An Efficient Radio Resource Allocation Scheme Between Cellular Users and Ad-Hoc Device To Device Users

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Abstract – To utilize spectrum resources more efficiently in a cellular network is very important but this is a very difficult task. Ad-hoc device to device communication was introduced for this purpose. By using spectrum sharing schemes we can avoid the under utilization of the spectrum. While designing such schemes interference management becomes a crucial issue. It is critical because the licensed users should maintain their QoS. A novel spectrum sharing protocol called distributed dynamic spectrum protocol is proposed in this paper. In this protocol ad hoc users communicate directly without getting connected to the base station. On the other hand macro users will be communicating with each other using traditional techniques. Network information is distributed by route discovery packet to establish a single hop or multi- hop link between D2D users. The discovery packet which contains network information will decrease the failure rate of the route discovery and also reduces the number of transmissions to find the route. Finally using the found route, the simulation result shows that two D2D users can communicate with a low probability of outage. Performance metrics such as throughput, PDR, BER, network overhead are analyzed. Here the route between the D2D users is achieved without connecting to the base station. So the spectrum resources are shared more efficiently between macro user and device to device user.

Keywords-- spectrum sharing; Device to Device; interference management; route discovery.

I. INTRODUCTION

The number of wireless users is increasing day by day. But the service providers cannot obtain new spectrum resources so easily because it is very costly. New technologies like International Mobile Telecommunication (IMT) advance and Third Generation Partnership Project (3GPP), Long Term Evolution will help to satisfy the increasing demand. It is really impractical for the service providers to increase the bandwidth with the rising number of users. Dynamic spectrum access techniques are becoming increasingly popular to meet this problem. There are different methods suggested by different service providers to improve the overall performance of their clients. A similar approach is to redistribute excess users to spectrum bands with excess capacity. Another approach is to place fixed relay station in the cell to form femtocell hotspots. A new step that is been implemented is base station take advantage of the user network topology and assign resources to mobile users so that they can communicate directly with each other without getting connected to the base station.

In this proposed method, we develop a distributed dynamic spectrum protocol to enable device to device communication. D2D users will use the statistical estimates of the channel gains to set their transmit power. This power has to be within the allowed interference temperature of the cellular network. Using the calculated transmit power, two D2D users will try to discover either a single-hop or multi-hop route connecting each other using dynamic source routing protocol. Initially route request packet is flooded in the network. The destination node, on receiving a RouteRequest packet, responds by sending a RouteReply packet back to the source, which carries the route traversed by the RouteRequest packet received. Random access techniques are used to ensure that only one D2D user access the spectrum at a given time. Once the route is found between the two users, the D2D link quality in terms of probability of outage can be quantified. Performance metrics such as throughput, BER, PDR, network overhead are analyzed. We then derive the outage probability for a D2D link.

II. NETWORK ARCHITECTURE

A. infrastructure and user model

The network model considered consists of a circular cell of radius R with a base station (BS). The uplink frame is considered here and it is assumed to be divided into Nc orthogonal channels. The same Nc orthogonal channels are available for use in each cell. Minimum SINR of β_B is required for a cellular link. Let us assume a margin κ in the required SINR at the base station. The first type of user is a macro user (MU) and communicates by establishing a link with the nearest base station and having their information transmitted to their required destination. The second type of user, a D2D user, communicates directly with each other in one or more hops without any assistance by the base station. All D2D users are uniformly distributed within a cluster having radius r. Then a twoD2D's are chosen at random, where one is a source (S) with data and the other one is destination (D). If a single hop is not possible between source and destination then a multi-hop route is assumed. D2D users communicate with each other on the same frequency channels used by macro users, however their use of those channels cannot cause the SINR of an active cellular link to fall by more than the allowed κ. In this paper we consider that D2D users will know the value of κ and calculate their powers accordingly. D2D's randomly access the channel using CSMA/CA and establish the link using DSR protocol. The D2D users and macro users only differ in their modes of communicating with each other, either directly or through the base station.

B. Channel model

The channel model consists of three arbitrary users: a transmitter i, a receiver j, and an interfere k . A path loss channel is assumed with multiplicative fading and additive white Gaussian noise. The large scale fading is determined by the Euclidian distance d_{ij} between two users i and j and the path loss exponent α. determines the small scale fading between the same two users is determined by a Rayleigh random variable f_{ij} . The power of user's signals and corresponding SINR of their links are mainly taken into account and thus define user j's SINR as

$$\Gamma_j = P_{Ti} d_{ij}^{-\alpha} h_{ij} / \sum_k P_{Tk} d_{ij}^{-\alpha} h_{ij} + \sigma^2 \qquad (1)$$

Where P_{Ti} is the power used by the transmitter, $d^{-\alpha}_{ij}$ is the path loss for the link between the transmitter and receiver, and $h_{ij} = |f_{ij}|^2$ is the channel gain. Similarly, P_{Tk} is the power used by the k'th interferer and $d^{-\alpha}_{kj}$ and $h_{kj} = |f_{kj}|^2$ are the path loss and channel gain for the link between the k'th users observe the same noise power of σ^2.

