ANALYSIS OF THROUGHPUT IMPROVEMENT IN WIRELESS LOCAL AREA NETWORK USING COOPERATIVE WIRELESS COMMUNICATION

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ABSTRACT : *The need for higher data rates is increasing at an exponential rate. Traditional wireless local area networks can provide data rate up to certain limit. Higher data rates are provided by the newer versions. Cooperative wireless communication provides data rate enhancement over traditional IEEE 802.11 WLAN standard by changing MAC layer protocols. It uses nearby nodes as relay to improve the link performance over traditional WLAN. When relay is used for data transmission the overhead increases. In this paper we have evaluated the best scenario of data rate for various conditions.*

KEY WORDS *: Cooperative wireless communication, IEEE 802.11, MAC layer, Throughput*

1. INTRODUCTION

Wireless communication is growing at a rapid rate. IEEE 802.11 (i.e. Wireless Local Area Networks) standards are gaining popularity for providing services to the nomadic users. But as the demands for higher data rate, higher reliability and lower energy consumption is increasing demand for new standards/protocol which can cater this demands increases. (P. Liu et al. 2007) But when we go for implementing new standards at that time, thousands of device which are working on elementary standards becomes useless or it will work with lesser specifications.

Cooperative wireless communication provides great solutions for this kind of scenario. With slighter modification or without any modification it can provide higher data rates, higher reliability and will consume less energy compared to IEEE 802.11 standards. (K. J. Ray Liu 2009)

Cooperative wireless communication takes advantage of broadcasting nature of wireless communication. When a node wants to communicate with other node, it will broadcast the request on wireless channel. The request will be heard by intended receiver as well as other nodes.

In normal WLAN standards the broadcasting nature is not exploited. The node who want to transmit data sends request to send (RTS). This RTS message will be heard by receiver as well as the other nodes who are in vicinity of the transmitter. These nodes refrain from transmission till the communication between transmitter and receiver node finishes. After receiving RTS the receiver node (if it is ready to receive) will send clear to send (CTS). The CTS message will be heard by all nodes which are in vicinity of the receiver node. After receiving CTS all this nodes will differ from transmission till the communication between transmitter node and receiver node completes.

In WLAN, the distance between transmitter and receiver node plays a pivotal role in deciding the data rate which can be offered to the any transmitter receiver pair. At shorter distances higher order modulation can be used. As the distance increases, to cope up with increased path loss and BER lower order modulation needs to be used, which maps to reduced data rate.

2. COOPERATIVE WIRELESS COMMUNICATION

Cooperative wireless communication utilizes broadcast nature of wireless communication and improves data rate, energy efficiency, reliability and range of communication.

When source node wants to communicate with access point in case of infrastructure based network or with destination node in case of ad hoc network, it transmits RTS. The RTS will be received by destination node as well as other nearby nodes. The destination node will receive RTS and will reply with CTS. The nearby nodes will also receive this message. On receiving RTS and CTS, those nodes will get the estimate of distance between R_{sd} (i.e. distance between source and destination), R_{sh} (i.e. distance between source and helper) and R_{hd} (i.e. distance between helper and destination) as shown in Figure 1. The offered data rate depends upon the distance between two nodes. The higher the distance the lesser the data rate. So when the intermediate nodes decide to become helper node, it is highly possible that data transmission via helper node will provide more data rate than direct transmission. So by this way cooperative communication can improve the data rate. (Thanasis Korakis et al., 2009)

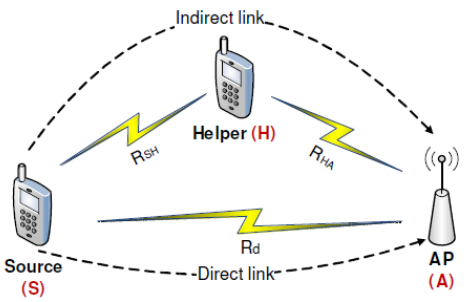

Figure 1 Cooperative Wireless Communication Scenario

At physical layer this scenario looks very promising. But as layers above it come in consideration the scenario becomes slight different.

In physical layer, it is assumed that the helper will get the RTS and CTS, which it will utilize to decide whether direct communication should be used or cooperative communication should be used. But in actual implementation, the relay has to transmit its willingness to participate in the communication as helper node. Source node and destination node will also check the claim and accept it if it is correct. So relay selection creates some overhead. (W. Zhuang, 2013)

Other issue with cooperative wireless communication is that it will increase the interference range. In case of direct transmission only the nodes in the vicinity of source node and destination node will refrain from transmission till the communication completes. But in case of cooperative wireless communication the nodes which are in the vicinity of source node, destination node and helper node have to refrain from the transmission till the communication completes.

