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Spectrum Sharing Scheme Between Cellular Users And Ad-Hoc Device To Device Users In Clusters

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Abstract— In order to utilize spectrum resources more efficiently, protocols sharing licensed spectrum with unlicensed users are receiving increased attention. Spatial reuse is a feasible complement to existing standards. During designing interference should be considered as a major component as it is critical that licensed users maintain their expected quality of service. A distributed dynamic spectrum protocol can be used in which ad-hoc device-to-device users opportunistically access the spectrum actively in use by cellular users. The interference caused should be within the allowed interference temperature and in order to keep that interference to that allowed value the channel gain estimates are used and further they are used to set the transmit powers which is feasible for device-to-device users. Then in a random access manner network information can be distributed by using route discovery packets and it helps to establish either a single-hop or multi-hop route between two device-to-device users. The number of necessary transmissions to find a route can be reduced by adding the network information in the discovery packet. By communicating directly with each other instead of utilizing the cellular base station, power can be saved significantly. For larger networks the network is divided into clusters and communication takes place between the devices in different cluster.

Keywords— Device-to-device, spectrum sharing, power control, interference management, route discovery, clustering

I. INTRODUCTION

As the number of wireless users is increasing at a much faster rate, the service provider cannot obtain new spectrum resources. With the rising number of users in mobile communication system in future, to fulfill the rising demands on bandwidth is impractical since the spectrum is already fully allocated. As another method to meet the high demand for service the dynamic spectrum access techniques become increasingly popular. In most of the existing spectrum policies the frequency spectrum is statically partitioned into fixed bands and that fixed bands are allocated to a specific standard or technology. As a result of these spectrum policies spatial locations are reserved to use a spectrum band for all time. The advantage of reserving frequency resources for all time is that it is the quickest and easiest way. If the spectrum is not shared interference will be less and higher data rates can be achieved. But the cost of this easy solution is very high. And also the problem arises whether it is the most efficient method of utilizing the limited resource like spectrum.

Thus to efficiently use the spectrum an opportunistic strategy called spectrum sharing can be used. Spectrum sharing occurs. When a given set of frequency resources are actively in use by one set of users and if they are interested in sharing the spectrum resources simultaneously with another set of users they it can be said as the spectrum sharing scheme. To bring efficiency to an underutilized resource spectrum sharing can be used, but interference management must be considered while designing and it should be strictly avoided. To manage the interference between users and between standards the frequency spectrum is licensed and strictly controlled. More and more transmitting users will be added to today's wireless networks by sharing the spectrum, which will in turn cause more interference.

II. RELATED WORK

The Device-to-device scheme could be a better option in the rollout of future generation cellular networks. By utilizing the Dynamic Source Routing (DSR)[2] protocol the issue of multi hop, discovery and routing problems can be addressed. When compared to other routing protocols it is having low overhead and suitable for mobile networks. And to reduce the total number of transmissions needed for discovery a modification on DSR protocol and also it will be helpful to reduce the overall contributed interference to the system. And in the presence of a larger network we can divide the network into different virtual groups and in order to discriminate the nodes allocated to different sub networks some rules are used. By doing this scalability can be achieved in presence of large network and high mobility [3].

The area of spectrum sharing encompasses a wide variety of works. The different methods to improve the overall performance of their own customers by co-operating the providers together are introduced in [4]. A protocol in which the base stations are taking advantage of the user topology and resources are assigned to cellular users is proposed in [5]. Through this they can communicate directly with each other without the use of the base station. This work is similar to the proposed D2D mode. In [6] to reuse frequency channels among neighboring base stations, a simple cellular model that adapts to channel conditions is introduced. A cluster-based multipath routing in MANET (CBMRP) in which it avoids congestion by distributing the traffic among diverse multiple paths and it optimizes bandwidth using and the sharing rate of channel is improved is developed in [9].

III. PROPOSED SYSTEM

This section defines the proposed system.

