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Wireless Cooperation: Challenges and Issues

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Abstract

Cooperation in wireless communication is a promising and practical technique that achieves spatial diversity gain and provides connectivity without infrastructure. There has been a growing interest in designing and evaluating efficient cooperative protocols in recent years. The wireless communication channel suffers from several problems such as path loss, shadowing, and fading that decrease its reliability. Due to channels fading in wireless Ad-hoc network can experience significant performance degradation. This paper present various issues and challenges in Physical layer, data link layer and network layer of cooperative wireless networking.

Keywords: ***Ad-hoc network,*** Cooperative Wireless Networking, Relay , diversity gain, Reliability

1. Introduction

Cooperative techniques can increase performance and reliability of wireless Ad-hoc networks against the signal impairments. Signal impairments in wireless networks can decrease the reliability of the channel. Cooperation among nodes and network can improve network performance and provide the communication with diversity, robustness, security and high data rates. In cooperative communication techniques every node cooperate with other node to increase their effective quality of service, network performance and communication enables single antenna mobiles in a multi-user environment to share their antennas and generate a virtual multiple-antenna transmitter that allows them to achieve cooperative diversity[3]. As illustrate in fig .1 a mobile user can act as a relay station in cooperative wireless communication.

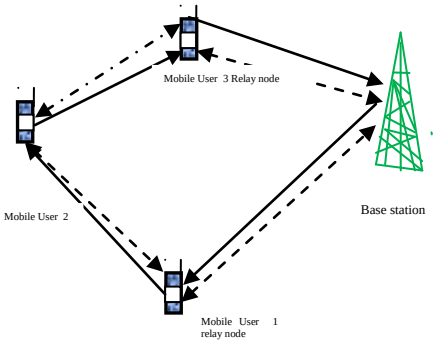

Fig1. Cooperative Communication

2. Why to Choose Cooperative Communication

In this section, we discuss the various advantages of cooperation in wireless network.

2.1 Cooperation Improve Reliability

The wireless communication channel suffers from several problems that decrease its reliability.

These problems include signal fading, path attenuations, channel impairments, interference and shadowing. Cooperation will improve channel reliability by utilizing spatial diversity. The concept of spatial diversity illustrated in fig.2. Cooperative communication create array of virtual antenna between the source and destination nodes and provide effective communication between source node and destination node. Hence, cooperative communication provides several independent paths between source and destination. So, destination node gets several copies of transmitted signals it will improve overall reliability of wireless channel. Destination can combine data received from various relay nodes and detect errors to improve transmission accuracy. Between source and destination there are several node called relay node, the relay node may be a mobile node or any devoted node, the relay node may improve channel condition in wireless network.

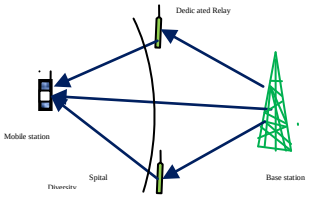

Fig. 2 spital diversity in wireless communication

2.2 Cooperation Reduce Interference

In wireless network, transmission is done in broadcast manner so it will increase interference at the different nodes in the coverage area (interference range) of each other[10]. This interference reduces the signal strength so it degrades their overall performance. Cooperative communication provide reliable channel condition which greatly reduces the interference ranges, cooperation method can solve the hidden terminal problem in wireless network so it reduce interference and it also improve the energy efficiency of the communication system[4]. Figure 3. Illustrate the concept of interference in direct and cooperative communication.

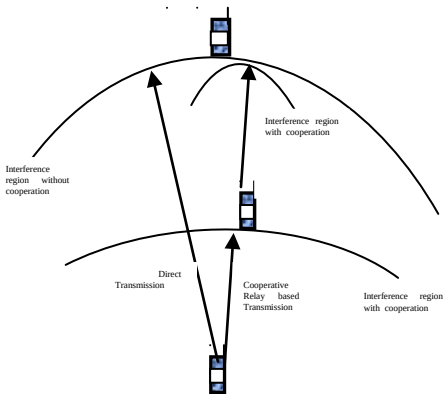

Fig.3. Interference in direct and cooperative communication

2.3 Operational Cost Reduction

Cooperation in wireless communication networks provide array of relay stations and several alternative relay path between source and destination, so this will reduce infrastructure cost and operation costs for both mobile users and service providers[4]. It will also reduce energy requirement which reduce energy cost. Cooperation extend coverage area by using relaying node which reduce overall operational cost requirement.

2.4 Minimize Call Dropping and Call Blocking

Call dropping and call blocking are main issues in wireless mobile communication. Some time due various channel conditions call terminates automatically it is known as call dropping. Cooperative techniques can help to provide error free communication and provide guarantee for uninterrupted call. Cooperative communication create various alternative path between source to destination, if any call is blocked in one path it still and continued by using another relay path, so the cooperation will help to reduce call dropping and call blocking. Figure 3 illustrate multipath channel relay that will help to minimize call dropping and call blocking.

