Outage Capacity of MIMO Mobile Ad Hoc Network

Soma Manna[1], Arun Kumar Mondal[2]

[1]Assistant Professor, Dept. of ECE, GNIT, Sodepur, Kolkata - 700114
[2] Professor, Dept. of ECE, GNIT, Sodepur, Kolkata - 700114

Abstract - *With the fast progress of wireless communication and its growing application in different areas, it is important to develop technologies to enable more efficient secure communication. Mobile Ad hoc, an infrastructure less communication, is an emerging area for anytime and anywhere communication. It is very challenging to coordinate node transmission in mobile ad hoc network for secure communication. MIMO holds the significant potential to maximize the resource uses. In this paper, the outage capacity analysis is made based on a model MIMO Ad Hoc network. We assume that each link occupies a geometric area that characterizes the amount of spatial resources occupied by a link. The amount of spatial resource of each link is measured with the interference effects that impose on other links. Here we also investigated the outage capacity considering the noise effect for the above MIMO Ad Hoc Network working in the noisy environment. The probability of the active link with interference effect is calculated first and then the outage throughput capacity is derived. Finally simulated results helps to find out number of active links and data rates within an area.*

Key Words: **Mobile Ad Hoc Network**, MIMO, **link layer capacity, co-channel interference.**

1. INTRODUCTION

Wireless Ad hoc networks are integral part of the new generation information exchanges infrastructure. These are basically peer-to-peer network of hosts that have no central administration or fixed communication infrastructure nor any base station[1,2]. The MIMO based Mobile Ad hoc network takes the advantages of meshed topology of the ad hoc network to maximize the data rate supporting different transmission priorities, reducing transmission delay and ensuring fair transmission among nodes. This integrated network improves the data rates and it uses IEEE 802.11n standard providing higher spectral efficiency such as high throughput to improve system performance than that of ordinary wireless systems. To achieve the performance analysis of the MIMO communication system, the channel performance like channel characteristic, mutual information are the basic parameters to represent the mathematical modeling of channel capacity and mutual information of the MIMO ad hoc network. Wireless data rate for MIMO systems with multiple numbers of antennas at both transmitter and receiver follow the following fundamental theoretical limit:

$$C = M * B * \log(1 + SNR) \qquad (1)$$

To achieve the performance analysis of the channel we have modeled the ad hoc network, mathematical representation of channel parameters (channel capacity, mutual information) with different channel state information. The availability of multiple antennas at the transmitter and receiver end improve the data rates by a factor of M times where $M = \min\{N_T, N_R\}; N_T$ and N_R are the number of transmitting and receiving antennas[3,4]. By using multiple antennas MIMO Ad hoc network increases channel capacity [5,6]. We can see the nodes in transmitter and receiver from NxM MIMO channel. We invoke Telatar' landmark MIMO capacity theorem.

$$C_{N,M} = E_\lambda\{R\log_2\left(1 + \tfrac{\lambda}{N}\rho\right)\} \qquad (2)$$

Here R=min(M,N);ρ=S/N represent the single to noise ratio.**λ** is the unordered eigenvalue of associated Wishart matrix W.

2. SYSTEM MODEL AND CHANNEL CAPACITY

The fig1shows the system model of mobile Ad Hoc Networks where mathematical analysis of this model is done with some assumptions. Here the MIMO nodes are uniformly distributed with in the network and each link between the transmitting and receiving antenna has same statistical characteristics. Here using mobile links all transmitting nodes are connected to the receiving nodes. Let us consider that the node M is the receiving node where the other nodes are transmitting nodes and the link H_R is receiving the signal and other link are transmitting signal and resulting the co-channel interference on link H_R. The data received by the receiving link is the superposition of the desired signal interference and noise which is given as follows.

$$X = \sqrt{\alpha_0 \rho_0} H_O x_o + \sum_{k=1}^{K} \sqrt{\alpha_k \rho_k} H_k x_k + n_0 \quad (3)$$

Here H_k is an m x m channel matrix which is representing the channel fading from the transmitter of the *k*th link to the receiver of tagged link.