3.1.Network Architecture

The network model is a circular cell of radius R with a base station (BS). The uplink frame is divided into orthogonal channels. Interference from the D2Ds will be received by the stationary base station during the uplink transmission phase. Macro users will be up linking to the base station so they will not receive any interference from the D2Ds. There would be interference at every macro user during the down link. In each cell same orthogonal channels are available for use. For a cellular link a minimum SINR of β_B is required. At each base station there is a margin κ exists in the required SINR.

Macro user (MU) is the first type of user and it communicates by establishes a link with the nearest base station and communicates with required destination by transmitting information. Standard control signaling method is used by the macro users to access the base station. D2D user is the second type of user. In one or more hops D2D users communicate with each other without any assistance by the base station. There is a cluster of radius r where $r << R$ and all D2D users are uniformly distributed within r. One D2D is randomly chosen as a source (S) with data and the other as destination (D). A multi-hop route is only assumed if there is no single hop between the source and destination. The only difference between the macro user and the D2D user is that macro user communicates with the base station and D2D user communicates with each other without being communicated with the base station on the same frequency channels used by macro users. However the SINR of an active cellular link should not fall by more than the allowed κ by D2D's use of those channels. The value of κ should be known by the D2D user and power is calculated accordingly. Using CSMA/CA D2D's randomly access the channel and the link is established using DSR protocol. Finally, for the existence of a D2D link a minimum SINR of β_D must be achieved between a transmitting D2D and a receiving D2D. The difference in the modes of communication of macro and D2D user is either directly or through the base station. In fact both classes of users would be composed of the same type of wireless devices. The base station can't serve the D2D user. The channel model is presented as a network and it consists of three arbitrary users: a transmitter, a receiver, and an interferer.

3.2. Device-To-Device Communication

A dynamic spectrum access protocol is a protocol in which using the same frequency resources the D2D users can communicate directly with each other as an active uplink between a macro user and the base station. This protocol will be opportunistic if the use of the spectrum by the D2D user stays within the interference temperature of the network and the SINR of the cellular link is not decreased by more than the allowed margin then the two device to device users. In order to accomplish this, during the uplink frame of the network the D2D users are only allowed to communicate with each other. The stationary base station will receive interference from the D2Ds during this phase only. Macro users will be uplinked to the base station so they won't receive any interference from the D2D. It is extremely difficult for D2D users to control the interference they cause by assuming the macro user locations and channel conditions. The power control is not affected by the macro user interference but in D2D link quality it will be considered when the SINR thresholds are evaluated.

In the protocol there are two main steps. First step is the power control for D2D users. Because the main determining factor in the protocol's performance will be the power control. After the calculation of power, the second step is discovering a single-hop or multi-hop route by the D2D user to their intended destination.

3.2.1.Power Control For Device-To-Device Users

For the existence of a macro user link with the base station a minimum SINR of β_B is required. Due to interference from a transmitting D2D user at most a κ change will be there in the base station's SINR. A macro user with perfect power control will achieve the required SINR of β_B only if D2D users control their interference perfectly. And by scaling its own transmit power by κ this result can be obtained by the macro user. A macro user link will be having an SNR or SINR with zero interference value of $\kappa\beta_B$ in the absence of D2D interference. By looking at the SNR at the base station the effects of κ in the macro user link can be seen. On rearranging terms, a bound on the transmit power of macro users is given as

$$\frac{P_{T_M} d_{MB}^{-\alpha} \mathrm{h}_{\mathrm{MB}}}{\sigma^2} \geq \kappa\beta_B \quad (1)$$

$$P_{T_M} \geq \kappa\beta_B d_{MB}^{\alpha} h_{MB}^{-1} \sigma^2 \triangleq P_{T_M}^{min} \quad (2)$$

Where $d_{MB}^{-\alpha}$ and h_{MB} are the pathloss and channel gain between a macro user and the base station. Assume that there is a perfect knowledge of the channel gain, the bound in (1) gives a transmit power for macro users so that the probability of outage will be zero.

