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Improving Connectivity Using Smart Antennas in Ad Hoc Networks

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Abstract: In this paper we study the connectivity for ad hoc networks by modeling geometric random graph using Honey gird model. We shall study the connectivity with random shadowing effect that is connection may be occur at out of range and no connection inside the range as well as effect of interference that is reduce desired power between parties consequently prevent the connection and reduces number of the nodes inside the coverage area. We shall model Connectivity with smart antennas; consequently exploit advantage of it to reduce the interference, increase the gain and power transmission to improve the connectivity.

I. INTRODUCTION& LITERATURE REVIEW

The very basic purpose of any network is to facilitate exchange of information between any two nodes. This can happen only when the network is connected. Hence the connectivity is one of the fundamental and most important issues of the MANETs (Mobile Ad hoc Networks).

Connectivity in ad hoc networks are effected by many factor some of them controllable (e.g. power transmission). Some of them uncontrollable (e.g. Interferences and obstructions and irregularities in the surroundings of the transmitting and the receiving antennas). We start our explanation with transmission power. We know as the power increase the numbers of the nodes inside the coverage area increase as well, consequently node degree also increase and connectivity improve. Due to physical constraints nodes are primarily powered by a weak battery. Since consequently energy is the limiting factor for network lifetime, great efforts have been made to reduce node power consumption and thus extend network lifetime. Hence as we increase the power transmission life time of the networks will reduce. Uncontrollable factors; in wireless ad-hoc networks communication between nodes takes place over radio channels. As long as all nodes use the same frequency band for communication, any node-to-node transmission will add to the level of interference experienced by other users. We know as interference increases that will reduce desired power consequently reduce the connectivity. However it is further assumed that average received power varies from location to location on the same distance in an apparently random manner due to signal fluctuation caused by irregularities in the surroundings of the receiving and transmitting antennas. Power fluctuations of radio signals reduce the amount of correlation between links, causing the network to behave like a random graph with uncorrelated links. Radio signal power variations increase the probability of long links while reduce the probability of short link, which may be enhances the probability of connectivity for the entire network.

Power control has been studies in various paper and effect of increase power transmission on the system performance (see e.g. [1]). Effect of interference on the connectivity has been studies in [2]. Effect of obstructions and irregularities in the surroundings of the transmitting and the receiving antennas (random shadowing effect) has been studies in [3].In [4] it has taking the effect of random shadowing such that connecting with farthest nodes is possible while he does not explain how is not possible to get connection with nearest nodes(nodes inside the coverage area). In this paper we have model the effect of interference on the connectivity, as undesired power increase the desired power decrease that will cause signal to interferences ratio (SIR) threshold (sensitivity) increase as well that is called (margin). Sensitivity is minimum receiving power to maintain the communication. For example, if receiver sensitivity without interference equal to (-85dB) then after interference is equal to (-65dB) so, power required to maintain the communication is more. Smart antennas are directional antennas that are transmitting in practical direction. Smart antennas transmitting adaptively in direction of desired user and null in direction of undesired user consequently increase spatial reuse and reduce interference and improve the connectivity.

In section III molding ad hoc networks with geometric random graph honey grid model.

In section IV we shall explain the effect of the random effect shadowing on the connectivity due to irregularities and obstacles surrounding transmitting and antennas receiving.

In section IIV we shall MAC layer in ad hoc networks and smart antennas.

In section V we shall model the signal to interference ratio (SIR) and matching the link probability with (SIR) to show how the interference effect on the link probability.

In section VI we shall explain the how the improve the connectivity over smart antennas, VII we simulate paper result then we summaries our result with in section VIII.

II. AD HOC MODELING

In this section we describe our model for a multi-hop ad-hoc network. We will discuss in this section most important parameters relating to ad hoc networks.