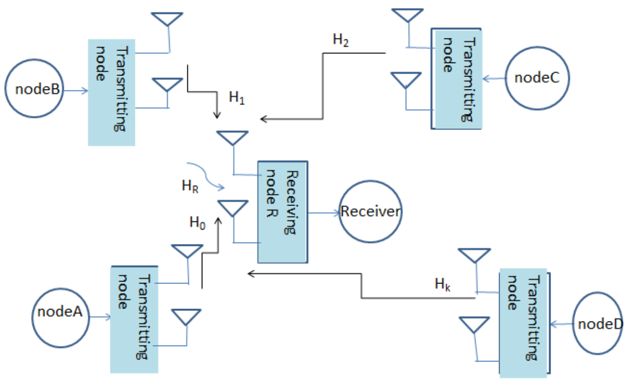

Fig.1 System Model for MIMO Ad Hoc communication

3. OUTAGE CAPACITY WITH SNR

Ad Hoc network works in an interference limited environment. Here an active link will transmit only one data stream. The throughput capacity of the link is the total data rate delivered through all single hop links[8]. Here the active link transmits at data rate S and successful transmission will be possible and then SNR will be maximize when SNR of the receiver side is higher than the threshold receiver which is the function of data rate R. Consider the data rate R and SNR value are given by

$$R = \log_2(1 + \frac{S}{N}) \quad (4)$$

The message which has SNR value less than the threshold. Hence the number of failure of signal per message is

$$P_{out} = P_{rop}(\frac{S}{N} < \frac{S}{N_{th}}) \quad (5)$$

The Poisson distribution is used to calculate the probability of active links in the network which is given by

$$P = \frac{e^{-\mu}\mu^{(x+1)}}{(x+1)!} \quad (6)$$

.

Now the active link transmits at data rate S, then successful transmission will be possible. The outage throughput capacity is

$$C = \sum_{x=0}^{\infty}(x+1)(1-P_{out})S\frac{e^{-\mu}\mu^{(x+1)}}{(x+1)!} \quad (7)$$

Here $\mu = \rho_0 \pi \frac{D^2}{4}$

Where μ is the mean or average number of active links , D is the diameter of the network and ρ_0 is the number of links per unit area.

4. SIMULATION AND NUMERICAL RESULTS

We have simulated the network to find the outage capacity of MIMO channel. From all the interfering nodes we have assumed that CSI at each receiving nodes are known that is the receiver knows the channel matrix h_k. The fig 2 shows the variation of the capacity with the active links when number of antenna at transmitter and receiver increased. The variation of cumulative probability density which is throughput capacity for the link layer with SNR is shown in fig3 for 3 interfering nodes. The fig4 shows the cumulative distribution function verses signal to noise ratio. Up to a certain level of SNR the link layer capacity is low. But after 30 db the capacity increases and reaches to a certain value. In this simulation the channel monitory range is taken as three units. The maximum throughput depends on the channel monitoring range.

