Outage Analysis of Cooperation over Wireless Network

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ABSTRACT

In this paper, we analyze the performance of cooperative communication system for independent and flat Nakagami-m fading channel parameters by using amplify and forward cooperative protocol. We have estimated the outage probability, channel capacity and ergodic capacity of the system. We further simulate the equations of these parameters by plotting them for verification.

INDEX TERMS: Diversity technique; cooperative communication; cooperative communication protocols; Nakagami-m fading; ergodic capacity; channel capacity; outage probability.

I. INTRODUCTION

An efficient technique of cooperation among the users having single antenna is required way to achieve the transmit diversity in such a system which is unable to support multiple antennas either at the transmitter/receiver side or on both sides due to size, cost, power, complexity of hardware [1], [2]. So, the virtual array of antennas is formed by cooperation in which the source broadcasts the multiple copies of the signal toward the relays and destination with same power. Relays also forward the received copies of the same signal toward the destination as shown in fig. 1. At the destination, we observe the resultant information after maximum ratio combining (MRC) of all the multiple received copies of signal [3], [4], [5].

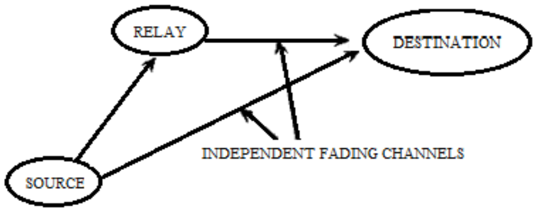

Fig.1 Cooperative communication

There are different types of cooperative communication protocols [6], [7], [8]-:
1. Amplify and forward,
2. Detect and forward, and
3. Coded cooperation.
4.

In this paper, we use amplify and forward cooperative protocol strategy in which relays amplify the received signals and retransmit them toward the destination as shown in figure 2.

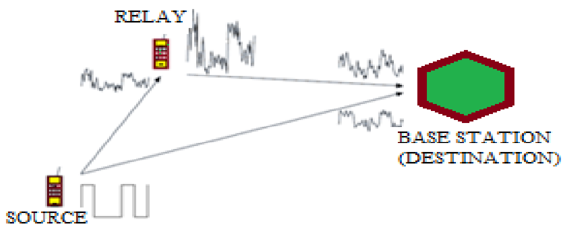

Fig. 2. Amplify and Forward

Here, we have considered Nakagami-m fading channels to be independent and flat with parameter m.

II. SYSTEM MODEL

We have considered a system, which has a source (S), multiple relays i.e. R_1, R_2,R_3, …Rn and the destination (D) as shown in fig. 3.

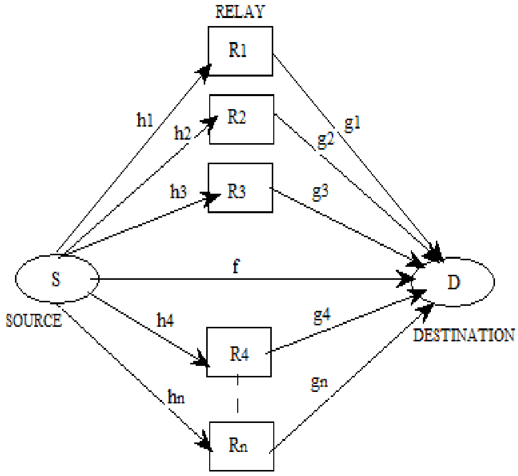

Fig.3. Cooperative communication network

The channel coefficient between source and destination is flat Nakagami-m fading coefficient denoted by f. The channel coefficient between source and ith relay is hi and between ith relay and destination is gi. These are the flat and independent Nakagami-m fading channels.

Here, i= 1, 2, 3, 4,…….,n. The signals are transmitted in two phases.
In first phase, source transmits the signal's one copy directly to the destination and multiple copies of the same signal toward the relays with the same power (i.e. Ps). In second phase, all the relays Ri, where i= 1, 2, 3, 4,…….,n, transmit the amplified versions of received signal copies toward the destination with power PRi. Where i= 1, 2, 3, 4,…….,n for n number of relays. Hence the total transmitted power toward the destination is as

$$P_T = Ps + \sum_{i=1}^{n} P_{R_i} \qquad (1)$$

We also know that the ratio of transmitted power from source to destination to the total transmitted power toward the destination is called the power distribution ratio i.e.

$$\alpha = \frac{P_S}{P_T} \qquad (2)$$

α lies between 0 and 1. The power transmitted by each relay is equal to $\{(1-\alpha)/n\}P_T$.