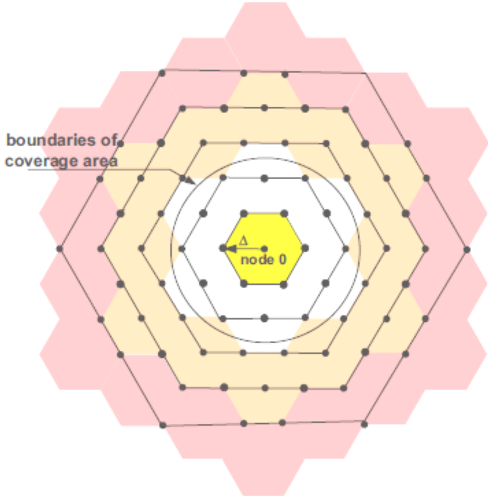

Figure (1) Honey Grid model to descript the parameters

The configuration that has been chosen is lattice hexagonal [5]. In this model, that we for obvious reasons will call the honey-grid model. Hexagonal geometry allows us:
(1) Easy to construct mathematical model.
(2)Largest coverage area from rectangular.
(3) Positions of nodes on the lattice overlap perfectly with the position of interfering nodes in the maximum interference.
Therefore, the honey-grid model is most suitable for studying interference effects under *worst case* conditions. From the view point of the center node in a honey-grid lattice, as illustrated in Figure 2, other nodes are positioned on co-centered hexagons:

Table 3.1 model parameters

Para.	Description
K	Co-centered hexagonal rings
Δ	Radius of hexagonal ring, contain 6 nodes
N	Number of the nodes around center node
deg	Node degree (No. of nodes inside coverage area) of the center node.
a	Number of rings inside the coverage area.
j	Seq. number of ring out of center node range
l	Seq. number of ring within center node range

Now we drive the relation between parameters in table (3.1):

K $=\left\lceil \sqrt{0.25+(N-1)/3}+0.5 \right\rceil$,

N $=1+\sum_{j=1}^{k} 6j = 1+3k(k+1)$ (1)

The degree of a node that is not at the borders of the service area is:

deg $=\sum_{l=1}^{a} 6l = 3a(a+1)$ (2)

If *a* number of rings inside coverage area of node0, the number of co-centered relay rings outside coverage area of node0 is $\lfloor k/a \rfloor$. The number of relay nodes (source node included) is then:

Nr $=1+\sum_{j=1}^{\lfloor k/a \rfloor} 6j = 1+3\lfloor k/a \rfloor (\lfloor k/a \rfloor + 1)$ (3)

In [] the mean hopcount in the entire network for the case that $a = 1$ and $a \neq 1$ respectively is found directly:

$E[h]_{a=1} = 0.53\sqrt{N}$ (4)

$E[h]_{a>1}=0.53\sqrt{Nr}+2(1-\frac{Nr}{N})$ (5)

The amount of interference in an ad-hoc network is directly related to the traffic produced per node (how much the nodes are active). As the amount of the traffics increase the amount of interference increase as well [6].This traffic consists of the node's own traffic that is generated by the host connected to the mobile node λ (including routing overhead) and the traffic that the node relays for other nodes λ (E[h] − 1). Where (E[h] − 1) average relay nodes between source and destination. The average total traffic per node:

$\Lambda= \lambda+ \lambda\ (E(h)-1),$

$=\lambda E(h)$ (6)

q, the probability of transmission per node per time-slot.

$q =1- e^{(-\lambda E(h))}$ (7)

From formula above, that probability of the transmission increase as the either the own traffic's increase or the average expected of the hop count increase, consequently increase the amount of interference.

III. RANDOM SHADOWING EFFECT

We know as the signal travel over predefine distance the receive signal strength will attenuate. This model is large scale fading:

$s_{ar}(d) = vg_{TR}(\frac{d}{do})^{-\alpha}$ (8)

Where $\mathbf{s_{ar}}$ is *average* received signal, d: T-R separation, d_o: reference separation, g_{TR}: (T&R antennas gain, *v:* power transmitting and wave length and α: is path loss exponent.

Formula (3) does not consider that surrounding environment clutter may vastly different at different location having same T-R separation [6]. This leads to measured signal which are vastly different than the *average value* predicted by formula (3).

$10\log_{10}s_r(d) = 10\log_{10}s_{ar}(d)+x\sigma$

We normalized above formula by $\gamma = v\ (\frac{D}{do})^{-\alpha}$,to obtain, where D radius of circular coverage area and γ is desired receive signal threshold:

$10\log_{10}\bar{S}_r(d) = 10g_{TR}P_g\log_{10}S_{ar}(\bar{d})^{-\alpha} + x\sigma$ (9)

Where$\bar{S}_r(d)$: received signal level that has log-normal distribution characteristics with mean $10\log_{10}g_{TR}S_{ar}(\bar{d})^{-\alpha}$and variance $x\sigma$.the log-normal distribution describes the random shadowing effects, which occur over a large number of measurement location which have the same T-R separation. So, we can conclude that we will get pure disk of transmission range that is because of random shadowing effect. $P_g$is the processing gain that we shall explain it in section VI.