III. DEVICE-TO-DEVICE COMMUNICATION

In this paper a dynamic spectrum access protocol is proposed in which D2D users can communicate directly with each other using the same frequency resources as an active uplink between a macro user and the base station. During the uplink transmission phase, only the stationary base station will receive interference from the D2D. To avoid interference D2D users should take into account the value of κ. There are two main steps in our protocol. First, the power control of device to device users and the second step is to discover either a single hop or multi-hop route to their intended destination. First the power required for the macro user is calculated using the formula given below

$$P_{TM} \geq \kappa \beta_B d^{\alpha}_{MB} h^{-1}_{MB} = P_{TM}^{min} \qquad (2)$$

P_{TM} is the power required for the macro user. A is the path loss exponent. D is the distance from mobile to base station. P_{TM}^{min} is the minimum power required for the macro user for communication. This power is broadcasted to the D2D users. Then D2D users adjust their powers accordingly so that it cause less interference to the macro users.D2D users will access the spectrum in a random access manner. After this D2D users establish routes either through single hop or multi hop.

A. Distributed Route Discovery for Two-way D2D Communication

Dynamic source protocol is used in the proposed scheme which is two way. Initially route request packet is flooded in the network. The destination node, on receiving a RouteRequest packet, responds by sending a RouteReply packet back to the source, which carries the route traversed by the RouteRequest packet received. After this D2D users establish routes either through single hop or multi hop.

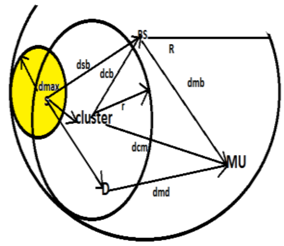

Figure1. network topology realization presenting the various random distances in the model

TABLE 1. Network Parameters

System parameters	**Value**
cell radius	2000m
Mean of Rayleigh fading	1
Cluster Radius(r)	500m
Number of Channels (NC)	30
Number of MUs (NM)	30
Minimum BS SINR(β_B)	10db
Interference Margin at BS(k)	3db

B. Simulation Results and Analysis

1. Throughput

Throughput is defined as the total amount of data a receiver receives from the sender divided by the time it takes for the receiver to get the last packet. The throughput is measured in bits per second (bit/s or bps). The throughput is shown in fig 5. According to our simulation results, best performance is shown by distributed dynamic spectrum protocol as it delivers data packets at higher rate as shown in the figure2. Throughput verses time is plotted.

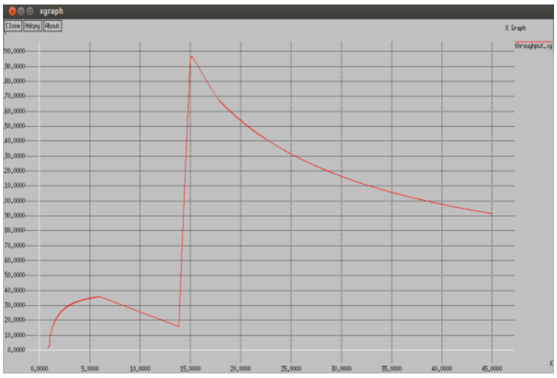

Figure2. Throughput graph

2. Packet Delivery Ratio

Packet delivery ratio is the fraction of packets sent by the application that are received by the receivers and is calculated by dividing the number of packets received. For better performance of a routing protocol, it should be better. Packet delivery ratio is shown in figure 3, distributed dynamic spectrum protocol perform much better. PDR verses time is plotted.

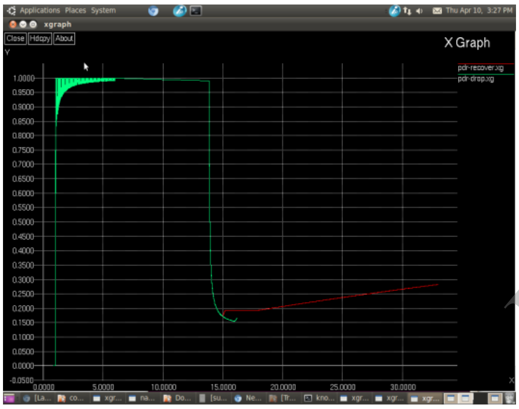

Figure3. Packet delivery ratio graph

3. Bit error rate

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. In the proposed scheme bit error rate is less and is shown in figure 4. BER verses time is plotted.

