (A)	$1000 \times 1000m^2$
Path loss Exponent (η)	3
Effective Sensing Range (R_m)	20 m
Threshold of received signal(δ)	-50 dB

Figures 1 show the results for different multipath and shadowing environment of detection probability P_{detect} versus the sensing radius. In Figure 1(a), the non-shadowing ($\sigma = 0$) and non-multipath ($\tau = 0$) environments, at maximum sensing radius the detection probability is found to be around 1. When the sensing radius R_s is decreased below 30% of R_m, it results in the degradation of the detection probability, in the multipath and shadowing environments. For instance, represented in the figure 1 (b) for for $\tau = 2dB$ and $\sigma = 4dB$, with sensing radius at its maximum i.e., 0.5 the detection probability is decreased through 85% as for non-multipath and non-shadowing environments. The maximum values of τ and σ specifies that with the decrease in the sensing radius, the detection probability is degraded drastically.



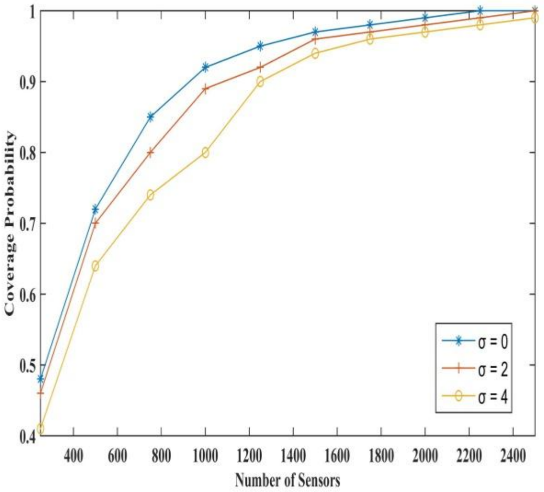
(a)multipath effect $\tau = 0$



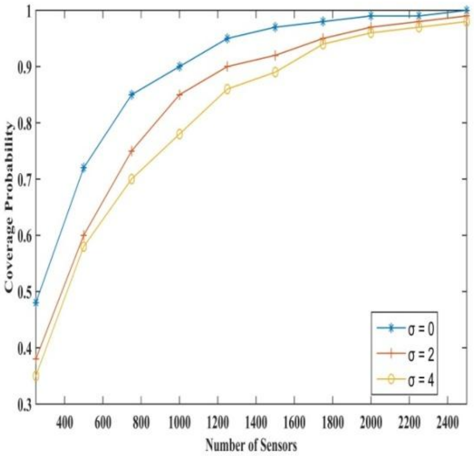
(b) multipath effect $\tau = 2$

Fig. 1. Detection Probability vs Sensing Radius for different shadowing and multipath environments

Figures 2, show the results for distinct multipath and shadowing environments of coverage probability P_{cov} versus number of sensors that are distributed randomly. Figure 2 (a) pronounced that the non-shadowing coverage $\sigma = 0dB$ as well as non-multipath environment $\tau = 0\ dB$ is nearly 52% of that is attained in the uniform deployment of nodes. Although, the figure 2(a) represents the $\tau = 0dB$ and $\sigma = 4dB$ for 91% sensing coverage which is attained when the number of sensor nodes $N = 1250$. In figure 2(b), for achieving a suitable sensing coverage of $P_{cov} = 0.90$ for $\tau = 2dB$, $\sigma = 4dB$ environment the number of sensors needed is approximately $N = 1750$. Hence, the above results clearly shows that for a harsh shadowing and multipath environment, we require maximum number of sensors to attain the suitable coverage.



(a) multipath effect $\tau = 0$



(b) multipath effect $\tau = 2$

Fig. 2. Coverage Probability vs number of Sensors for different shadowing and multipath environments

Figures 3 show the result for shadowing and multipath environments ($\sigma = 2dB\ and\ \tau = 2dB$) of the coverage probability versus the number of sensors. The sensor's average sensing radius is decreased when there is increase in the multipath and shadowing environment's standard deviation, and thus for attaining the suitable coverage more sensors are required. As represented in figure 3, to offer the 3-coverage with $probability > 90\%$ as well as multipath and shadowing parameters, there is need of 1250 sensor nodes in that specified area. Therefore, it is concluded that node density ratio remains unaffected by the coverage probability as there is increase in the standard deviation.

