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ANALYSIS OF WIRELESS AD HOC SENSOR NETWORK FOR SELECTION COMBINING AND THRESHOLD-HYBRID SELECTION/MAXIMAL RATIO COMBINING

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ABSTRACT

The presented paper discusses and presents the analytical as well as simulated performance analysis allied with network connectivity and key problems of network coverage in Wireless Sensor Networks (WSN). The issue of network connectivity may be considered as one of the most significant problem in wireless network. The connectivity issue or coverage problem significantly influences the network capability and overall network efficiency. In the presented paper, we propose a research work oriented towards computation of node isolation probability and to perform analysis of network connectivity in the presence randomness in channel behavior, while considering of fading effects like Rayleigh fading of threshold-based hybrid selection/maximal-ratio combining (T-HS/MRC). In this paper, the analysis of selection combining has been done while considering the independent communication paths and even with correlated paths. On the basis of predetermined normalized threshold parameter a T-HS/MRC combiner selects the combined branches and it finds the potency of the instant signal-to-noise ratio (SNR) of individual network branch. Consequently, the number of combined branches is always a random variable, to a certain extent than a predetermined number, as in conformist hybrid selection mechanism/ maximal-ratio combining (H-S/MRC) technique. The present analytical and simulated work motivates to design more practical and reliable system.
Keywords: *Ad-hoc Network, Hybrid Selection, Maximal-Ratio Combining, Rayleigh Fading, Selection Combining.*

1. INTRODUCTION

In the last few years, a number of researches have been done for self-organizing, infrastructure less wireless multi-hop network protocol. In this kind of self-configuring networks, the communication between mobile transceivers takes place in a peer-to-peer fashion without requiring any kind of infrastructure or base stations. In order to explore, investigate and optimize the fundamental behaviors like network connectivity and distribution of degree and of course the performance of network, a skilled and optimized modeling is required.

In practical aspects, the network connectivity refers a precondition for providing consistent applications or uses for users of ad hoc network.

As per best of our knowledge the first paper dedicated for deep rooted study and investigation of network connectivity in ad hoc network. In this work, it has analyzed and investigated up to what extent a node's data or message can percolates if all the network nodes are distrusted in random fashion using Poisson Point process (PPP) over an infinite large communication area[1]. Similarly the connectivity problem was discussed for nodes distributed homogeneously on a 1-D line segment. In order to maintain the network connectivity in ad hoc wireless network, the analysis of transmission range was studied in [2], [3] and [4]. The statistical analysis of the probability of network connectivity was discussed in reference [3] while the work for controlling node density for ensuring active node function was carried out in [5]. This work was accomplished by fulfilling two predominant requirements. These requirements were coverage and connectivity, where coverage defines the communication area that can be monitored, is not smaller in size as that which can be monitored by set of active sensors. Similarly, there connectivity was realized with sensor networks in connected state, thereby

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relaying the information collected back to data sink or network controllers. In order to accomplish the goal of a well-connected ad hoc network, it is required to have a communication path from any specific node to other node in network. Such network path might be of single hop or multi-hops in nature. In case of the absence of path in at least one source-destination pair, the network is referred to as disconnected. Even a disconnected network might be in the form of small nodal clusters and the largest cluster in communication network might be referred to as a giant component [6].

In order to accomplish the goal of connected coverage, in reference [7] author has studied the problem of deterministic node placement that is in fact sensing the area of interest with minimum sensor nodes in connected mode. In this work, it has been assumed that the sensor node follows unit disk model behavior while possessing homogeneous or similar sensing areas. In the similar way to optimize the protocol, author in literature [8] illustrates the approximation of network connectivity by means of node isolation probability. The realization of noise links was first analyzed in literature [9] employing the realization framework of graph theory and percolation. Here, the author demonstrates that the overall connectivity can be improved whenever new network links ahead of the range make up for broken links. In reference [10], the network connectivity was studied and analyzed in a finite network disk and was defined as a sub-section of an intact vast network at a steady node density. Since, the nodes present outside the network disk can support in creating network connectivity with nodes active in inside disk, therefore this definition is considerably different.