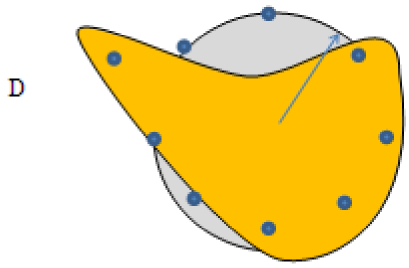

Figure (2) effect of random shadowing on transmission dimensions.

So, some of the nodes inside the coverage area shall not get connection while other node outside the coverage area it will get connection. Now to determine link probability and it is effect on connectivity. In this paper we will measure the connectivity as function of node degree, when the node degree increase connectivity improves as well and when the node degree reduces connectivity reduces as well.

The link probability that received signal level will be below 1 or (0 dB) can be calculated by Cumulative Density Function (CDF) as:

$Pr\ (Sr < 0)= Q\ (\frac{10gTR\ \log(\bar{d})-\alpha-0dB}{\sigma}),$

$= 0.5\ (1+ \mathrm{erf}\ (\frac{-10gTR\ \log(\bar{d})}{\sqrt{2}\sigma/\alpha}))$(10)

The link probability that received signal level will be exceeding 1 or (0 dB) as:

$Pr\ (Sr > 0) = Q\ (\frac{0dB-10gTR\ \log(\bar{d})-\alpha}{\sigma}),$

$$= 0.5\ (1-\mathrm{erf}\ (\frac{10gTR\ \log(\bar{d})}{\sqrt{2}\sigma/\alpha}))\ (11)$$

In fact, if we are not consider the effect interference and g_{TR}=1. Then we can determine the actual node degree by multiplying the node degree by formula (5) and (6):

$deg_{actual}=deg\ .[Pr\ (Sr < 0) + Pr\ (Sr > 0)]$(12)

IV. MAC LAYER WITH SMART ANTENNAS

It is well known smart antennas systems, that is directed the transmission in direction of desired nodes and null in direction of undesired nodes. We should not confused with directional antennas that can directed the beam of transmission without steering of beam and omnidirectional antennas it is transmit in circular direction. Smarts antennas are divide into two types:

(1) Switch-beam antennas.
(2) Adaptive beam antennas.

In this paper we shall use adaptive beam antennas. In [7] a good introduction to smart antennas. In fact, smart antennas it has high advantage for radio packet networks because radio packet network use contention bases in Medium Access Network (MAC layer) and as we know that all nodes provided with transvers, As long as all nodes use the same frequency band for communication, any node-to-node transmission will add to the level of interference experienced by other users. So, we can conclude that using smart antennas is increase the spatial reuse and reduces from the nodes that using same frequency band.

Medium Access Control (MAC layer), it is sublayer of second layer of OSI model. MAC layer is use to restrict number of simultaneous transmission per coverage area (we should not confuse with service area that is mean complete area over which nodes distributed). MAC protocols divide into (a) contention based (FDMA, CDMA, etc.), (b) contention free (ALOHA, CSMA, CSMA/CA, etc.), with packet radio network usually use contention base. there so many MAC protocols contention base has been proposed with smart antennas and explain it issue when they are using with smart antennas for example [8]. In this paper we shall use directional CSMA/CA; carrier sense multiple access/ collision avoidance is restrict the nodes from transmission (inside coverage area of center node) when the center node on Honey Grid model communicate with other nodes. So, only outside the coverage area of the center node shall transmit.

V. MODELING (SIR) ON HONEY GRID MODEL

Interference typically either due to hostile environment (jamming) or friendly, in our article we consider only friendly interference. Interference is major limiting factor in performance of the wireless networks. In ad hoc network interference of a center nodefor Honey Grid Model is defined as the number of nodes in the graph that cover center node transmission range with their transmission disks when they communicate with their farthest neighbor in the graph [8]. In fact amount of interference depend completely on type of MAC protocols that has been used. As we have explain in previous section that only interference will come from the nodes on the rings outside the coverage area at distance (a+1) on figure 1and each rings contain *6j* nodes, expected value of Interference from inside coverage area of center node E(I):

[1] Number of interferer nodes = 6*j*.

[2] Distance to first interferer ring = $j\Delta(a+1)$.

[3] Interfere power coming from each interfere node using random shadowing effect:
$g_{TR}\ v(\frac{j\Delta(a+1)}{do})^{-\alpha}$.

[4] Interferer power coming from all interferer nodes on the ring:
$6jqvg_{TR}(\frac{j\Delta(a+1)}{do})^{-\alpha}$

[5] Number of interferer rings seen from center Node = $\lfloor k/a+1 \rfloor$.