Then the SINR of a macro user link that is interfered by a single random D2D user is to be evaluated. Consider the D2D as the source S. If P_{TM} taken to be the minimum allowed in (1), after rearranging terms, a bound on the transmit power of a D2D user will get as

$$\frac{P_{T_M} d_{MB}^{-\alpha} h_{MB}}{P_{T_S} d_{SB}^{-\alpha} h_{SB} + \sigma^2} \geq \beta_B \quad (3)$$

$$P_{T_S}^{max} \triangleq (\kappa - 1) d_{SB}^{\alpha} h_{SB}^{-1} \sigma^2 \geq P_{T_S} \quad (4)$$

Where $d_{SB}^{-\alpha}$ and h_{SB} are the pathloss and channel gain between the source and the base station. Assuming that a D2D has perfect knowledge of κ and h_{SB}, the bound in (2) gives a transmit power that a D2D can use and not cause a macro user to go into outage.

3.2.2. Distributed Route Discovery for Two-Way Device-To-Device Communication

DSR is one among the source initiated packet based discovery protocol. The DSR exchanges the address of relay nodes in the network by flooding the network with discovery packets. So the destination will know how to reach the source with the help of a virtual map. As there is diversity in the discovery message by traversing more than one link these flooding techniques are beneficial. The nodes in the route and near to the route will learn of the route's existence by flooding route information through the network. If any conditions like the node mobility or adverse channel conditions affect the route and if the route causes to break, then the nearby nodes can help to repair the route easily. However, flooding causes some problems also especially in terms of interference and overhead. To prevent the looping problems the discovery packets are only allowed to traverse small areas of the network and will never traverse the same link twice. And to ensure that only one D2D accesses the channel at a given time D2Ds employ CSMA/CA. By these rules, the number of discovery transmission can be reduced and thus reducing both the overhead and the interference effects of DSR.

A timer based protocol was used for the relay selection. A random timer was set by each possible relay. At the end of each timer, the presence of each corresponding relay will be broadcasted. The timer's value will be a function of the SNR of the links connecting each relay to the source and destination. The SNR of the channel will also be random in a network of randomly placed nodes with random channel coefficients. The nodes could set an internal timer as a function of the received SNR after receiving a route request packet. The timers will be configured in such a manner that nodes with a good link will have shorter timers. Thus the better links will be able to broadcast their availability first. The timers are inversely proportional to the SNR of the link. The receiving nodes which are located very close to transmitting nodes will have a virtual infinite SNR. To account for this, an additional time value is added.

A packet structure can be modified by including the channel number and transmits power used for transmission as well as the interference power seen by the transmitting node is used. In order to keep the routing overhead small the flooding rules in D2DR will be helpful. In the implementation of D2DR protocol, in addition to their address the forwarding relays are intended to add their transmission power and measured interference power to the discovery packet. In D2D to start transmission source broadcasts packet intended for the destination and it also includes in the packet its transmission power and its own measured interference power, IS. If a single hop is possible then the source (S) communicates over that single hop to destination say D1, or they opt for the multi hop by using R_i relays over a multi hop route to another destination say D2. The D2D destination will have a list of relay nodes after receiving the packet that form a multi-hop route with the D2D source.

3.2.3. Grouping of Users In Clusters

In practical case, the number of users in a network won't be a small number. There will a very large number of users in the network. So the better solution for communication between the users is by the means of a cluster. Clustering is the method of dividing the network into different virtual groups. In order to provide more efficient use of resources for large dynamic networks cluster based control structures can be used. Based on some rules grouping can be done in order to differentiate the nodes allocated to different sub networks. To achieve scalability in presence of large network and high mobility clustering can be used. There will be a set up phase and steady phase for clustering in general case. The main goal of the set-up phase is to make cluster and select the cluster head for each of the cluster. Next phase is the steady phase and it is comparatively longer in duration than the set-up. It deals mainly with the transmission of data aggregated to the base station and the data aggregation at the cluster heads. There are three fundamental steps for the set up phase. To inform the cluster nodes that they have become a cluster head, cluster head sends the advertisement in the first step. The non cluster head nodes are the members of the cluster under that cluster head and they inform the cluster head by sending join request to the cluster after receiving the cluster head advertisement during the second step. Each of the cluster head chosen will create a transmission schedule for the member nodes of their cluster in the last step. According to the number of nodes in the cluster TDMA schedule is created. In the allocated time schedule each node then started transmitting its data.