A number of approaches have been proposed for connectivity analysis in Ad hoc network. Most of them do analyze connectivity with different approaches like, k- connectivity, border effects scheme etc. Some other techniques are there that can be very significant in connectivity analysis of connectivity analysis in not only homogenous network, but also the networks of heterogeneous types. Selection combining can be one of the efficient approaches for the same objective. Selection combining can be an efficient approach for connectivity analysis where the nodes have been distributed randomly but in homogenous Poisson point process. The mentioned selection combining approach [11] for signal that selects a specific diversity branch possessing the highest posteriori probability is a highly effective approach in network analysis. This approach of selection combining do performs in the same way as it does in maximal ratio combining (MRC)[11][12]. The different is only that the MRC approach selects or chooses the diversity branch possessing highest signal power. A further application oriented research for Rayleigh fading channel was observed in [18] where this approach advocates and even proved its robustness for channel estimation and network analysis. The various researches conducted for selection combining approach [13] implementation in Ad hoc networks has illustrated that the aforementioned technique might be highly effective and would yield a better analysis and accurate result for node analysis in homogenous as well as heterogeneous network.

Further reviews have depicted that the threshold based hybrid selection combining approach might be highly effective in network analysis and even might be significant for channels with nakagami-m fading [14]. The mean value of error rate in threshold based hybrid selection/MRC approach with encompassing Nakagami-m fading can be easily obtained for (+) integers of fading parameters few specific correlation approach [15]. Few more researches were conducted for satisfying the minimum transceiver chains in network region by employing a new approach called Hybrid Selection and Maximum-Ratio Combining approach [16]. The significance and robustness of this approach could be visible in this work as this approach does minimizes the dependencies on channel estimation and is effective for self-configurable networks as in our proposed Ad hoc network. The similar work was done in reference [17] where various performance and network components were investigated and this approach illustrated a sound technique for channel estimation and further connectivity optimization. Thus considering these robust approaches for system design for network analysis might be an effective and optimistic approach for system optimization. Here, in this paper, the author has selected these approaches together and a hybrid system has been developed for connectivity analysis in Ad hoc network and its optimistic prediction might ensure the optimization of existing approaches like border effect based schemes.

The work present in [19], provides analysis of node isolation probability or 1-connectivity where author has given the impact of diversity scheme over node isolation probability. Conducting a deep rooted literature survey it was concluded that there is a lack of analysis for node

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isolation probability or 1-connectivty for diversity scheme where number of branch is random.

In this presented research work, the estimation of node isolation probability has been done and the analysis of network connectivity has been done in the presence of channel randomness taking into account the effects of Rayleigh fading of threshold-based hybrid selection/maximal-ratio combining (T-HS/MRC). We have also done the analysis for selection combining (SC) considering independent paths as well as correlated paths. The other sub-sections of the presented manuscript are as follows: Section 2 discusses the dominant assumptions considered and the developed system models for research realization. The ascending section (Section 3) presents the mathematical or analytical evaluation of node isolation probability in the presented research which is followed by presentation of the numerical and simulation results in Section 4. The last section (Section 5) discusses the conclusion of presented research.

2. SYSTEM MODEL

Considering a wireless multi-hop communication network encompassing actives nodes distributed randomly in homogenous way. The homogeneously node distribution in region of interest is done according to Poisson point process (PPP) with node density (λ) depicting the anticipated number of active nodes per unit square and lying in range ($0 < \lambda < \infty$). Consider, P_I refers the probability of node isolation. The assumption that the transmission between two constituting nodes ℓ and ℓ' takes place in the case only when the signal to noise ratio (SNR) γ at the destination node becomes higher than the minimum valueψ, becomes the basis of a switched link model. In case of received mean SNR value, consider the probability that the received SNR γ is higher than threshold ψ, is presented by a variable $P_s(y)$. In case of long code implementation, the expression for $P_s(y)$ reaches to a step function, mentioned in [20]. Supplementary, consider that the communication range of particular node is given by R in such a way that this specific node is capable of communicating with all other constituting nodes available within communication range R. For a deterministic channel model, R is always deterministic. But, in contrary, the same parameter R (communication range) varies randomly with *cumulative distribution function* (CDF) $F_R(\rho)$ and second moment $E[R^2]$ in case of lognormal shadowing and small scale fading.

As communication range R of a node is always is non-negative,

$$E[R^2] = \int_0^{\infty} 2\rho d\rho F_R^c(\rho) \quad (1)$$

Where $F_R^c(\rho)$ is the complimentaryCDF.