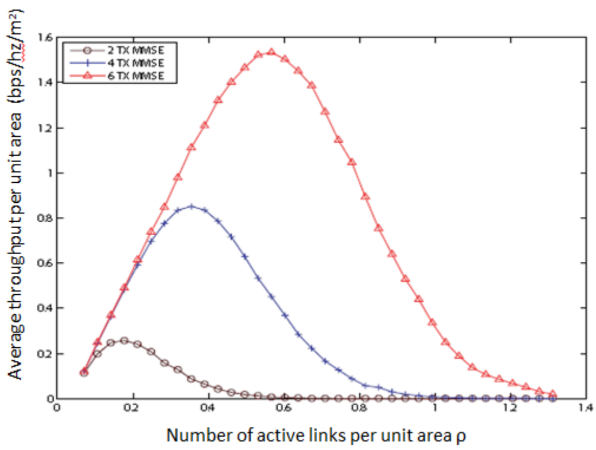

Fig .2 Numbers of links per unit area

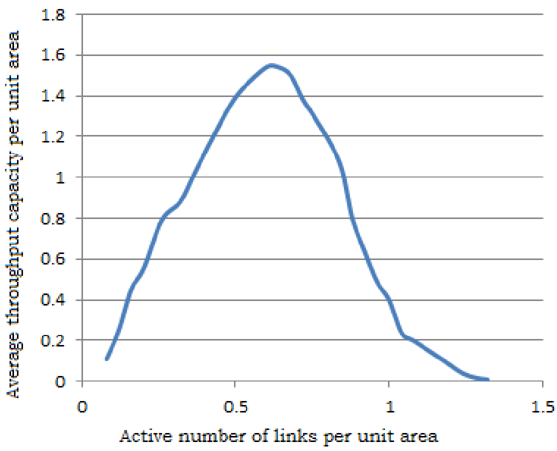

Fig.3 Throughput capacity vs link layer outage capacity

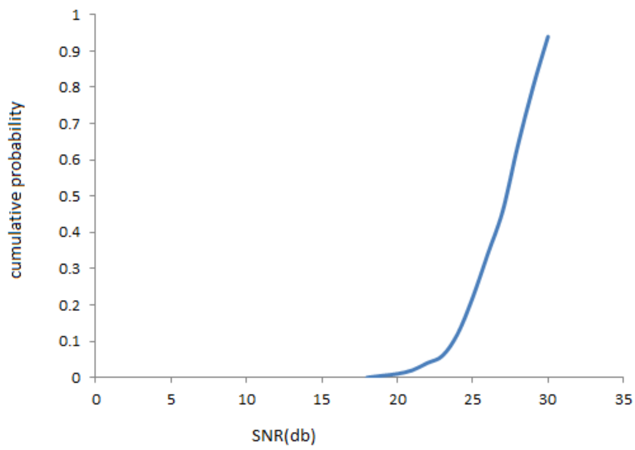

Fig.4 CDF vs SNR

In the channel estimation range the channel capacity is higher than the low range coverage. Out of the restricted zone the interference is considered as noise. When we restrict the channel-monitoring range, the maximum throughput capacity is reduced from its original value.

3. CONCLUSIONS

In this paper we simulated the Ad hoc network with multiple antennas to investigate the outage capacity. In this paper the throughput capacity and outage capacity are calculated and simulated to make the comparison. The effect of active number of links on the outage capacity for different monitoring range is considered. In future we used the concept of allocation of degree of freedoms to solve the MAC layer interference.

REFERENCES

[1] Iwata et al "Scalable Routing Strategies for Ad hoc Wireless Network"IEEE Journal on Selected Area in Communication ,Special Issues on Ad-hoc Networks Aug,1999 pp1369-1379.

[2] S.R.Das,R.Castaeda,J.Yan and R.Sengupta, "Comparative Performance Evaluation of Routing Protocol for Mobile Ad hoc Networks"in Proceeding of 7th International Conference on Computer Communication and Networks(IC3N),,october 1998 pp 153-161.

[3] Win M.Z., Winters J.H., Analysis of hybrid selection/maximal-ratio combing of diversity branches with unequal SNR in Rayleigh fading, IEEE Vehicular Technology Conference Proceedings; 215-220, 1999.

[4] Telatar I.E., Capacity of multi antenna Gaussian channels,AT&T Bell Laboratories, Tech. Memo. 1995.

[5] Win M. Z., Beaulieu N. C., Shepp L. A., Logan B. F., Winters J. H., On the SNR penalty of MPSK with hybrid selection/maximal ratio combining over IID Rayleigh fading channels, IEEE Transactions on Communications; No. 51(6) : 1012-1023, 2003.

[6] Murch R.D., Letaief K.B., Antenna systems for broadband wireless access, IEEE Communications Magazine; No. 40(4): 76-83, 2002.