There should be a cluster head for each group. The cluster head passes on information to the BS after collecting and aggregating the information from nodes in its own cluster. The cluster heads can be selected randomly or based on any particular criteria. Three criteria are used to select CHs including number of neighbors, distance from the base station of the nodes and the residual energy. Ideal cluster head is the one which has the highest number of neighbor nodes, the smallest distance from base station and the highest residual energy. Each node elects itself as a CH based on any particular scheme and its availability is broadcasted to all the sensor nodes present in the neighboring area. The selection of cluster head here is in such a manner that the node which is located at the centroid and node having maximum energy will elect as the cluster head. One of the parameter for determining the communication distance between the nodes is the received signal strength. And based on the received signal strength each non cluster head node decides to which cluster it needs to join. The CH performs aggregation of the packets received from all the nodes present in their cluster.

IV. SIMULATION AND EXPERIMENTAL RESULTS

The network model was simulated in NS2. The performance of the network can be quantified by looking at the power savings and the number of transmissions required for finding a route. The various network parameters used for the simulations are shown in Table I

Table 1. Network Parameters

System Parameters	Value
Cell Radius (R)	2000
Cluster Radius (r)	500
Number of Channels	30
Number of MUs	30
Noise	-104 dBm
Minimum BS SINR	10
Minimum D2D SINR	5
Interference Margin	3

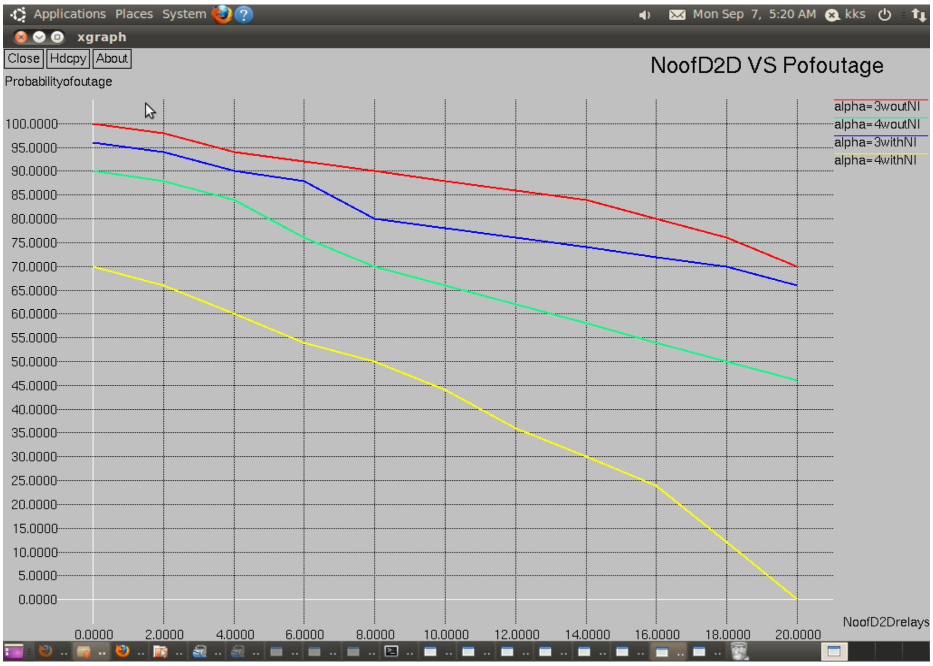

Figure.1. Probability of outage in discovering a two way d2d route

Figure. 1 shows the probability of outage in discovering a two-way D2D route versus the number of available D2D relays (ND) in the cluster. From the graph it can be noted that for a given value of ND, all the relays are not participating in the route connecting the source and destination. As ND increases, the outage rate gets decreased. To overcome high attenuation channels due to large distances and random fading relays which are willing to forward information for the D2D source will be helpful. As α increase, probability of outage gets decreased. Interference from cellular users is lower eventhough each hop in the D2D route sees higher attenuation, and D2Ds interfere with the BS less allowing them to transmit at a higher power.