The node isolation probability can be presented as follows [10, 19]:

$$P_I = e^{-\lambda\pi E[R^2]} \quad (2)$$

Expressions for computing node isolation probability for various channel conditions are presented in the next subsections.

2.1. Combined Path-Loss and Lognormal Shadowing Model

Consider, all the active nodes do transmit power at a constant level given as P_{tx} and the total white noise power available at receiver terminal or node is given as$W$. The average path loss stated by $K\rho^{-\alpha}$ where ρ represents transceiver separation; path loss exponent is given by α and K refers a constant associated with considered path loss model.

The signal to noise power ratio at receiver terminal for such channel model can be presented by expression$\gamma(\rho) = (P_{tx}(\rho)/W)$, where the path loss occurred between transmitter and receiver node is given by$l(\rho)$. The extent where the SNR value falls down to predefined threshold ψ can be used or consider for estimation of communication range$R$.

Now, considering mentioned parameters, the variables $F_R(\rho)$ and $E[R^2]$ can be presented by following expressions [19]:

$$F_R(\rho) = P[\gamma(\rho) \le \psi] = P\left[l(\rho) \le \frac{W\psi}{P_{tx}}\right] = 1 - \int_{\frac{W\psi}{P_{tx}}}^{\infty} f_{l/r}\left(\frac{a}{\rho}\right) da \quad (3)$$

$$E[R^2] = \int_0^{\infty} 2\rho d\rho \int_{\frac{W\psi}{P_{tx}}}^{\infty} f_{l/r}\left(\frac{a}{\rho}\right) da \quad (4)$$

Where $f_{l/r}\left(\frac{a}{\rho}\right)$ refers the probability density function (PDF) of path loss under lognormal shadowing and can be given as:

$$f_{l/r}\left(\frac{a}{\rho}\right) = \frac{1}{\sqrt{2\pi\sigma a}} e^{-\frac{1}{2}\left(\frac{ln\alpha - \ln(K\rho^{-\alpha})}{\sigma}\right)^2} \quad (5)$$

In above mentioned expression the variable σ refers the standard deviation of the fundamental Gaussian process illustrating the shadowing observable fact.

2.2. Small Scale Fading and Lognormal Shadowing

If small scale fading should be taken into consideration while ignoring lognormal shadowing, let γ be the received instantaneous SNR and $y = E[\gamma]$, its average. Given that the transmitter-receiver separation is ρ and for average SNR which is received:

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$$y = \left(\frac{KP_{tx}\rho^{-\alpha}}{W}\right)$$

Let us assume that $P_S(y)$ is the probability which the received SNR γ with PDF $f_\gamma(x/y)$ is greater than a threshold ψ. Now $P_s(y)$ is given by:

$$P_s(y) = \int_\psi^\infty f_\gamma(x/y)dx \quad (6)$$

Then the quantity $E[R^2]$ is computed as follows:

$$E[R^2] = \int_0^\infty 2\rho d\rho P_s\left(\frac{KP_{tx}\rho^{-\alpha}}{W}\right) \quad (7)$$

When the lognormal shadowing is superimposed over the small scale fading effect the calculation of $F_R(\rho)$ and $E[R^2]$ can be done as follows:

$$F_R(\rho) = 1 - \int_0^\infty P_s(y) f_{l/r}(a/\rho)da \quad (8)$$

$$E[R^2] = \int_0^\infty da \int_0^\infty 2\rho d\rho P_s\left(\frac{\alpha P_{tx}}{W}\right) f_{l/r}(a/\rho) \quad (9)$$

3. ANALYTICAL EVALUATION OF NODE ISOLATION PROBABILITY

3.1. SC With Independent Nakagami Fading

If taken in to the consideration the diversity combining techniques Selection Combining (SC) is one of the least complex, the branch having the highest SNR only is chosen and then processed by the combiner. If the independent Nakagami fading is taken into consideration the CDF of selection combiner output SNR γ with respect to it can be calculated as follows [21]:

$$F_\gamma(x/y) = \left[1 - e^{\frac{-ma}{y}} \sum_{k=0}^{m-1} \frac{\left(\frac{ma}{y}\right)^k}{k!}\right]^M$$

$$= \sum_{n=0}^{M} (-1)^n\, {}^M C_n \exp\left(\frac{-nma}{y}\right)\left[\sum_{k=0}^{m-1} \frac{\left(\frac{ma}{y}\right)^k}{k!}\right]^n$$

$$= \sum_{n=0}^{M} (-1)^n\, {}^M C_n \exp\left(\frac{-nma}{y}\right) \sum_{k=0}^{n(m-1)} \beta_{kn}\left(\frac{ma}{y}\right)^k \quad (10)$$