Above mentioned two issues arises when we consider functionality of both layers (i.e. physical layer and MAC layer). So the decision of whether to use cooperative communication should be taken considering both the layers otherwise the advantage at physical layer will vanish.(P. Ju, et al 2013)

3. SYSTEM MODEL

The system model for our consideration is given in Figure 2. It has many nodes which are randomly distributed. Out of these one node wants to transmit so it will be considered source node. The node which is receiving the data is considered destination node. Out of the remaining nodes, one most promising node is selected as relay node. (S. Kim, et al 2013)

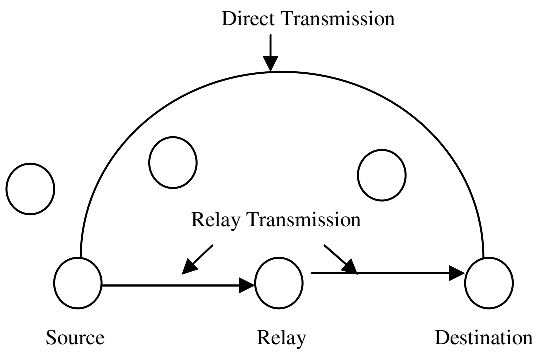

Figure 2 System Model

The data transmission can be done in either using direct transmission or using relay node. We have considered Decode and Forward relay scheme for this model. The another important assumption is that all nodes are using same MAC protocol and same transmit power. We have selected rayliegh fading channel which has distance dependent path loss. The transmission power is P_t. Then received power will be

$$P_r = (k/d)^{\alpha} \; P_t \qquad \text{......... (1)}$$

In eq. 1 α is path loss exponent which varies between 2 to 4. k is total number of hops involved. So for direct communication k=1 and for relay communication k=2.

The channel capacity will be

$$S = W * E_h (\log_2(1 + |h|^2 (k/d)^{\alpha} \; P_t / N_o W) \qquad \text{.............. (2)}$$

In this equation h represents fading process and W is bandwidth.

At MAC layer, we have observed a relationship between contending nodes and transmit power which is given below

The distance which will be reserved by ongoing communication is

$$d_{rsev} = (Pt / P_{th})^{1/\alpha} \quad \text{.......... (3)}$$

The average number of nodes who will contend will be

$$n = \rho \, \pi \, d_{rsev}^{2} \quad \text{......... (4)}$$

ρ is node distribution density.

4. DELAY ANALYSIS

As per our discussion in previous section physical layer supports data rate of S bits/sec. The data packet size is assumed to be M. So data packet transmission rate would be

$$D_{data} = M / S \quad \text{......... (5)}$$

The total delay can be given by

$$D_{total} = k\,(D_{mac} + D_{data}) \quad \text{......... (6)}$$

Combined throughput will be

$$T = I / D_{total} \quad \text{........(7)}$$

I is size of user data in actual data transmission without considering overhead.

Two random variables are defined to analyze the delay at MAC layer. Let X is a random variable that represents number of backoff counts for the source node to gain channel access. Let L be a random variable that represents the time for a decrease in the backoff count. Define T_c as the time consumption from collision between RTS packets and p is the collision probability when a node transmits a packet.

$$D_{MAC} = E[X] \cdot E[L] + pTc/1 - p + T_{RTS} + T_{CTS} + T_{ACK} + 4\delta + 3T_{SIFS} + T_{DIFS}. \quad \text{........ (8)}$$

p_{tr} represents the probability that at least one transmission at a randomly chosen time, and p_s is the conditional probability that a transmission occurring in the channel is successful given that at least one transmission in the channel. Successful transmission happens when only one node transmits over the channel.

$$p_{tr} = 1 - (1-\tau)^{n}$$
$$p_s = n\,\tau\,(1-\tau)^{n-1} / p_{tr} \quad \text{.... (9)}$$

τ represents the probability that a node transmits a packet at any time, Let p be the collision probability when node transmits a packet.

$$\tau = 2(1 - 2p) / ((1 - 2p)(W + 1) + pW(1 - (2p)^{m})) \quad \text{........ (10)}$$

$$p = 1 - (1 - \tau)^{n} \quad \text{......... (11)}$$

W represents minimum contention window.

$$T_s = T_{RTS} + T_{CTS} + T_{ACK} + T_H + T_D + 4\delta + 3T_{SIFS} + T_{DIFS} \quad \text{........ (12)}$$

is time consumed to reduce backoff counter after successful transmission.

$$T_c = T_{RTS} + \delta + T_{DIFS} \quad \text{........ (13)}$$

is time consumed to reduce backoff counter after collision.

$$E[L] = (1 - p_{tr})\sigma + p_{tr}\,p_s T_s + p_{tr}(1 - p_s)T_c. \quad \text{...(14)}$$

which represents average time to reduce backoff counter by one. After evaluating all the values from eq. 9 to eq. 14 we can get D_{MAC} and eventually we can find D_{total} and throughput from this.

5. SIMULATION AND RESULTS

We have used following data for the simulation of our system model.

RTS =20 bytes, CTS=14 bytes, ACK=14 bytes, Header length=36 bytes, Data = 2000 bytes, CW_{min} = 16 slots, CW_{max} = 1024 slots, Bandwidth = 20 MHz, node density = 0.00001 nodes/m^2, pathloss exponent = 4,slottime = 9 µsec, DIFS = 34 µsec, SIFS=16 µsec.