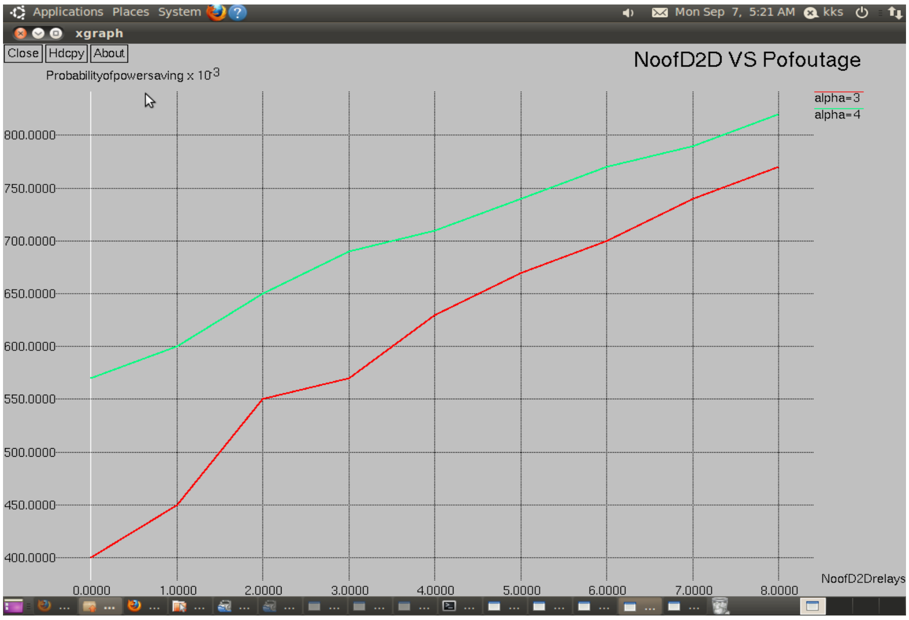

Figure.2. Probability of outage in discovering a two way d2d route

Another parameter for quantifying performance of the network is the power savings when D2D communication with perfect channel gain estimates and statistical estimates are considered. The cellular mode power is calculated to be the sum of the powers for the D2D source to reach the base station, PTSB, and for the base station to reach the D2D destination, PTBD . The D2D mode power is calculated for a route of length NHops as the sum of the D2D's transmit power used in the route where the n'th D2D transmits with power PTDn. Using these powers, the power savings is calculated as

$$P_{save} = \frac{P_{T_{SB}} + P_{T_{BD}} - \sum_{n=1}^{N_{Hops}} P^*_{T_{D_n}}}{P_{T_{SB}} + P_{T_{BD}}} \qquad (5)$$

Figure. 2 shows the power savings in D2D. A single-hop route between the source and destination corresponds to ND equals to 0. Significant amount of power saving can be achieved when α ≥ 3. The D2Ds can communicate more efficiently over shorter distances than longer links with the base station. If α value is a larger then D2Ds become more isolated from the base station making shorter distance hops more efficient.