[6] Total interferer power from all interferer rings:
$\sum_{j=1}^{\lfloor k/a+1 \rfloor} gTR\ 6jqv(\frac{j\Delta(a+1)}{do})^{-\alpha}$.

We *normalized the interference po*wer to $\gamma = v\ (\frac{a\Delta}{do})^{-\alpha}$, then expected interference power:

$E(I_{rse})= 6q\ g_{TR}j(1+a^{-1}))^{-\alpha}\sum_{j=1}^{\lfloor k/a+1 \rfloor} j-\propto +1$

(13)

Where $E(I_{rse})$ is interference with random shadowing effect, q is the probability of transmission that is related to traffic per nodes (see e.g. [5]) and in this thesis we consider it constant and equal to =0.7.

To calculate expected value of desired power base on honey grid model and taking into account random shadowing effect, the total number of nodes inside the coverage area of center node according to formula (2) is 3a (a + 1). The lth ring ($j \leq a$) contains $6l$ nodes at distance Δl to center node. The probability that the wanted signal is originated from distance Δl is then = 6j/3a (a+1). Using formula (2) and taking into account all possible positions for the wanted signal transmitter, the expected value for desired power S in [5] is:

$$E(S_{rse}) = \frac{\sum_{l=1}^{a} 6l}{3a(a+1)}[g_{TR} v(\frac{\Delta l}{do})^{-\alpha}],$$

by dividing formula above by $\gamma = v\,(\frac{a\Delta}{do})^{-\alpha}$:

$$E(S_{rse}) = \frac{2\ gTR}{a-\alpha+1(a+1)} \sum_{l=1}^{a} \quad l^{-\alpha+1}$$

(14)

Now we easily divide the desired signal power from formula (14) on undesired signal power from formula (13) to obtain signal to interference ratio with effect of random shadowing:

$$E(S/I) = \frac{Pg \frac{2\ gTR}{a-\alpha+1(a+1)} \sum_{l=1}^{a} \quad l^{-\alpha+1}}{6q\ gTR\ j(1+a-1)) - \alpha \sum_{j=1}^{\lfloor k/a+1 \rfloor} j^{-\alpha+1}}$$

$$E(S/I) = \frac{Pg \sum_{l=1}^{a} \quad l^{-\alpha+1}}{3a(a+1)-\alpha+1(1-e(-\lambda E(h))) \sum_{j=1}^{\lfloor k/a+1 \rfloor} j^{-\alpha+1}}$$

(15)

Where Pg = 10.4 is processing gain is realized with modulating each information bit by 11 bit using Barker codes. Where above formula represent signal to interference ratio with effect of random shadowing.

VI. CONNECTIVITY OVER SMART ANTENNAS

Very simple definition for networking is set of elements (nodes) and set of edges (link) that is interconnecting between them, so when the nodes are exist and linking (connectivity) is weak or not exist then network also weak and not exist. Connectivity is ability on receiving the signal under channel impairment and network topology. When we talk about wireless channel impairment that is mean large and small scale fading and random shadowing effect, when we talk about network topology that is mean how the nodes distributed over practical area. In fact, network topology in ad hoc networks approach to randomness that is dynamically change and also distribution of the node over service area depends on service area itself whether it(e.g. mall, airport, battlefield or hospital).

In fact, as we will show in the next section how the random shadowing effect is has been approximately eliminated and we got circular transmission instead of random transmissions range.

Now we need to match the minimum amount of signal to interference ratio with link probability. In fact, in this matching we required to determine the (SIR) threshold that required maintaining the communication, but in ad hoc network this is difficult to determine $SIR_{threshold}$ because of dynamic topology of ad hoc networks. To evaluate link probability under interference condition we match the signal to interference ratio to cumulative density function (CDF).Where the signal to interference ratio it has normal distribution with variance 1or 0 dB (because of using smart antennas and spread spectrum tech.) and mean is E(S/I). Signal to interference ratio should have value more than β to maintain the connection. Link probabilities that signal to interference ratio exceed threshold level is:

$Pr\ (SIR > \beta) = Q\ (\frac{\beta - E(SIR)}{\sqrt{2}}),$

$Pr\ (SIR > \beta) = 0.5\ (1\text{-}erf\ (\frac{\beta - E(SIR)}{\sqrt{2}}))$(17)

Where above formula represent probability of link under interference condition, number of the hops, number of the nodes and node degree.