2.5 Enhance Overall Network Throughput

The cooperative transmissions can increase the achieved throughput through aggregating the offered resources from different relay nodes. As cooperation improves channel reliability in wireless network this will directly improve network throughput. Overall throughput is achieved by utilizing cooperative techniques in different layer of computer network, i.e. in network layer data packets transmitted through multiple paths are not the same copies of transmitted signal, but different transmission channel and carry different data packets, so that it will improve overall performance gain and network throughput[8].

3. **Challenges and Issues in Physical Layer**

As compared to wired network, there are many problems in wireless communication, because in wireless network both sender and receiver may move from one location to another as result signals may scattered and collide with may object and may loss energy, and environment condition also effect strength and quality of signals. When sender and receiver move from one location to other the SNR (Signal to Noise Ratio) and BER (Bit Error Rate) may changes drastically[1], this will reduce signal quality gradually. The SNR is used to estimate strength of signal at the receiver against to the noise on the channel. Suppose

the R(t) is the received signal and T(t) is the transmitted signal
Then

$$R(t)=H(t)T(t)+N(t)$$

where H(t) denotes channel gain which is determine by (attenuation, shadowing , fading and interference) and N(t) denotes random noise added by channel. If channel gain is decreases due to attenuation, shadowing , fading and interference effect, as result it increases bit errors.
Shannon's define the capacity of channel, according to his theorem the maximum capacity of reliable communication is given by

$$C = B \log2(1 + SNR)$$

Where B is the bandwidth of the channel. The Shannon's theorem define the maximum capacity of reliable communication but his theorem do not define how to achieve maximum capacity of the channel, so it is require to use various techniques that will improve the reliability of the transmission.

The signals are broadcast in free space in wireless communication, so signals are normally accessible to anyone who has device capable of getting them. The physical layer deal with the radio and microwave signals in wireless communication, this layer provide several techniques for receiving and forwarding signals, mostly three types of method used in physical layer, first amplify and forward (AF) method, in this method the relay node amplify the signal before it forward to next node, the second method is a decode and forward method, in this method relay node decode the signal, after decoding the signal, the relay node re-encode and re-transmit the signal to the next node, the third method is coded cooperation (CC) method, in this method the relay node include the channel coding with the signal and transmit it to the next node[7]. Fig 4. illustrate the concept or relay channels.

The physical layer and data link layer deal with the most of the complexity of wireless network. The physical layer receive data packet from logical link layer and broadcast the bits over the wireless medium using radio frequency. The physical layer also detect and correct the transmission errors, physical layer estimate probability of error e.g. if BER is estimated 10-7 to 10 -10 then physical layer decide that no bit error in single frame. The challenges of physical layer is to reduce bit error rate and improve simultaneous transmission rate of signals. In following section we discuss various problems of wireless network like interference, attenuation , shadowing and fading.

3.1 Interference : In wireless network many signals are present in free space at the same time and medium is shared by many users, as result signals are corrupted and not decodable at the receiving site. This is known as interference, it is commonly handled by link layer by using some access method.

3.2 Attenuation and Shadowing : In wireless network when a signals moves in free space, after traveling some distance they losses some energy at the rate $r\alpha$ where (α is a path loss exponent and r is distance from the source) called attenuation effect . The signals also losses energy due to some obstacle present in travelling path is known as shadowing effect.

3.3 Fading: When a sender transmit a signal, multiple copies of that signal travels via different path to the receiver then it suffer from channel induced changes. Repetitive copies of signal between the multiple transmitters and the receiver create interference which cause channel fading. The fading can decrease the signal performance considerably. These copies of the signal, which differ partially from each other in (frequency, amplitude or phase) this variation is caused due to multipath propagation effect is known as multipath fading. One challenge of physical layer to reduce all the effect described above.

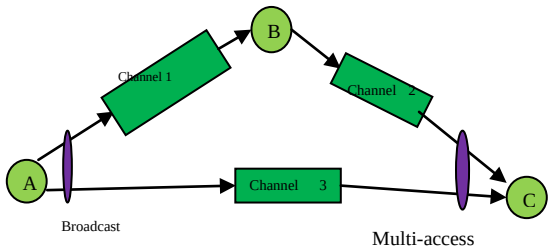

Fig 4. Multi Path Channel Relay Channel Relay

4. Challenges and Issues in Data Link Layer :

The data link layer is divided into two sub layers first medium access layer (MAC) and second is Logical link Control layer (LLC). In wireless network MAC layer is responsible for deciding whether cooperation is needed or not and it is also responsible for choose optimal nodes for cooperation among various existing nodes. To apply cooperation relay techniques in wireless network require to changes in MAC layer design, because MAC layer provide various protocol related to medium access, for cooperation relay it is necessary to design some protocol that solve questions like when to cooperate , whom to cooperate , how to cooperate , how to select relay node, how to solve hidden and exposed terminal problem in various cooperative strategies and how to reduce interference etc.