Now, the instantaneous received power over source to destination link is expressed as

$$P_f = |f|^2 \alpha P_T \qquad (3)$$

Instantaneous received power over source to ith relay link is as:

$$P_{h_i} = |h_i|^2 \alpha P_T \quad (4)$$

And the instantaneous received power over ith relay to destination link is expressed as

$$P_{g_i} = |g_i|^2 \frac{(1-\alpha)}{n} P_T \qquad (5)$$

By using maximum ratio combining (MRC), different independently faded versions are combined at the destination and total received power at the destination is as

$$P_r = P_f + \sum_{i=1}^{n} \frac{P_{h_i} P_{g_i}}{1 + P_{h_i} + P_{g_i}} \qquad (6)$$

The maximum rate of transmission of information per second is the channel capacity per second which analyzes the performance of the system. If the received power is so high due to which noise power is negligible, then channel capacity by Shannon's formula is as:

$$\overline{C}(P_r) = \log_{10}(1 + P_r) \qquad (7)$$

After putting the value of P_r from equation (6) in equation (7), we get

$$\overline{C}(P_r) = \log_{10}\left(1 + P_f + \sum_{i=1}^{n}\frac{P_{h_i}P_{g_i}}{1+P_{h_i}+P_{g_i}}\right) \qquad (8)$$

For Nakagami-m distribution, Gamma distributed probability density function (PDF) is expressed as

$$P(P_r) = \frac{1}{\Gamma(m)}\left(\frac{m}{P_{avg}}\right)^{m}(P_r)^{m-1}e^{\left(\frac{-mP_r}{P_{avg}}\right)} \qquad (9)$$

After putting the value of P_r from equation (6) in equation (9), we get PDF as:

$$P(P_r) = \frac{1}{\Gamma(m)}\left(\frac{m}{P_{avg}}\right)^{m}\left(P_f + \sum_{i=1}^{n}\frac{P_{h_i}P_{g_i}}{1+P_{h_i}+P_{g_i}}\right)^{m-1}e^{\left(\frac{-mP_r}{P_{avg}}\right)} \qquad (10)$$

Here, $\Gamma(.)$ is the gamma function, parameter m is the shape factor and P_{avg} **is the average received power over the fading and shadowing effects.**

The ergodic capacity analyzes the performance of the system which is the ensamble average of the information rate over the distribution of the elements of the channel which is denoted as

$$\overline{C}_E = \int_0^{\infty}\overline{C}(P_r)\,P(P_r)\,dP_r \qquad (11) \text{ or}$$

$$\overline{C}_E = \int_0^{\infty}\left(\frac{1}{\Gamma(m)}\left(\frac{m}{P_{avg}}\right)^{m}\left(P_f + \sum_{i=1}^{n}\frac{P_{h_i}P_{g_i}}{1+P_{h_i}+P_{g_i}}\right)^{m-1}e^{\left(\frac{-mP_r}{P_{avg}}\right)}\right)$$

$$\log_{10}\left(1 + P_f + \sum_{i=1}^{n}\frac{P_{h_i}P_{g_i}}{1+P_{h_i}+P_{g_i}}\right)dP_r \qquad (12)$$

III. PERFORMANCE ANALYSIS

To analyse the performance of cooperative communication wireless system model, the outage probability of the system also plays an important role in our study.

(a) Outage probability

To analyze the outage behaviour of cooperative communication wireless network, we select a threshold power level (P_n) in such a manner that if the total received power is below this level, then the system is said to be in outage for this particular channel and the probability of the system in outage condition is called the outage probability [6],

$$P_{out} = P_{rb}\{P_r < P_n\} = \int_0^{P_n} P(P_r)\,dP_r \qquad (13)$$

After putting the value of $P(P_r)$ from eq. (10) in eq.(13), we get

$$P_{out} = \int_0^{P_n}\left(\frac{1}{\Gamma(m)}\left(\frac{m}{P_{avg}}\right)^{m}\left(P_f + \sum_{i=1}^{n}\frac{P_{h_i}P_{g_i}}{1+P_{h_i}+P_{g_i}}\right)^{m-1}e^{\left(\frac{-mP_r}{P_{avg}}\right)}\right)dP_r \qquad (14)$$

Where, P_n is selected threshold power level , m is Nakagami-m parameter, P_{avg} is the average received power over the fading and shadowing effects and P_r is total power received at the destination as mentioned earlier in eq.(6).

IV. SIMULATION RESULTS

In this section, we have shown our results of outage probability, channel capacity and ergodic capacity and total received power versus total average power at the destination. We get the simulated results using MATLAB software.