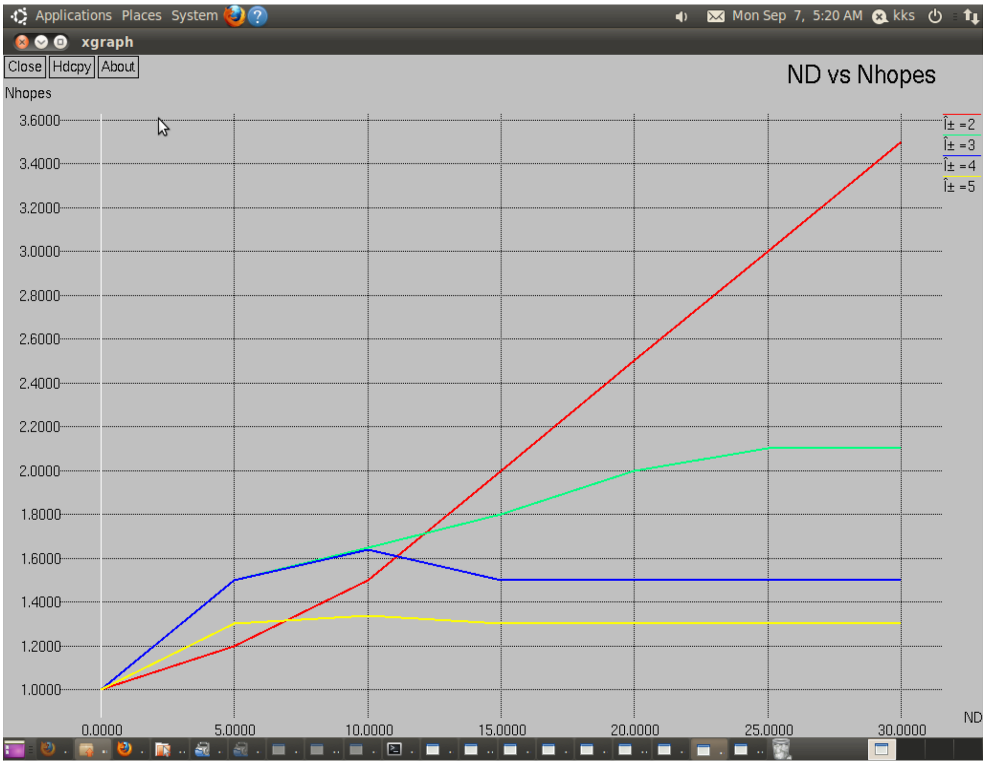

Figure.3. Number of hops (N_{Hops}) for a multi-hop D2D route

The performance of the network can further be quantified by looking the average number of hops (NHops) for a multi-hop D2D route connecting a random source-destination pair. In Figure. 3 we can see as ND increases to large values and for α ≥ 3, the route length starts saturating to a low number of hops and tends to be two hops or less. In the high interference scenario for α = 2, in order to establish a route routes will span higher number of hops. This result shows us that the usually one to two relays can suffice in establishing a two-way D2D route distances and the source and destination try to span are not significantly larger than the single-hop distance. In small pathloss environments to limit the interference to the base station, D2D users must lower their transmit power thus resulting in routes with many hops.

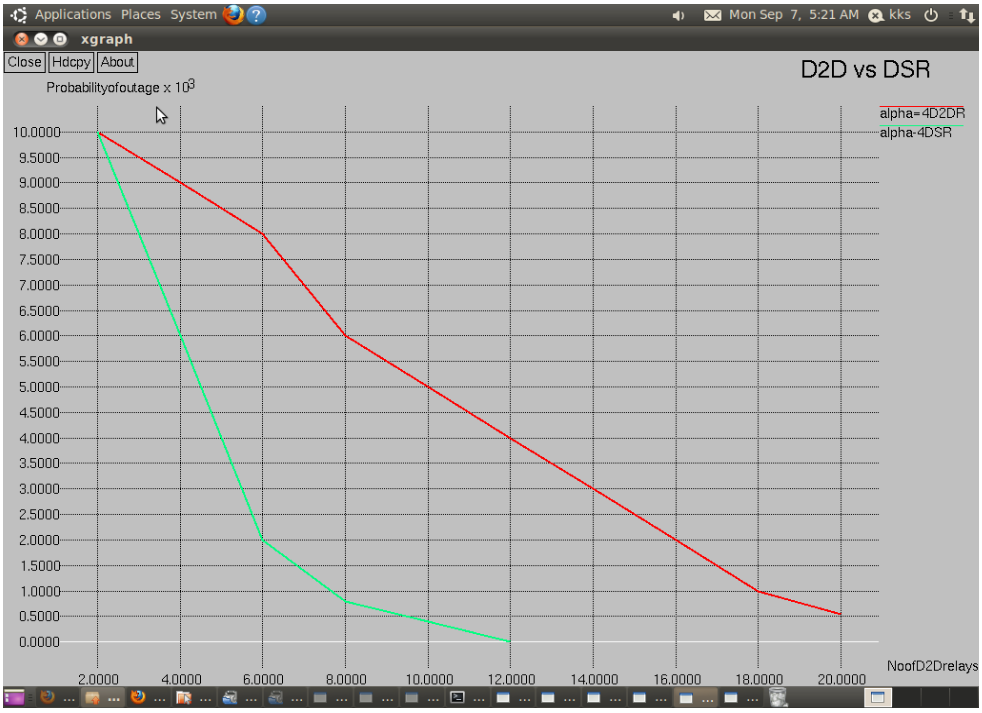

Figure.4. Comparison of D2D protocol and DSR protocol

Figure. 4 shows comparison between D2DR and DSR. It can be observed as the number of available D2D relay increases, probability of outage will get reduced. The path loss α = 4 for D2DR outperforms DSR. D2DR will never discover a 1-way route as done by DSR. With sufficient numbers of potential relays, D2DR increases in discovering a 2-way route.

