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Delay Control in MANETs using Cooperative Communication

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Abstract

Cooperative communication has very beneficial impact in wireless communication networks. Till now the work that has been done on cooperative communication is related to physical layer issues like outage probability and outage capacity. As we consider about network and upper layer issues like topology control, delay time, network capacity etc. it is discussed that how cooperative communication helps to control the network topology.

As topology control has very great impact on delay time. In this paper, we take the advantages of cooperative communication approach i.e. Capacity Optimized Cooperative Communication to improve the network capacity by reducing the delay time of transmission.

Through application based simulation we show that how cooperative communication helps to reduce the delay time by reducing the transmission time in MANETs.

1. Introduction

As more and more speed of data transmission is an ever demanding aspect of wireless network. As per previous studies in simple wireless networks mobile agents may not be able to support multiple transmit antennas due to the size, cost and hardware limitations. Using cooperative communication single antennas mobiles in multi-user environment share their antennas in a manner that creates virtual MIMO system and take the advantages of actual MIMO (Multiple-Input, Multiple-Output) systems. A problem of end-to-end delay is caused by Fading (signal attenuation) due to multi-path effects, shadowing and interference etc. in simple wireless networks, in this situation some packets can be lost and needs to be retransmitted. The transmission and spatial diversity that is achieved by cooperative communication helps to reduce the signal attenuation and delay [1].

2. Types of transmission

As per the work of Q.Guan, F.R.Yu, S.Jiang, Leung and Mehrvar [2] analyzed three types of transmission manners in MANETS:

2.1. Direct Transmission: A direct transmission utilizes no relays.

Figure 1. Direct Transmission Diagram[2]

2.2. Multi-hop Transmission: A multi-hop transmission utilizes relays but does not combine signals at the destination.

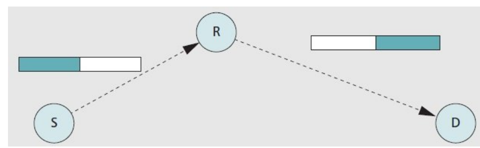

Figure 2. Multi-hop Transmission Diagram[2]

2.3. Cooperative Transmission: In cooperative transmission other nodes act as relay for other nodes. They send other node's information with their own information.

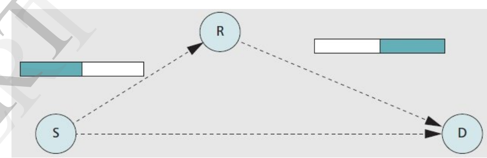

Figure 3.Cooperative Transmission Diagram[2]

3. Introduction to different aspects of Cooperative Communication

In this section we will discuss about cooperative communication, its beneficial impacts on MANETs and its different aspects.

3.1. Cooperative communication

Cooperative communication is a system that uses the concept of relaying but in this system different sources act as relay for other sources. The intermediate sources cooperate and send other source's data by combining with their own data.

Cooperative techniques observe that a source signal intended for a particular destination can be overheard at neighbouring nodes.

These nodes, called *relays*, process the signals they overhear and transmit them toward the destination. The relay can decode then re-encode the information or simply amplify the received signal and then forward; or can be involved in more sophisticated strategies such as forwarding only part of the information, compressing the overheard signal, and then forwarding. The destination combines the signals coming from the source and relays, enabling higher transmission rates and robustness against channel variations due to fading[1].

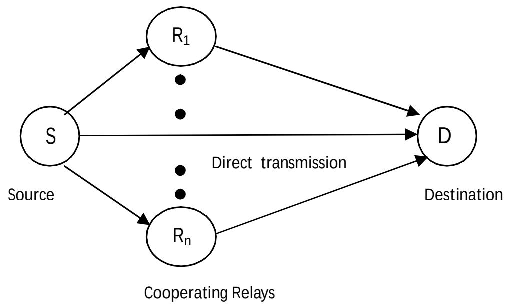

Figure 4.Cooperative Communication Diagram.

3.2. Relaying Strategies

Cover and E. Gamal [3] analyzed the capacity of the three-node network consisting of a source, a destination and a relay. It was assumed that all nodes operate in the same band, so from source the system can be viewed as broadcast channel and from the viewpoint of destination it will be a multiple access channel.