Here m = Nakagami fading factor, M = number of branch, and β_{kn} is determined as:

$$\beta_{kn} = \sum_{i=k-m+1}^{k} \frac{\beta_{i(n-1)}}{(k-i)!} I_{[0,\ (n-1)(m-1)]}{}^{(n)};\ \beta_{00} = \beta_{0n} = 1,\ \ \beta_{k1} = \frac{1}{k!}$$

$$I_{[a,b]}{}^{(n)} = \begin{cases} 1, & a \le n \le b \\ 0, & Otherwise \end{cases} \quad (11)$$

The probability which signifies that the SNR in minimum one branch is having the higher value than ψ is known as the success probability and can be calculated as:

$$P_s(y) = -\sum_{n=1}^{M} (-1)^n\, {}^M C_n \exp\left(\frac{-nm\psi}{y}\right) \sum_{k=0}^{n(m-1)} \beta_{kn}\left(\frac{m\psi}{y}\right)^k \quad (12)$$

And it is the complement of the probability which represents SNR lower than ψ.

Expression for $E[R^2]$ is obtained by substituting (5) and (12) in (9) and is computed as follows:

$$E[R^2] = \int_0^\infty da \int_0^\infty d\rho\, 2\rho \frac{1}{\sqrt{2\pi a\rho}} e^{-\left(\frac{ln\left(\frac{a\rho^\alpha}{k}\right)}{\sigma}\right)^2} \sum_{n=0}^{\infty} (-1)^n\, {}^M C_n\ e^{\frac{-nmw\psi}{\alpha P_{tx}}} E(R^2)$$

$$= -\frac{2}{\alpha}\left(\frac{m\psi w}{kP_{tx}}\right)^{-\frac{2}{\alpha}} e^{\left(\frac{\sqrt{2}\sigma}{\alpha}\right)^2} \sum_{h=1}^{M} {}^M C_h \sum_{l=0}^{h(m-1)} \beta_{lh} h^{-\left(\frac{2}{\alpha}+l\right)} \Gamma\left(\frac{2}{\alpha}+l\right) \quad (13)$$

If the presented expression (2) and (13) are taken into the consideration the node isolation probability can be calculated as:

$$P_I = exp\left\{-\lambda\pi \frac{2}{\alpha}\left(\frac{m\psi w}{kP_{tx}}\right)^{-\frac{2}{\alpha}} e^{\frac{2\sigma^2}{\alpha^2}} \sum_{h=1}^{M} (-1)^h\, {}^M C_h \sum_{l=0}^{h(m-1)} \beta_{lh} h^{-\left(\left(\frac{2}{\alpha}\right)+l\right)} \Gamma\left(\left(\frac{2}{\alpha}\right)+l\right)\right\} \quad (14)$$

3.2. Dual selection combining scheme with Correlated Nakagami Fading

When the Nakagami fading effect is correlated with the dual selection combiner output SNR γ the PDF can be mathematically presented as follows [21]:

$$f_r(\gamma) = \frac{\left(\frac{m}{\bar{\gamma}_1}\right)^m \cdot \gamma^{m-1}}{\Gamma(m)} exp\left(\frac{-m\gamma}{\bar{\gamma}_1}\right) \cdot \left[1 - \Phi_m\left(A_1\sqrt{2\rho\bar{\gamma}}\, A_2\sqrt{2\gamma}\right)\right] + \frac{\left(\frac{m}{\bar{\gamma}_2}\right)^m \cdot \gamma^{m-1}}{\Gamma(m)} exp\left(\frac{-m\gamma}{\bar{\gamma}_2}\right) \cdot \left[1 - \Phi_m\left(A_2\sqrt{2\rho\bar{\gamma}}\, A_1\sqrt{2\gamma}\right)\right] \quad (15)$$

Where

$$A_l = \sqrt{\frac{m}{\bar{\gamma}_l(1-\rho)}}$$

And, $\rho = \beta$ is the correlation coefficient. m Refers the Nakagami fading factor