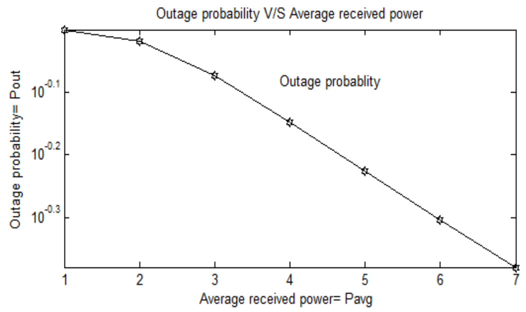

Fig. 4. Outage probability V/S average received power at destination

Fig.4. shows the outage performance at different values of total average power. This curve shows that the outage probability reduces fast as the value of total average power increases causing improvement in the performance of the system. For a particular value of total average power at the destination node, the channel capacity and ergodic capacity increase as shown in fig.5 and fig.6 respectively.

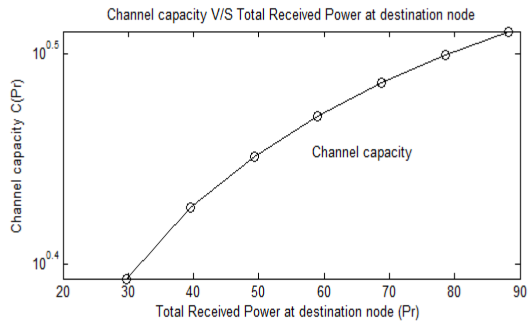

Fig.5. Channel capacity V/S average received power at destination

In this section, we have considered threshold power level P_n = 5 dB, Nakagami-m parameter (shape factor) m=2,

$P_f = P_{h_i} = P_{g_i}$ = 20 dB.

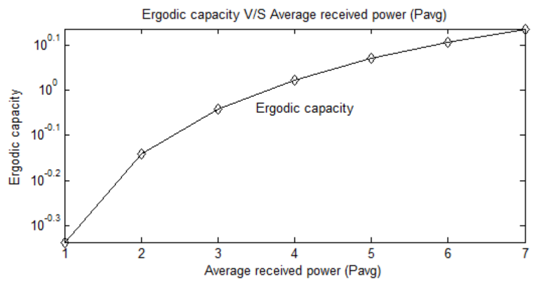

Fig. 6. Ergodic capacity V/S average power received at the destination

As the average value of received power (P_{avg}) increases, the value of probability density function of Nakagami-m fading distribution decreases resulting in the proper operation of the system due to lower outage probability that is the probability of the system to be in outage state in which state, system does not work properly.

V. CONCLUSION

From the simulation results, we can observe that system parameters such as channel capacity, ergodic capacity increase and outage probability decreases as the value of average received power increases and it shows that the system becomes more reliable and efficient.

REFERENCES

[1] A. Sendonaris, E. Erkip, and B. Aazhang, "User cooperation diversity-Part I: System description", IEEE Trans. Commun., vol. 51, No. 11, pp. 1927-1938, Nov. 2003.

[2] A. Sendonaris, E. Erkip, and B. Aazhang, "User Cooperation Diversity-Part II: Implementation aspects and performance analysis", IEEE Trans. Comm., vol. 51, no. 11, pp. 1939-1948, Nov. 2003.

[3] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, "Cooperative diversity in wireless networks efficient protocols and outage behaviour", IEEE Trans. Inf. Theory, vol. 50, no. 12, pp. 3062–3080, 2004.

[4] J. N. Laneman and G. Wornell, "Energy-efficient antenna sharing and relaying for wireless networks", in Proc. Wireless Commun. Networking Conf. 2000, vol. 1, pp. 3062–3080.

[5] J. N. Laneman and G. Wornell, "Distributed space-time coded protocols for exploiting cooperative diversity in wireless networks", in Proc. Glob. Telecomm. Conf. 2002, vol. 1, pp. 77–81.

[6] Ankur Bansal and Parul Garg, "Performance Analysis of Coded Cooperation Under Nakagami-m Fading Channels", in Proc. IEEE Int. Conf. on Comm. (ICC), Cape Town, South Africa, May 2010.

[7] J. N. Laneman, G. W. Wornell, D. N. C. Tse,"An efficient protocol for realizing cooperative diversity in wireless networks", in proc. IEEE Int. Symp. Inform. Theory, Washington, DC, pp. 294, Jun. 2001.

[8] T. E. Hunter and A. Nostratinia, "Cooperation diversity through coding", in Proc. IEEE Int. Symp. Inform. Theory, Laussane, Switzerland, pp. 220, Jun. 2002