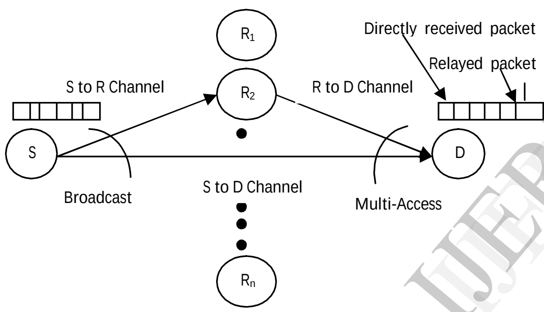

Figure 5. Relay Channel Diagram.

The basic idea of cooperative communication is that some nodes overheard the signal or information transmitted from other node and transfers it to the destination instead of treating it as interference. The CDMA technique will be used to separate the signals from different nodes.

There are two basic types of relaying strategies that could be used in cooperative communication [1] [4]. In this scheme the transmission of data is performed in two phases. In first phase the source transmits the data towards the destination and relay using direct communication and if direct communication fails then relay transmits this data to the destination in second phase. So, the second phase does not occur if first one is successful and that can utilize resources and time [5].

3.2.1. Amplify and forward(AF)

In amplify-and-forward, the relay nodes simply boost the energy of the signal received from the sender and retransmit it to the receiver.

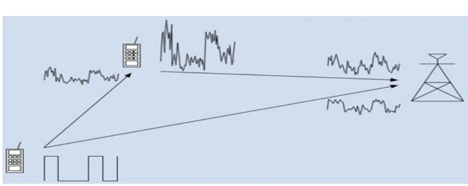

Figure 6.Amplify and Forward[4]

The relay nodes overhear the information bits from source node amplify it and then forward it to the destination without treating it as interference. At the destination it combines the coming signals from source and relays to regenerate the original signal.

3.2.2. Decode and forward(DF)

In decode-and-forward, the relay nodes will perform physical-layer decoding and then forward the decoding result to the destinations. If multiple nodes are available for cooperation, their antennas can employ a space-time code in transmitting the relay signals.

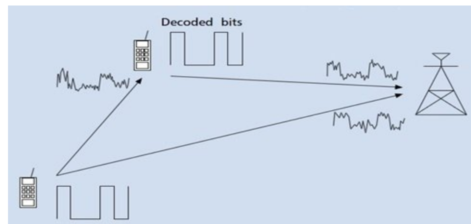

Figure 7.Decode and Forward[4]

As per the work of Sendonaris et al.[6], if two users are paired to cooperate with each other then they use simple CDMA (Code Division Multiple Access) technique to implement decode and forward cooperative signaling, each one has its own spreading code, denoted by $c_1(t)$ and $c_2(t)$. There data bits are denoted by $\mathbf{b}_i^{(n)}$ where i=1,2 are the user indices and n denotes the time index of information bits. Factors $\mathbf{a}_{i,j}$ denote signal amplitudes, and hence represent power allocation to various parts of the signaling.

$$X_1(t)=[a_{11}b_1^{(1)}c_1(t),a_{12}b_1^{(2)}c_1(t),a_{13}b_1^{(2)}c_1(t)+a_{14}b_2^{(2)}c_2(t)]$$

$$X_2(t)=[a_{21}b_2^{(1)}c_2(t), a_{22}b_2^{(2)}c_2(t), a_{23}b_2^{(2)}c_2(t)+a_{14}b_1^{(2)}c_1(t)]$$

So, in first and second intervals, each user transmits its own bits. Then after they detect the other user's bit and transmit a linear combination of their own second bit and the partner's second bit, each multiplied by appropriate spreading code. So, whenever the inter user channel is favorable more power will be allocated to cooperation otherwise cooperation is reduced.

3.2.3. Comparison of AF and DF relaying strategy

The work of Pengyu Zhang and others [7] analyzed that, both two cooperative strategies, Amplify-and-Forward and Decode-and-Forward, can facilitate secure communication. The existence of relay provides additional channels to transmit secret information and nonzero secrecy rate are achieved. Cooperative AF relay can be deployed in larger area with lower secrecy rate. In contrary, the deployment area of cooperative DF relay is smaller but the secrecy rate is higher.

It was shown in the work of G. Farhadi and N. Beaulieu [8] that single antenna multi-hop Rayleigh-fading relay channels under the Decode-and-Forward protocol achieve higher mean capacity than under the Amplify-and-Forward one. A similar conclusion was

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obtained in the work of Y. Fan and J. Thompson [9] for the mean capacity of MIMO multi-hop relay systems.

