IMPROVED ENERGY EFFICIENCY AND THROUGHPUT IN COOPERATIVE WIRELESS COMMUNICATION

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ABSTRACT : *Initial research in the field of cooperative wireless communication was focused towards improving data rate. When the nodes operate at higher transmit power to improve data rate they consume more energy. Generally the nodes are battery operated so the nodes will go down much early. So at any point of time the decision of selection of relay node should consider energy efficiency and throughput both for longer network lifetime at higher data rate. The paper discuss the points of operation, which can either give higher data rate or higher energy efficiency or optimized point data rate and energy efficiency.*

KEY WORDS *: Cooperative wireless communication, MAC layer, Throughput, Energy efficiency*

1. INTRODUCTION

Due to multimedia communication and live streaming demands the quest to operate at higher data rate is increasing day by day. Various mobile communication technologies tries to address this issue. Wireless local area network provides variable data rate depending upon the distance between transmitter and receiver, transmitted power. MIMO can be used to solve this problem of higher data rate. But the requirement of minimum distance between pair of antennas make implementation difficult for smaller devices.

Cooperative wireless communication forms virtual antenna array using nearby nodes as relay to facilitate the transmission between transmitter and receiver. So the two hop communication will reduce the distance between transmitter and receiver. This reduction in distance can be utilized in two ways. Either we can reduce the transmitted power for achieving the same data rate and have higher energy efficiency (longer network life) or we can transmit the same power and achieve higher data rate. (K J Ri Liu 2009)

Network life time can be defined as the time till the first node in the network runs out of battery. When all nodes are active, we can select the best node out of all available nodes.

The relay selection can be proactive or reactive. In proactive relay selection each node maintains a table of relay node and the data rate which can be offered if that node is selected. The database of relays is created and updated periodically based on passive listening of nearby communication. In reactive relay selection, the nodes overhear the data transmission request and if they find themselves the best among peers then they send their request to be relay node for upcoming communication.

Energy efficiency is a very important criteria now a days. The energy consumed by networking in increasing at exponential rate. So for every network technology it is essential to consider energy efficiency as a decision matrix. So here in this paper we will have studied a tradeoff between throughput and energy efficiency.

2. COOPERATIVE WIRELESS COMMUNICATION

The advantage of cooperative wireless communication includes higher data rate, higher reliability, lesser energy consumption and higher coverage range.

The node which transmits the data is called the source node. The source node transmits request to send (RTS). It will be received by the destination node as well as the nodes which are near to either transmitter or receiver or both. By receiving the RTS all nodes will predict the channel condition and on base of that they will calculate the data rate/energy consumption or other similar parameters. The destination node also receives RTS and in reply to RTS it will send Clear To Send (CTS). The CTS will have the information of data rate/energy consumption for direct transmission. The nearby nodes will overhear the CTS and will compare their own evaluation with this. If they can improve the quality of service then they will broadcast their willingness to be relay. The source and destination nodes receive the message and after that the data transmission is done via that particular relay node. (P. Liu et al. 2007)

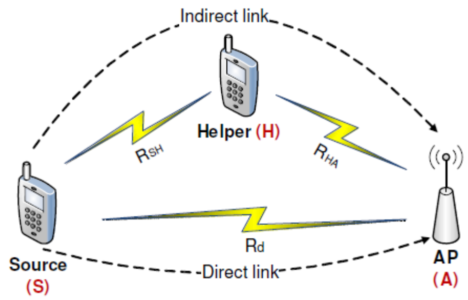

Figure 1 Cooperative Wireless Communication Scenario

The disadvantage of employing relay are more visible at MAC layer. When any node transmits data at that time nodes in nearby region cannot start other communication because their communication may interfere with current communication. So when relay communication is used at that time we will have three regions which will block communication near to them. (W Zhuang et al. 2013)

Some of the network resources will be used in decision making of whether to use direct communication or relay communication. In some protocols after this decision next decision is out of all prominent relay, which relay should be selected. The energy consumption of relay node should be dealt properly for pro long network lifetime.

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)

In our scenario most promising node should have higher data rate with higher energy efficiency.

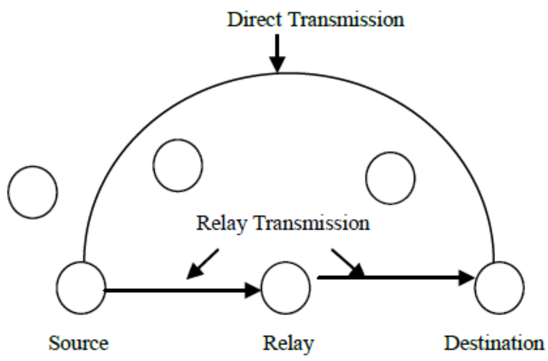

Figure 2 System Model

4. ENERGY CONSUMPTION MODEL

Any wireless node generally has two block

1. Signal processing
2. RF transmission (Power amplifiers)

In transmission side the total power consumption consists of power consumption of signal processing and power consumption of RF transmission. The power consumption of RF transmission is more because it is responsible for transmission of signal upto larger distance.

$$P_{tx} = P_{RF} + P_{SP} \qquad \text{......... (1)}$$

At receiver end the power consumption will be less because receiver has no need to amplify the signal upto larger extent. We have assumed that certain finite power P_{rx} is necessary for faithful reception.