Let $\bar{\gamma}_1 = \bar{\gamma}_2 = \bar{\gamma} = y$

By simplifying the equation (15) forth it can be obtained as:

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$$f_r(\gamma) = 2\frac{\left(\frac{m}{y}\right)^m}{\Gamma(m)}\cdot\left[a^{m-1}.exp\left(\frac{-ma}{y}\right) - \frac{\beta^{\frac{-m+1}{2}}}{(1+\rho)^{\frac{1}{2}}}a^{m-1}exp\left(\frac{-m\,2(1-\sqrt{\beta})}{(1-\beta)}\frac{a}{y}\right)\right] \quad (16)$$

The mathematical expression (16) leads to:

$$I_1 = 2\frac{\left(\frac{m}{y}\right)^m}{\Gamma(m)}a^{m-1}.exp\left(\frac{-ma}{y}\right) \quad (17)$$

And

$$I_2 = \frac{\rho^{\frac{m+1}{2}}}{(1+y)^{\frac{1}{2}}}\,2\frac{\left(\frac{m}{y}\right)^m}{\Gamma(m)}a^{m-1}exp\left(\frac{-2m(1-\sqrt{\rho})}{(1-\rho)}\frac{a}{y}\right) \quad (18)$$

The probability which signifies that the SNR in minimum one branch is having the higher value than ψ is known as the success probability and for I_1 it can be calculated as:

$$P_{S/\Gamma_{SC}}(\gamma)\,for\,I_1 = 2\,e^{-\frac{m\psi}{y}}\sum_{l=0}^{m-1}\frac{\left(\frac{m\psi}{y}\right)^l}{l!} \quad (19)$$

By putting the equations (5), (19) in equation (9) we can simply calculate the equation for $E[R^2]$ and is follows as:

Similarly, for I_2 the success probability can be calculated as:

$$P_{S/\Gamma_{SC}}(\gamma) = \frac{2\rho^{\frac{m+1}{2}}}{(1+\rho)^{\frac{1}{2}}}\left(\frac{(1-\rho)}{2(1-\sqrt{\rho})}\right)^m e^{-\frac{2m(1-\sqrt{\rho})\psi}{y(1-\rho)}}\sum_{l=0}^{m-1}\frac{\left(\frac{2m(1-\sqrt{\rho})}{y(1-\rho)}\right)^l}{l!} \quad (20)$$

Similarly, by putting the equations (5), (20) in equation (9) we can simply calculate the equation for $E[R^2]$ which follows as:

$$E(R^2)\,of\,I_2 = \left(\frac{2}{\alpha}\right)\left(\frac{2m\psi(1-\sqrt{\rho})w}{(1-\rho)kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{l=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!}\cdot\left[\frac{2\rho^{\frac{m+1}{2}}}{(1+\rho)^{\frac{1}{2}}}\left(\frac{(1-\rho)}{2(1-\sqrt{\rho})}\right)^m\right] \quad (21)$$

From equation (19) and (21) we can write

$$E(R^2) = 2\left(\frac{2}{\alpha}\right)\left(\frac{m\psi w}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{l=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!}\left[1 - \frac{\rho^{\frac{m+1}{2}}}{(1+\rho)^{\frac{1}{2}}}\left(\frac{2(1-\sqrt{\rho})}{(1-\rho)}\right)^{-\left(\frac{2}{\alpha}+m\right)}\right] \quad (22)$$

In order to calculate the node isolation probability the equations (2) and (22) needs to get combine and the result will be as follows:

$$P_1 = e^{-\lambda\pi 2\left(\frac{2}{\alpha}\right)\left(\frac{m\psi w}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{l=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!}\left[1-\frac{\rho^{\frac{m+1}{2}}}{(1+\rho)^{\frac{1}{2}}}\left(\frac{2(1-\sqrt{\rho})}{(1-\rho)}\right)^{-\left(\frac{2}{\alpha}+m\right)}\right]} \quad (23)$$