As per the work of Y. Zhu et al. [10] it has been remarked that AF significantly saves transmission power. However compared to DF, AF has two main drawbacks one is that it does not have coding gains and other is that it also amplify and forward noise. DF has advantages of regenerating the signal, and correcting the errors at the relay.

4. Introduction to Existing problem

Till now most of current works on wireless networks or in MANETs attempt to create, adapt, and manage a network on a maze of point-to-point non-cooperative wireless links. Such architectures can be seen as complex networks of simple links.

Even in cooperative communication most existing works are focused on link-level physical layer issues, such as outage probability and outage capacity. Consequently, the impacts of cooperative communications on network-level upper layer issues, such as delay time, reliability, topology control, routing and network capacity, are largely ignored [1].

As in existing system while using multi-hop routing scheme for transmission if anywhere a node failure will occur then retransmission of signal must be done and this will increase the delay time. There are several aspects that can be seen as drawbacks using multi-hop routing scheme:

- High delay time.
- Low network capacity.
- Low reliability.
- It is not benefitted by the advantages of MIMO system.

In this paper we are attempting to reduce the delay time of transmission of data.

5. Introduction to Proposed Solution

After a deep study of related papers a solution this problem will be proposed that is called "Capacity Optimized Cooperative Communication".

. As in this scheme we took the advantages of cooperative transmission in which the source broadcasts its messages to the relay and destination in the first slot. The relay node decodes and re-encodes the signal from the source, and then forwards it to the destination in the second slot with its own information. The two signals of the source and the relay are decoded by maximal rate combining at the destination. So, even in condition or node failure there is no need to retransmit the information bit because in this approach we are taking the transmission diversity and other benefits of cooperative communication.

There are some expected improvements that can be achieved:

- Reduced delay time: As cooperation removes need of retransmission because even on a node failure condition data will be reached to destination through other relays.
- High network capacity: Cooperation controls the topology that has very great impact on network capacity.
- Improved reliability: Data will surely reach to the destination because of using several relays.
- Improved network connectivity
- Reduce fading: As in cooperative scheme a node forward other's data either after decoding and re-encoding it or after amplifying it.
- It is benefitted by the advantages of MIMO system.

6. Implementation and results

In this section we analyze the performance of proposed capacity optimized cooperative communication scheme against existing multi-hop communication scheme. The implementation is done in .Net platform using C# language. We consider a MANET with 1 source node, 1 destination node and 7 intermediate relay nodes. The number of nodes can also be changed according to our need. We performed routing of data using existing multi-hop routing without cooperative communication , proposed capacity optimized cooperative communication and analyze the performance graph of both routing.

The performance graph is a time graph that denotes the total time consumed in transmitting the data from source to destination node.

The snapshots shown below denote the transmission time graph in simple multi-hop communication and cooperative communication in one case (a file transmission).

6.1. Time graph for multi-hop for single file

This result is calculated while sending a file in simple multi-hop routing scheme. The transmission time calculated in milliseconds is **11984.375**.

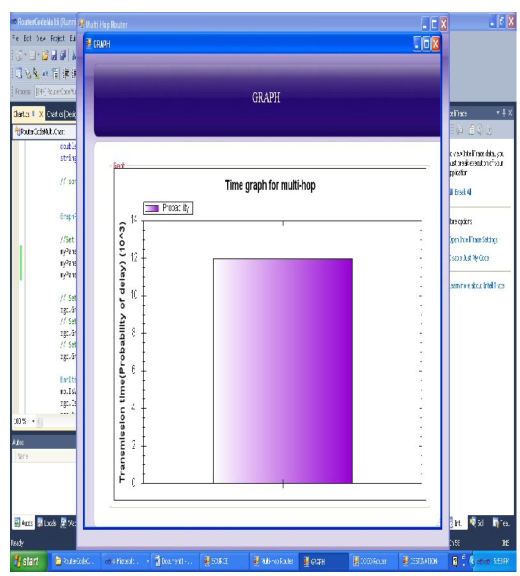

Figure 8.Time graph of multi-hop routing snapshot.

6.2. Time graph for cooperative communication (COCO) for single file

This result is calculated while sending a file in Capacity optimized cooperative communication routing scheme. The transmission time calculated in milliseconds is **10859.375**.