Energy is power multiplied by the time of transmission. So higher the transmission time higher the energy consumed.

The overall energy consumption is divided into two parts. One is energy consumption due to data transmission and other is energy consumption due to MAC layer functionality.

Overall delay is defined as

$$D_{total} = k\ (D_{data} + D_{MAC}) \qquad \text{..... (2)}$$

So energy consumption due to data transmission will be

$$E_{data} = (P_{tx} + P_{rx})\ D_{data} \qquad \text{..... (3)}$$

Here transmit power can affect in two way. Increase transmit power will increase P_{tx} which will increase $E_{data.}$ But at the same time it will increase the data transmission rate which will reduce the D_{data} which can eventually reduce $E_{data.}$

The MAC layer energy consumption can be classified in two categories
1. Energy consumed in listening till backoff counter expires i.e. E_{await}

$$E_{await} = ((1 - p)P_{rx}\sigma + p_{tr}\, p_s P_{rx} T_{RTS} + p_{tr}(1 - p_s)P_{rx}T_{RTS})E[X] \qquad \text{...... (4)}$$

First term indicates no transmission, second term indicates successful transmission and third term represents collision.

$$= ((1 - p_{tr})\sigma + p_{tr}T_{RTS})\, P_{rx}E[X] \qquad \text{.......(5)}$$

2. Energy consumed in accessing the channel i.e. E_{access}

$$E_{access} = (p/\ 1-p)\, P_{tx}T_{RTS} + (P_{tx}+ P_{rx})(T_{RTS}+ T_{CTS}+ T_{ACK}) \qquad \text{..........(6)}$$

First term indicates energy consumption due to unsuccessful packet transmission and last term indicates energy consumption due to final successful handshake

Over all energy consumption due to MAC layer functionality is given by

$$E_{MAC} = E_{await} + E_{access} \qquad \text{...........(7)}$$

Overall energy consumption which includes energy consumption of data and overhead packet transmission is given by

$$E_{total} = k\ (E_{DATA} + E_{MAC}) \qquad \text{.........(8)}$$

Here k=1 for direct transmission and k=2 for relay transmission.

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.

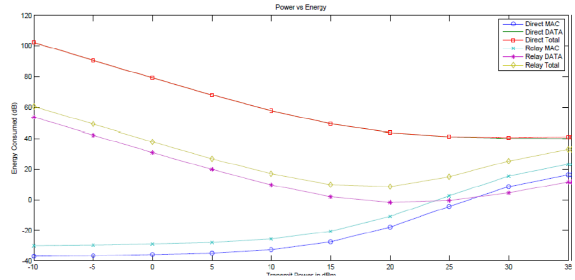

Figure 3 Transmitted power v/s energy consumption

Above mentioned figure indicates that at lower transmit power the energy consumption due to data transmission is significant. As the transmit power increases the energy consumption of MAC increases because number of contending nodes increases which increases MAC activity.

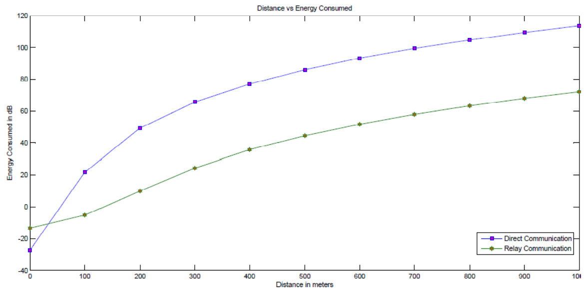

Figure 4 Distance v/s energy consumption

From above figure we can conclude that for distance higher than 50 meters relay transmission is better than direct transmission. After 50 meters relay transmission provides far superior performance.

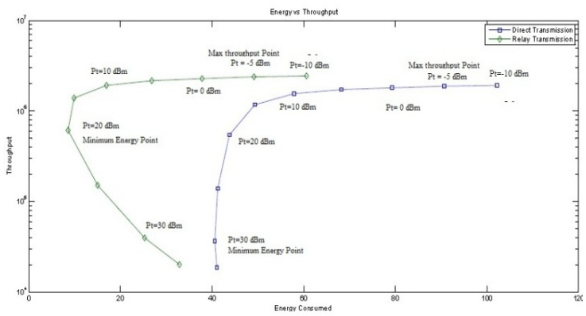

Figure 5 Energy v/s throughput

Figure 5 gives the relationship between energy consumption and throughput. From this figure we can find two points for each mode of communication. One point indicates best performance in terms of data rate and other point indicates the best performance in terms energy efficiency. One can decide for trade off point which can give better performance in terms of throughput and energy efficiency.

5 CONCLUSION AND FUTURE WORK

In this paper, we have seen the relationship between throughput and energy efficiency. The relay selection process is important for cooperative wireless communication. The consideration of energy efficiency and throughput is important in relay selection. As both are almost inverse for longer network life time and better QoS we have to use a optimized point which give us maximum possible throughput at minimum possible energy consumption.

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