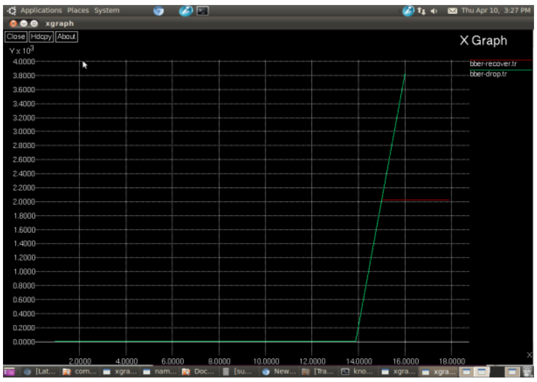

Figure4. Bit error rate graph

IV. OUTAGE ANALYSIS OF DEVICE - TO - DEVICE COMMUNICATION

The D2D outage probability is derived considering both the distance and fading channel probability distributions. Here all D2D locations in the macro cell and all possible channel conditions between users are considered.

A. Probability of Outage Derivation

Here we derive the outage probability of a single-hop link between two randomly placed D2Ds. The probability is defined as *PoutD* . As a first step, the outage probability is driven for all channels in terms of the outage probability for a single channel. The available bandwidth is divided into *NC* orthogonal channels and D2Ds are able to access any of them. Because of the orthogonality principle we can write

$$P_{Dout}=(P^{out}_{D/ci})^{Nc} \qquad (3)$$

which gives the probability of outage for a single-hop D2Dlink. *dmax* is the maximum transmission distance of the source and defines a region around the source, shown by the shaded area in figure 1, in which the destination must be located in order to satisfy the required SINR βD. Thus, the probability of a link satisfying the SINR requirement and not being in outage, *Pr*[*dSD* $\leq$ *dmax*], is the ratio of all the feasible locations of the destination that result in a successful link, which is the coverage region of the source, to all possible destination locations, the area of the entire cluster. We use a fixed radius ratio of *r/R* = 0.25 and vary the number of channels in the network. We first consider a perfect channel estimate of *_hSD* = *hSD* for the power control which gives a lower bound on the outage probability. Perfect knowledge of the channel is difficult to obtain in practice so our protocol uses a statistical estimate of *_hSD* = E[*hSD*] in the power control. We can see that as *NC* increases, PD_{out} decreases as shown in the figure5 and 6. D2Ds have more diversity in the resources that they can use.

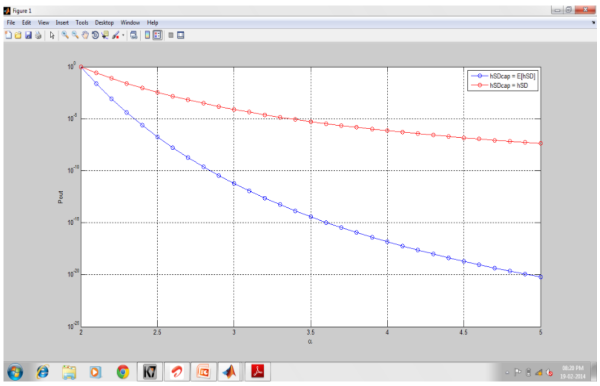

Figure5. Probability of outage for Nc =30

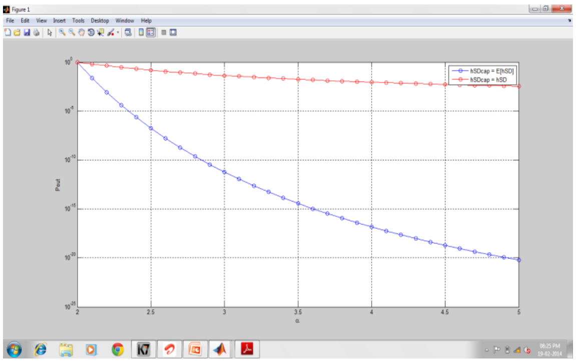

Figure6. Probability of outage for Nc =10

V. CONCLUSION

In this paper distributed dynamic spectrum protocol is presented in which an ad-hoc Device-to-Device network opportunistically access the spectrum in a random manner and simultaneously communicate using the same frequency resources as a fully loaded cellular radio network. D2D's communicate without using the base station. The D2D users first control their powers to a level which causes minimal interference to the base station. Then using the calculated power, the second step is to employ a discovery protocol to establish a route connecting them to their required destination. Performance metrics like throughput, BER, PDR are analyzed. Good results are obtained using distributed dynamic spectrum protocol. For a D2D link probability of outage is derived. Large improvements in the D2D's performance come at a cost of only a small loss in macro user performance. Hence the spectrum is efficiently used.

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