3.3. Threshold-Based Hybrid Selection/Maximal-Ratio Combining Scheme

When the Nakagami fading effect is correlated to the Threshold-Based Hybrid Selection/Maximal-Ratio combining method output SNR γ the PDF can be obtained as [22]:

$$f_\gamma(\gamma/y) = L\left({}^{N}C_L\right)\sum_{p=0}^{L-1}\left({}^{L-1}C_p\right)\frac{(-1)^p\gamma^{L-1}e^{-\frac{\gamma}{\Gamma}}}{\Gamma^L C_p(L-1)!} + L\left({}^{N}C_L\right)\sum_{q=0}^{N-L}\sum_{p=0}^{L-1}\left({}^{N-L}C_q\right)\left({}^{L-1}C_p\right)\frac{(-1)^{p+q+L-1}C_p^{L-2}}{y(qG)^{L-1}}\left[e^{-\frac{C_p+q.G}{yC_p}\gamma} - e^{-\frac{\gamma}{M}}\sum_{m=0}^{L-2}\frac{(-qG)^m\gamma^m}{m!\,(yC_p)^m}\right] \quad (24)$$

Let

$$T = L\left({}^{N}C_L\right)\sum_{p=0}^{L-1}\left({}^{L-1}C_p\right)\frac{(-1)^p}{C_p(L-1)!} \quad (25)$$

$$U = L\left({}^{N}C_L\right)\sum_{q=0}^{N-L}\sum_{p=0}^{L-1}\left({}^{N-L}C_q\right)\left({}^{L-1}C_p\right)\frac{(-1)^{p+q+L-1}C_p^{L-2}}{(qG)^{L-1}} \quad (26)$$

From equation (24), (25) and (26) we can write the probability in which SNR in at least one branch is higher than ψ i.e. the success probability, which is calculated as follows:

$$P_s(y) = T\,(L-1)!\,\frac{2}{\alpha}\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{l=0}^{L-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!} + U\left[\frac{1}{A}\left(\frac{2}{\alpha}\right)\left(\frac{\psi AW}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\Gamma\left(\frac{2}{\alpha}\right) - V\left\{\left(\frac{\psi}{y}\right)^m e^{-\frac{\psi}{y}} + m!\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{l=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!}\right\}\right] \quad (27)$$

Where $A = \dfrac{C_p + q\mu}{C_p}$, L = number of diversity branch, $0<\mu<1$ and $C_p = 1+(1-\mu)p+\mu(L-1)$

Again, by putting Equations (5) and (27) in the equation (9) we can get $E[R^2]$ which follows as:

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$$E(R^2) = Z + U\left[\frac{1}{A}\left(\frac{2}{\alpha}\right)\left(\frac{\psi AW}{kP_{tx}}\right)^{-\frac{2}{\alpha}} \Gamma\left(\frac{L}{\alpha}\right) - V\left\{\left(\frac{2}{\alpha}\right)\Gamma\left(\frac{2}{\alpha}+m\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\left(\frac{2}{\alpha}\right)} + m!\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} \sum_{l=0}^{m-1}\frac{\Gamma\left(\frac{L}{\alpha}+l\right)}{l!}\right\}\right] \quad (28)$$

Where

$$Z = L\left({}^{N}C_{L}\right)\sum_{p=0}^{L-1}\frac{(-1)^p}{C_p(L-1)!}\left({}^{L-1}C_{p}\right)(L-1)!\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} \sum_{l=0}^{L-1}\frac{\Gamma\left(\frac{2}{\alpha}+l\right)}{l!} \quad (29)$$

From equation (28) and (29) we can write

$$E(R^2) = L\left({}^{N}C_{L}\right)\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} \sum_{p=0}^{L-1}\frac{(-1)^p}{C_p}\left({}^{L-1}C_{p}\right)\frac{\Gamma\left(\frac{2}{\alpha}+p\right)}{p!} + U\left[\frac{C_p}{C_p+qG}\left(\frac{2}{\alpha}\right)\left(\frac{\psi W(C_p+qG)}{C_p kP_{tx}}\right)^{-\frac{2}{\alpha}}\Gamma\left(\frac{2}{\alpha}\right) - \sum_{m=0}^{L-2}\frac{(-qG)^m}{m!\,C_p{}^m}\left\{\left(\frac{2}{\alpha}\right)\Gamma\left(\frac{2}{\alpha}+m\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} + m!\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{t=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+t\right)}{l!}\right\}\right] \quad (30)$$