4.1 How to Select Relay Nodes: MAC layer play important role in selecting relay nodes among all existing nodes. The optimal selection of relay node depends on three things[6]: first how many relay stations are selected for cooperation (single versus multiple selection), second is selection method (centralized vs. distributed) , third is how the relay nodes must cooperate to achieve optimal cooperation and throughput[5].

4.2 When to Cooperate: It is essential to develop MAC protocols that use cooperation only when it is needed, because it is not necessary that every time cooperation is beneficial in wireless communication, because it is depend on cooperation gain. If cooperation improve the channel reliability, and throughput of the source node, and if it achieve high transmission rate as compared to direct transmission in this case cooperation is beneficial. The other factors is the resource aggregation, when in direct transmission resources are not enough to satisfy the required service then resource aggregation will improve throughput of network[9].

4.3 Reduce Overhead : The design of MAC protocol also required to investigate some overhead issues in wireless network, because cooperation among various node include some overhead. Selection of optimal relay node include another type of overhead and selection of optimal path from existing multiple path increase probability of collision, to overcome from collision situation will also include another type of overhead.

5. **Challenges and Issues in Network Layer**

Network layer is responsible to decide routs between source and destination for delivering data packets. The main function of network layer is a routing. In wireless network, network layer define some routing protocol which is used for routing data packets using relay nodes. The wireless cooperation is need to define some challenges that will help to develop some new protocol in network layer.

There are several challenges in network layer described below.

5.1 Multipath Interference: In cooperative wireless network when it is needed to select multipath route, it require to select mutually independent path and ensure minimum interference between these paths,
because paths are in the interference range of each other then this will degrade the overall throughput of the network[2].

5.2 Cost of Route : In multipath routing there are three types of routes are basically available first one is node disjoint route, in this case no routes and links are common. The second type route is link disjoint, in this case there is no link is common but may have some nodes are common . The third type of route is disjoint route in this case link and nodes create some common paths. Figure 5. illustrate three method of multipath routing.

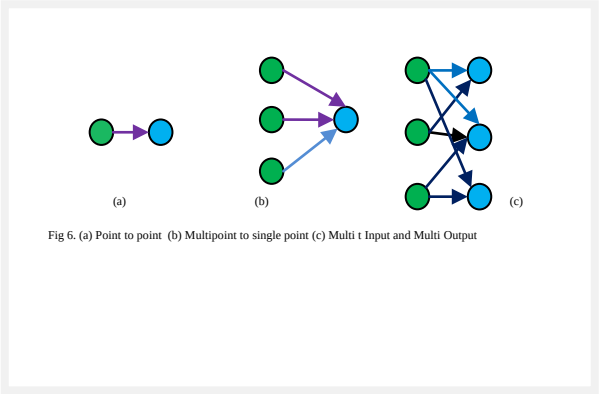

Fig 6. (a) Point to point (b) Multipoint to single point (c) Multi t Input and Multi Output

5.3 Multi-path and Multi-flow Routing - In wireless cooperation the network layer is required to develop such protocol that will help to route the packet in multi-path and multi-flow situation, because cooperative method increases in the number of flows in network and MIMO links provide several paths between sources and destinations so it is necessary to develop optimal multi-path and multi-flow routing. The optimal multi-path and multi-flow routing is require to develop in such a manner that it will increase overall throughput and resource aggregation so that we can get maximum cooperation gain. The multipath routing suffer from differential delay problem, because in multipath may have different end-to-end delays. As a result, the received packets from different paths need to be buffered for reordering. The multi-path routing algorithm should be carefully designed so that it utilize maximum bandwidth and also manage the differential delays.

5.4 Interference Consideration: In wireless cooperation when we use multipath routing it can aggregate resources from different paths and increases throughput. If these path suffer from interference this will degrade the throughput and resource utilization [2]. So it is require choosing only those paths that are as mutually independent as possible to ensure minimal interference among these paths.

Conclusion : The cooperative communication allow multiple node as array of virtual relay nodes,
the relay node are used as cooperative entities, cooperative communication require less infrastructure and provide diversity gain. Carefully design of protocol in different layer will increase reliability, throughput and energy efficiency. In this paper we investigate some challenges and issues in first three layers, various challenges and issues in other layer are also required to investigate.

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