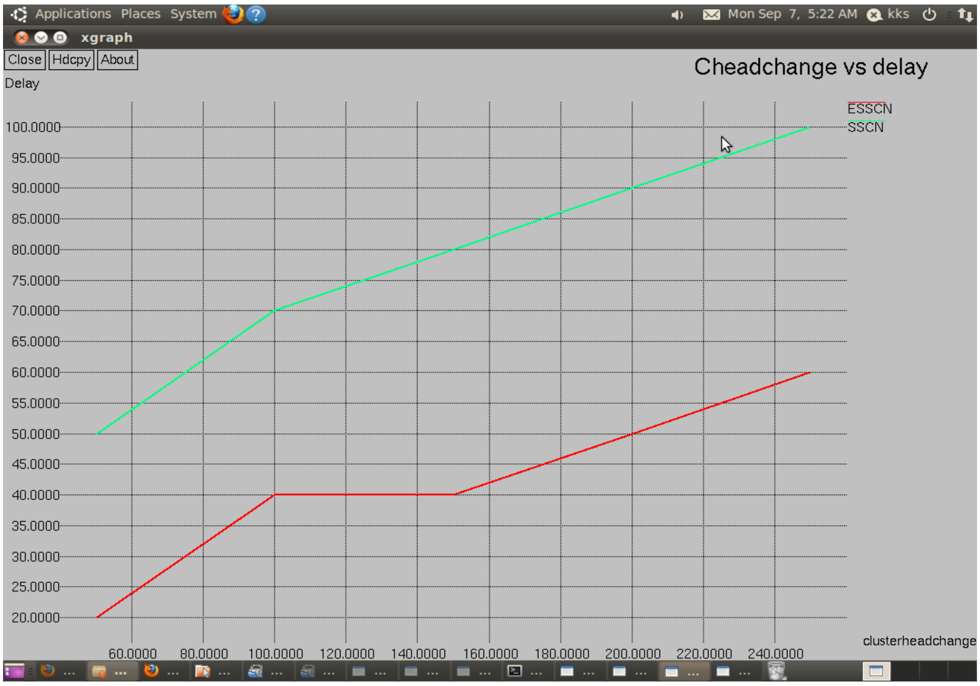

Figure.5. Cluster head change Vs Delay

In Figure.5 we can see a plot between the cluster head change and the delay. In the case of spectrum sharing scheme without clustering, the delay to reach from a source to destination in larger network is very large. So we are going for the clustering in modified spectrum sharing scheme. In the enhanced spectrum sharing the nodes are divided into clusters and the nodes communicate through the cluster heads. Thus the time taken for a transmission to take place between the source and destination is less. The graph shows the delay will be more for the network without clustering.

V. CONCLUSION

A communication scheme in which an ad-hoc Device-to- Device network can simultaneously communicate on the same set of frequency resources as of the macro user is implemented. A practical protocol for D2D's has been developed to use this scheme in a distributed manner and it has no coordination with the base station. From the simulation results it is seen that the modified DSR protocol outperforms the dynamic source routing protocol. To minimize the interference to the base station the power of the D2D user is controlled to a level in the first step. Then employ a discovery protocol to establish a route connecting the source and destination. Results show that on including network information in the discovery packet, the number of transmissions necessary to discover a route to the destination can be significantly reduced. Furthermore, simulation results show that significant power savings can be gained using D2D routes rather than connecting to the cellular base station. For the network with a large number of nodes the network is divided into a number of groups called clusters. Thus the device from different clusters can communicate with each other.

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