VII. SIMULATION AND RESULT

In this section we will show how the connectivity is affected by network topology (nodes distribution over practical area)

In fact in ad hoc wireless network is completely different from the other wireless network that is because there is no base station (infrastructureless) to control the transmission and nodes mobility is possible, so, may the nodes dense in practical area and other location it is spars. Ad hoc network we can say approach to impossible to predict there nodes distribution and also we can't predict statically behavior of the node in the service area**.**

Table (1) simulation parameters

Parameters	Symbols	Values
Processing gain	Pg	10.4 dB
Pathloss exp.	$\alpha^{(1)}$	2.4 and 3
Smart antennas gain	$g_{TR}^{(2)}$	6.5dBi
Random shad. effect	$\sigma/\alpha=y$	1~4
Own traffic	$\lambda^{(3)}$	0.025.rs
$SIR_{Threshold}$	SIR	11dB

(1) Where pathloss exponent represent how much fast signal will decay over travelling practicable distance between transmitter and receiver. Pathloss exponent in the wireless depend on the service area environment (either LOS or NLOS) [3]. (2) In fact, we have chosen omnidirectional antennas gain equal to 1while for smart antennas we have chosen it equal to 6.5dBi from company that is product different types of smart antennas, name of this product (Maxbeam75 Part B24755C000) for IEEEb/g with dimensions (90, 90, 23) ~ length, width and height respectively [9].

(3) Where rs: data rate that for IEEEb is 1, 2, 5.5 and 11Mbps, in this paper we talk about 2Mbps [10].

The questions that will arsis, which parameters now are effected through using smart antennas**??**

In fact, we can see that effect of smart antennas gain has been canceled out from formula (15), only spatial reuse will takeplace over this formula that number of the interferer nodes reduces to half (in fact that depend on the beam width).

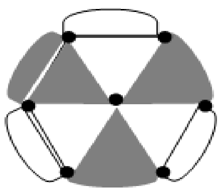

Figure (3) using smart antennas over hexagonal configuration that shown sectors.

In fact, in this thesis we chosen the beam can cover only one sector that is mean only two nodes fall inside each beam. So, number of interferer nodes coming from outside coverage area is approximately reduce to half from using omnidirectional antennas.

Interferer node over smart antennas = ½ Interferer node over Omni. We can easily form the formula of the interference by dividing the interference formula by 2 that is meaning multiplying the SIR by 2 then:

$E\,(SIR)_{smart\ antennas}=2\ E(SIR)_{omnidirectional}$ (18)