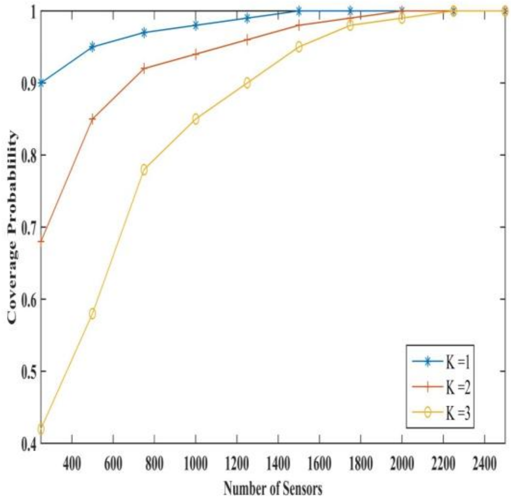
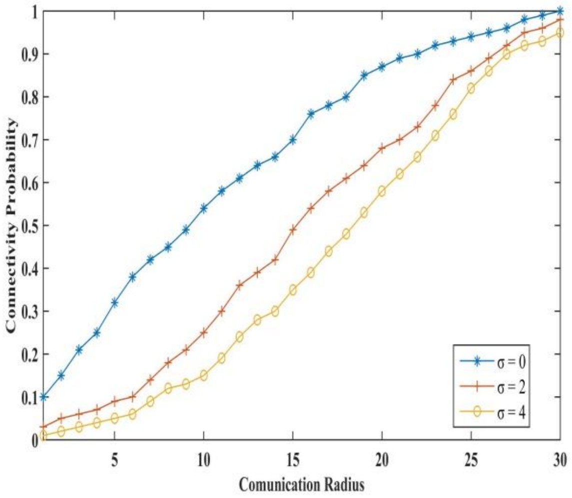
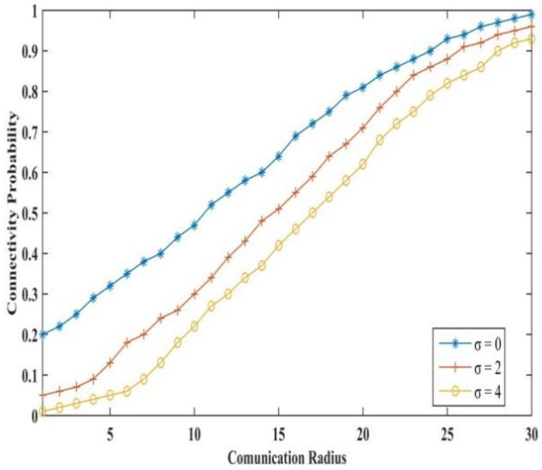


Fig. 3. K-Coverage vs Number of Sensors

Figure 4 shows connectivity probability versus communication radius for different shadowing and multipath environment. It represents how network connectivity is affected by the communication radius. The sensors' communication radius is directly proportional to the network connectivity. In Figure 4(a), the non-shadowing ($\sigma = 0\,dB$) and non-multipath ($\tau = 0\,dB$) environments, the connectivity probability at maximum communication radius is nearly 1. As the communication radius increases from 20m, there is increase in the connectivity probability and it results to nearly 90%. In the shadowing and multipath environment, communication radius increases from 26m, the probability of connectivity is increased upto nearly 90%. In Figure 4(b) for $\tau = 2dB\ and\ \sigma = 4dB$, communication radius increases from 28m, the connectivity increases and reaches to approximately 90%.