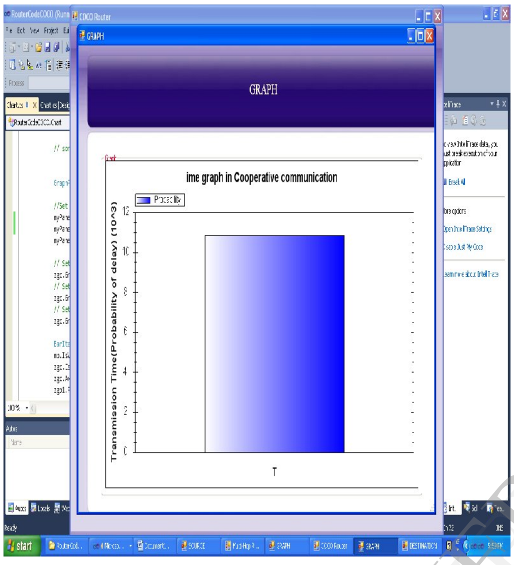

Figure 9.Time graph of cooperative routing snapshot.

6.3. Time comparison graph for both schemes

In this graph we can see that the transmission time calculated in both scheme while sending the same file. We observed that the time consumed in COCO scheme is less than the time consumed in simple multi-hop scheme.

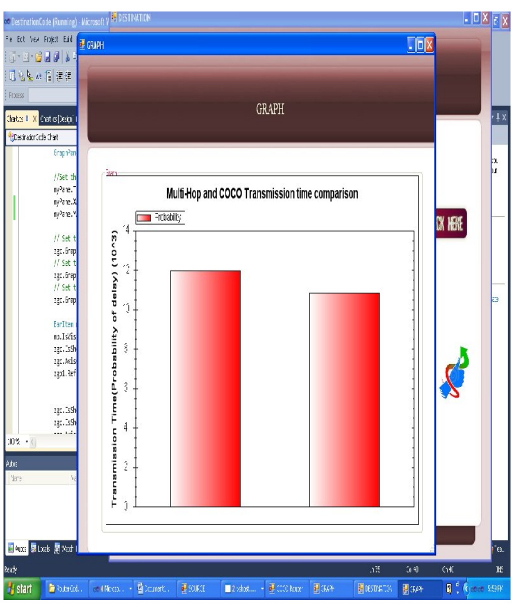

Figure 10.Time comparison graph of multi-hop and cooperative communication

6.4. Comparison table and bar graph for transmission time in different cases

In this table we have analyzed the transmission time in multi-hop communication and COCO communication schemes while sending different files of variable size. Through this result we can say that cooperative communication reduces the transmission time (probability of delay).

Table 1. Comparison of transmission time in COCO and multi-hop routing

CASES	FILE SIZE (MB)	MULTI-HOP (Time in ms)	COOPERATIVE (Time in ms)
1	1.79	11343.75	10109.375
2	7.24	10734.375	9968.75
3	17.8	11546.875	9750
4	31.78	11390.625	9875
5	43	14343.75	9687
6	63.5	13312.5	9781.25
7	70.2	15390.625	9843.75

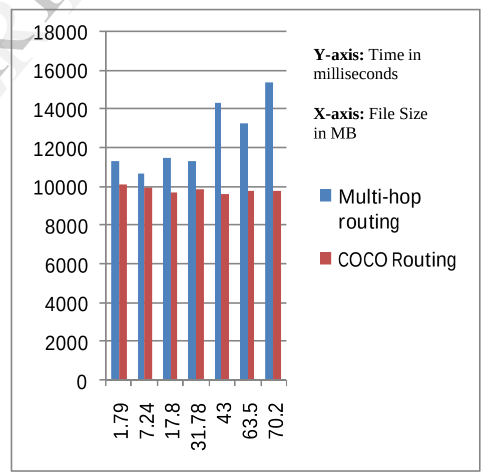

Figure 11.Bar-graph for transmission time in multi-hop and COCO routing.

5. Conclusion

The complete study of other related papers to this issue concludes that there are many challenges found and already resolved in MANETs such as outage probability and outage capacity etc. but they are link – level physical layer issues and there are so many challenges related to network-level upper layer issues like delay time, topology control, routing, that are needed to work on.

This paper deals with the network capacity to reduce the delay time using a Capacity Optimized cooperative communication scheme and show that how cooperation will improve the network performance by reducing the total delay time consumed in transmitting the data towards destination.

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