For further simplification of node isolation probability equation (2) and (30) needs to get combined and the result will be as follows:

$$P_{I=}\, e^{-\lambda\pi L\left({}^{N}C_{L}\right)\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} \sum_{p=0}^{L-1}\frac{(-1)^p}{C_p}\left({}^{L-1}C_{p}\right)} + U\left[\frac{C_p}{C_p+qG}\left(\frac{2}{\alpha}\right)\left(\frac{\psi W(C_p+qG)}{C_p kP_{tx}}\right)^{-\frac{2}{\alpha}}\Gamma\left(\frac{2}{\alpha}\right) - \sum_{m=0}^{L-2}\frac{(-qG)^m}{m!\,C_p{}^m}\left\{\left(\frac{2}{\alpha}\right)\Gamma\left(\frac{2}{\alpha}+m\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}} + m!\left(\frac{2}{\alpha}\right)\left(\frac{\psi W}{kP_{tx}}\right)^{-\frac{2}{\alpha}}\sum_{t=0}^{m-1}\frac{\Gamma\left(\frac{2}{\alpha}+t\right)}{l!}\right\}\right] \quad (31)$$

4. NUMERICAL AND SIMULATION RESULTS

An analytical model has been developed using MATLAB and the simulation framework and numerical results are attained from them keeping into consideration that the constraints are selected as $K = 10dB$, $Ptx = 1mW$, $W = 0.01mW$, $\psi = 1\,Watt$. After that we properly choose the other constraints which are m, λ, α, and σ. A constant dimension of 100mX100m has been used for the simulation purpose. Finally to obtain the node isolation probability 1000 simulation runs has been performed. Fig.4.1a – 4.1b represents the simulated network architecture for various channel conditions.

Figure 4.2 gives the plot for impact of lognormal shadowing standard deviation sigma over node isolation probability for dual selection combining. Result of 4.2 shows that sigma is having positive impact on connectivity that is if sigma will increase correspondingly node isolation probability will decrees. Where result 4.3 concludes that branch correlation is having negative impact on connectivity and node density lambda is having positive relation to connectivity. Figure 4.4 gives the plot for impact of Nakagami fading factor 'm' over node isolation probability for dual selection combining. Result of 4.4 shows that 'm' is having positive impact on connectivity that is if 'm' will increase correspondingly node isolation probability will decrees. Figure 4.5 gives the plot for impact of lognormal shadowing standard deviation sigma over node isolation probability for T-HS/MRC scheme where number of branch will select corresponding to threshold value. Result of 4.5 shows that sigma is having positive impact on connectivity that is if sigma will increase correspondingly node isolation probability will decrees. Where result 4.6 concludes that number of branch is having positive impact on connectivity and also node density lambda is having positive relation to network connectivity.

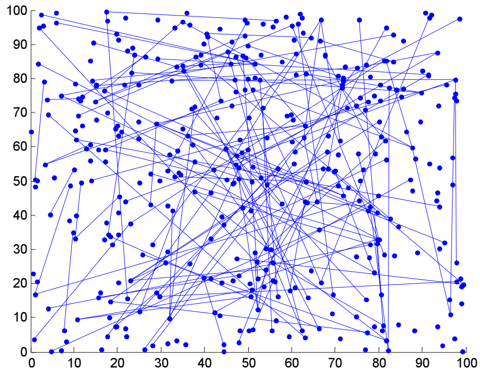

Fig. 4.1(a): Simulated network topology (sigma=2).

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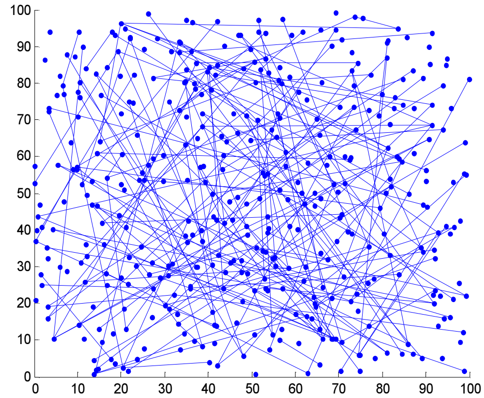

Fig. 4.1(B): Simulated Network Topology (Sigma=4).