(a) multipath effect $\tau = 0$

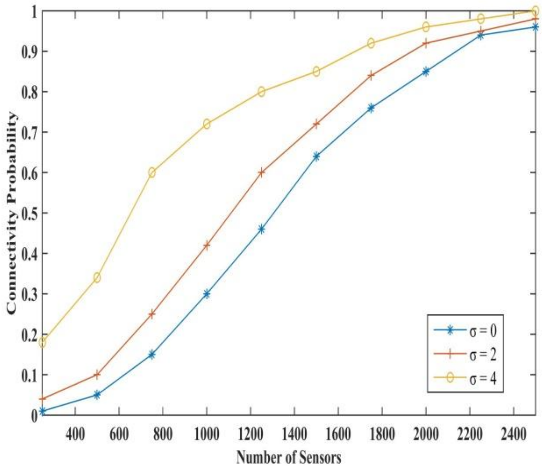


(b) multipath effect $\tau = 2$

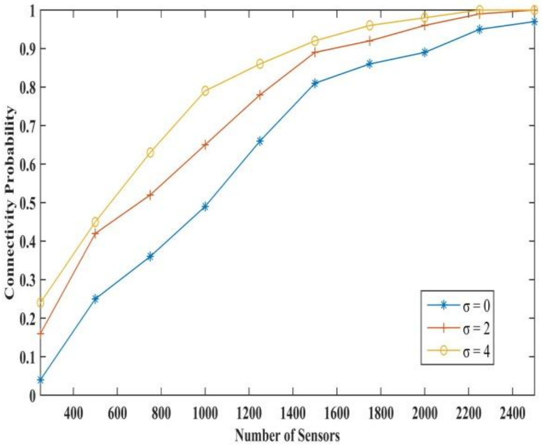
Fig. 4. Connectivity Probability vs Communication Radius for different shadowing and multipath environments

Figure 5 shows the comparison result for different shadowing and multipath parameters of Connectivity Probability and number of Sensors. In figure 5(a), completely connected network with $probability > 90\%$, in the square area of $1000\,m \times 1000\,m$, we needed nearly 2250 nodes when there is non-shadowing and non-multipath environment.

If we increase shadowing parameters $\sigma = 4\,dB\ and\ \tau = 0\,dB$ number of nodes approximate 1750 are enough for making the network connected along with the similar probability. For figure 5(b), where connected network having $probability > 90\%$, around 2200 nodes in the particular area is required when there is non-shadowing $\sigma = 0\,dB$ and multipath $\tau = 2\,dB$ environment. If we increase shadowing parameters $\sigma = 4\,dB\ and\ \tau = 2\,dB$ number of nodes approximate 1500 are ample to make the connected network with similar probability. therefore, the connectivity probability increased when log-normal multipath and shadowing fading are present.



(a) multipath effect $\tau = 0$



(b) multipath effect $\tau = 2$

Fig. 5. Connectivity Probability vs number of Sensors for different shadowing and multipath environments

The K-connectivity with N nodes results are represented in figure 6. When a square area of $1000\,m \times 1000\,m$ is deployed with the 100 nodes, then it is discovered that there is no connection in the network. Nearly 1900 sensor nodes are required with $probability \geq 90\%$ for 1-connected network. When the same region is deployed with the 2100 nodes, then the resultant network has $probability > 90\%$ and is 3-connected network. Thus, it is clearly demonstrated by the graph below that there is a transition from low connectivity to high connectivity when sensor node density is increased.

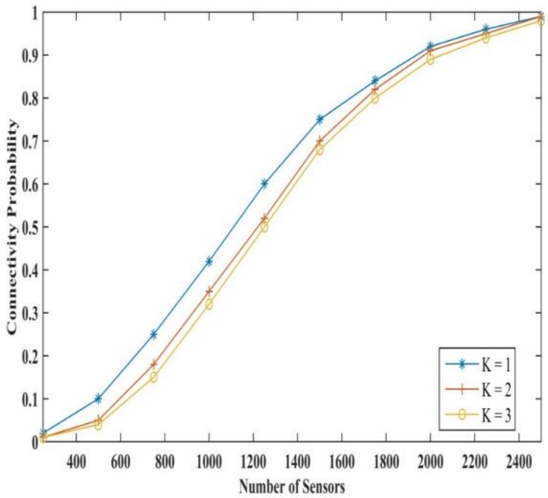


Fig. 6. K-Connectivity vs Number of Sensors

VII. CONCLUSION AND FUTURE WORK

Through the present research, an attempt is made for promoting the new model for sensing channel which evaluates the effect of shadow fading along with some multipath impacts. To estimate the probability of both coverage and detection, a mathematical model is implemented. It was estimated that there was a degradation in both sensing coverage and detection probability with decreasing sensing radius in a fading environment. We have additionally maintained that the required quantity of sensors raises for the coverage desired with prominent effects of fading. We have also comprehended that the probability of network coverage and connectivity is based on both standard deviation as well as the node density. The average sensor radius for sensing is decreased when the standard deviation is of higher value. Hence it leads to the degradation of network coverage probability. Opposing to this the connectivity is improved when high fading variance in comparison to removal of links, tends to add more links. We have attempted to show that this promoted sensing model gives efficient coverage and connectivity of the network under realistic environment than any of the sensing model present in the past state-of-art methods. Hence, this proposed model proves to be more useful for evaluating WSNs performance under any environment. This paper can be concluded with a statement that fading model and node density have a remarkable effect on coverage and connectivity. The proposed system can be applied for exploring the sensor coverage aspects, in future however keeping in mind the interference effects.

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