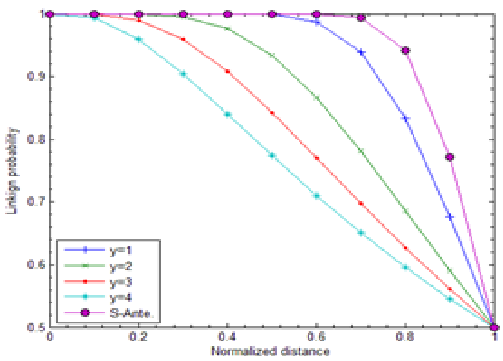

Figure (4) link probabilty with neighbors and effect of random shadowing

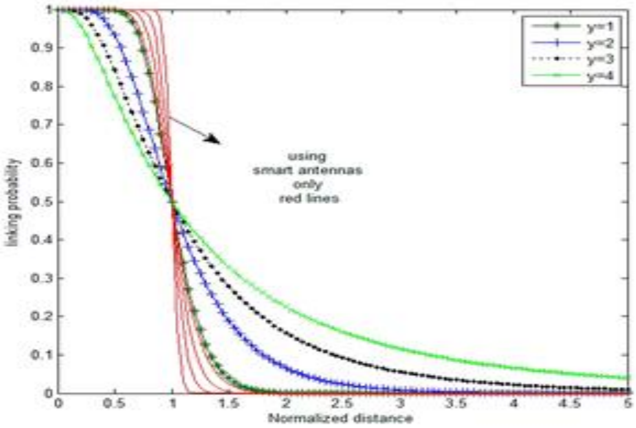

Figure (5) link probabilty with effect of random shadowing using samrt antennas

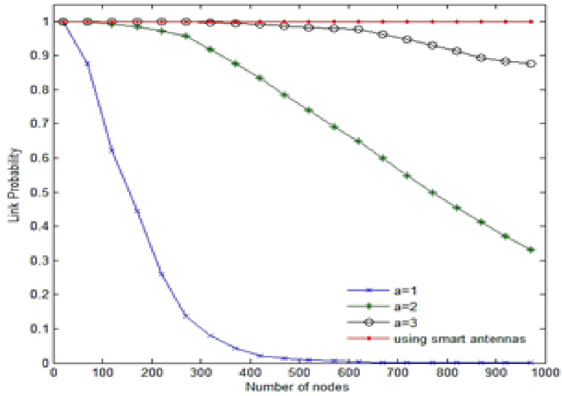

Figure (6) link probabilty with effect of interference

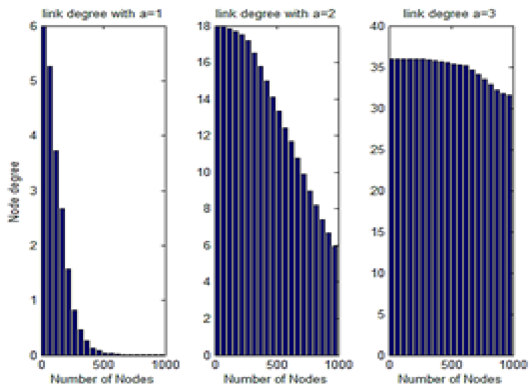

Figure (7) node degree with effect of interference

VIII. SUMMERY

In this section we are going to summries our paper just for center node as :

(1) We have match the effect of the interference to link probability and we have shown as number of the nodes increase interfrence increase as well and link probability will reduce as it shown in figure (6) and also number of the nodes that inside the coverage area will reduces as well as in figure (7).

(2) We have explain as (a) increase (node degree) connectivity improve as well that because (I) increase number of the nodes inside the coverage area that is mean increase the probability of the connectinwith fartest nodes (II) reduces the interference that si because increase the number of the node inside the prohibted area as we using MAC protocols – CSMA/CA.

(3) How the random shadowing can be harmfull if it is increase transmission range without increasing the power**?**First;Random shadowing increase the prower in some direction and reduces it in other direction as in figure (2) that will unintentionally disturbing other nodes and causing interferences Second; reduction in power in some direction will reduce thenieghbores correlation (comunication with some nearest nieghbores imposible).

(4) After using smart antennas we have**:**
(I) Minimized or eliminate the effect of random shadowing by adjacenting the power in direction of desired nodes as we have shown in figure (2 & 3).
(II) Reduce the interfreence consequentlly improve receiver sensitivty and improve the conectivity.(III) Increase spatial reuse that allow for many nodes to share subchannel an the practiclar area and that improve the connectivity as shown in the figure (6).
(6) Improving the gain in the direction of desired nodes (in fact, gain here is not amplifying the signal) here gain is like directed the megaphone in direction of desired lestiner. Even in severe channel enviroment still we can decode the data.
In this paper it can show we can improve the connectivity in ad hoc wireless network by:
(1) Using smart antenaas to increase spaitial reuse.
(2) Using such type of MAC protocols that is not increase the prohibit transmission area (e.g. CSMA/CA with resevation) or using such type of MAC protocols that allow to all to transmite whenever they have data (e.g. ALOHA protocols).

REFERENCES

[1]. Tomas Johansso et al. ‘’ reducing the interference in MANET’’ Copyright 2005 ACM, cologne, Germany.
[2]. Olivier Dousse et al. ‘’ Impact of interference on Connectivity in ad hoc networks’’ IEEE INFOCOM 2003, from page No.3.
[3]. T.S. Rappaport ‘’ wireless communication: principle and practice’’, © 2002 by Prentice-Hall.
[4]. R. Hakmet et al. ‘’ connectivity in wireless ad hoc networks with log normal radio model’’ ©2006 springer science + business media.
[5]. R. Hakmet et al.’’ Interference in wireless ad hoc network and it effect on the capacity’’ wireless network journal.vol10,pp,389-399, july 2004.
[6]. R. Hekmat ‘’ Ad networks: fundamentals properties and networks topology’’ ©2006 by springer. From chapter 9.
[7]. www.iec.org, the international engineering consortium’ ’introduction to smart antennas ‘’.
[8]. Subir Kumar et al. ‘’ ad hoc mobile wireless networks: principle, protocols, application’’ © 2006 by Taylor and Francies group. Chapter 2, from pages No. 37-40.
[9]. www.airgain.com.
[10]. IEEE 802.11 WIRELESS LOCAL AREA NETWORKS **-** The Working Group for WLAN Standards, “ANSI/IEEE Std 802.11, part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications,” tech. rep., IEEE 802 LAN/MAN Standards Committee, 1999.