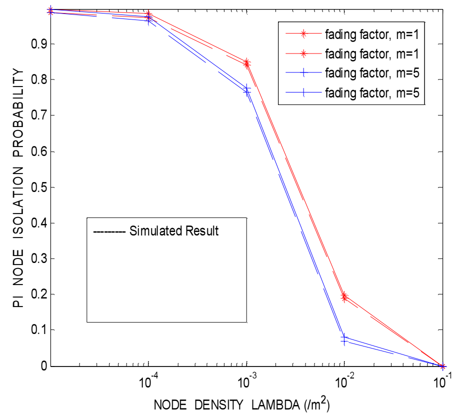

Fig. 4.4: Simulated Network Topology (Sigma=2).

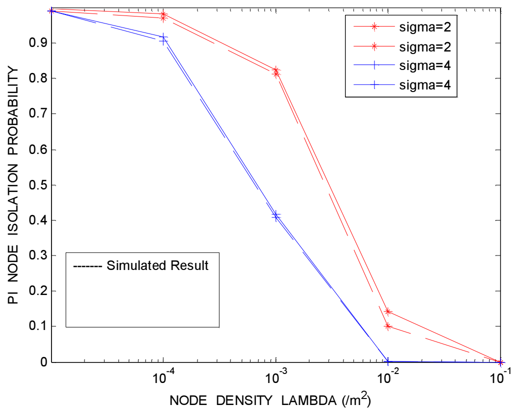

Fig. 4.2: Simulated Network Topology (Sigma=2).

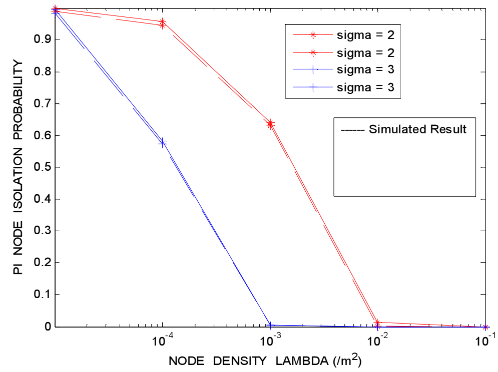

Fig. 4.5: Simulated Network Topology (Sigma=2).

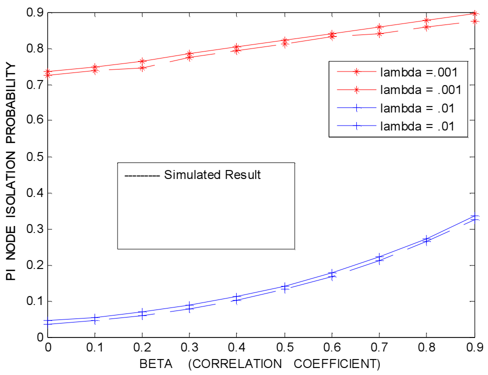

Fig. 4.3: Simulated Network Topology (Sigma=2).

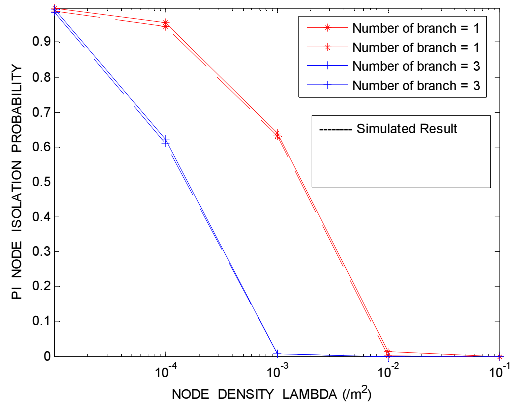

Fig. 4.6: Simulated Network Topology (Sigma=2).

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5. CONCLUSION

The node isolation probability has been studied and analyzed in this paper and further by using it the investigation of connectivity characteristics of wireless multi-hop network has been done. The derivation of mathematical expression for node isolation probability has been done further. By contrasting the earlier research work related to this field we use lognormal shadowing and T-HS/MRC method. By combining the simulation based method and analytical method, we come to know the impact of path loss exponent, Nakagami-m effect, node density and lognormal spread on the node isolation probability. What is the outcome of varying diversity branch on the network connectivity has also been explored in the paper. The values of node density which are calculated are used in practical significance for wireless multi-hop networks for designing and simulation purpose. To get a total covered network containing a certain area a minimum node density is required which we can obtain from the results in the paper for a given channel model and parameters.

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