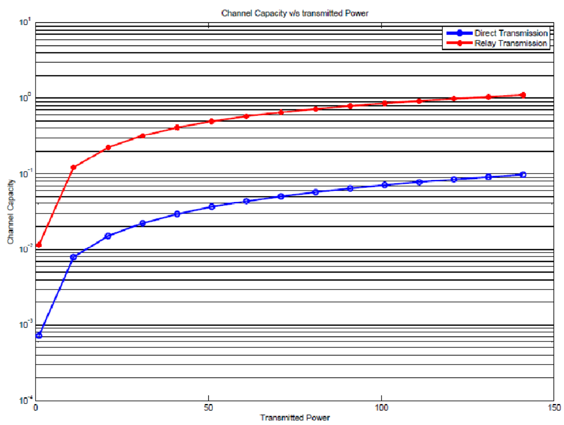

Figure 3 : Channel capacity v/s transmitted power

It is evident from figure 3 that from the point of view of physical layer in every case relay transmission provides better channel capacity that direct transmission.

From figure 4 we can conclude that relay transmission provides better performance that direct transmission.

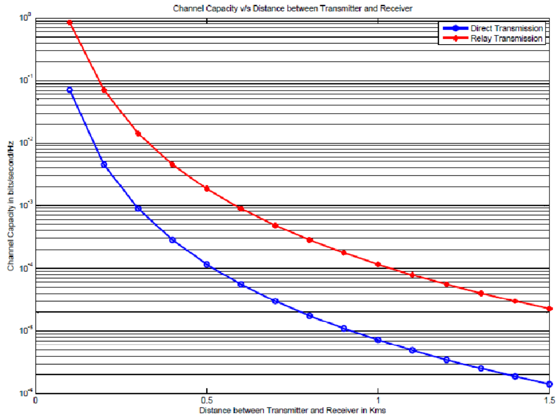

Figure 4 : Distance v/s channel capacity

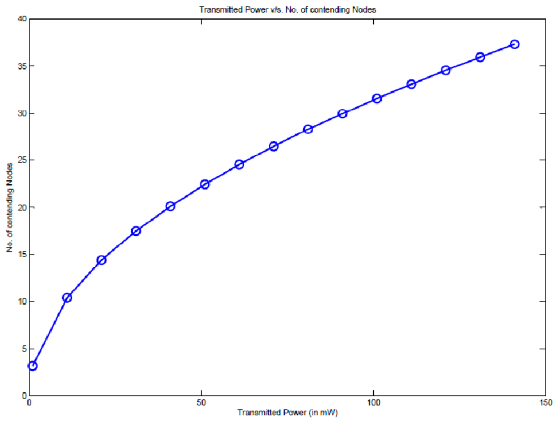

Figure 5 : No of nodes v/s transmitted power

In analysis of figure 5 we have found that as the transmitted power increases number of contending nodes also increases. The increase in number of contending node will affect the performance of the system adversely.

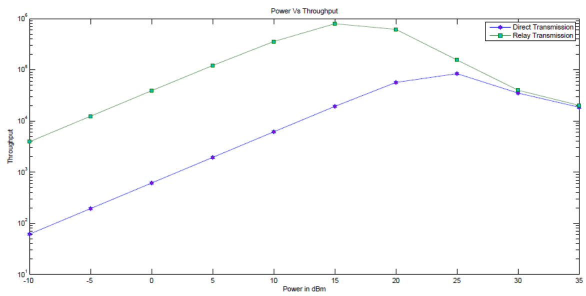

Figure 6 : Power v/s throughput

By analyzing the results of figure 6, we can state that for lower transmitted power relay transmission provides superior performance. But as the transmitted power increases, number of contending nodes also increases, which increases the contention period and eventually relay transmission does not provide much benefit compared to direct transmission.

Figure 7 indicates that for smaller distances direct transmission is better than relay transmission because of overhead of deciding the helper node. As the distance between transmitter and receiver increases relay transmission proves its edge over direct transmission

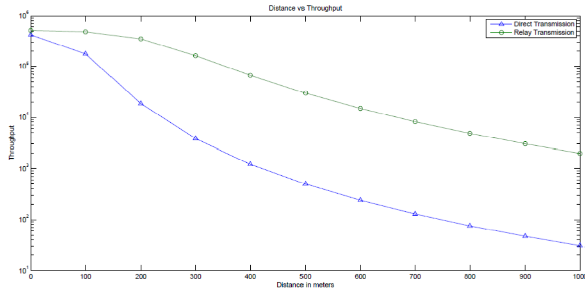

Figure 7 : Distance v/s throughput

5 CONCLUSION AND FUTURE WORK

We have analyzed the effect of relay transmission over direct transmission in this paper. If we only consider the physical layer scenario, then in every case relay transmission is better. But to be more realistic we have considered the effect of relay transmission at MAC layer also. This shows that performance is not same. So for decision making of whether to go for direct or relay transmission the cross layer results should be taken into consideration.

In future, the energy utilization of relay transmission should also be compared with direct transmission so that we can have more accurate decision making.

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