Interference Management by Resource Exchange for D2D Communication in Cellular Network

Amel Austine, R. Suji Pramila

Abstract*: *Scarcity in communication spectrum in cellular network is one of the major challenges faced by the service providers around the world. Many efforts were put forth to manage the efficient spectrum distribution among various cells in the network. Reusing the resources by different cells in a safe distance without interference is the current mechanism to improve spectrum efficiency. Spectrum efficiency can be even improved by reusing the resources within a single cell. Device to Device (D2D) communication, a new technology boosts the spectrum reuse inside a cell in 5G. The major hurdle in implementing D2D is in the management of interference in a highly mobile environment. This high mobility risks the life-time of a D2D link and frequent shifting from D2D mode to normal cellular mode will occur. In this paper an effort is put forward to maintain the D2D link as long as possible through a resource exchange mechanism. The exchange occurs when interference by a cellular or D2D link threatens another D2D link. This approach can improve the life-time of a D2D link and thereby improving the consistency of the network.

Keywords*: *Cellular Network, CQI, D2D Communication, Interference Management.

I. INTRODUCTION

Device to Device communication is an innovative proposal to deal with the scarcity in communication spectrum in cellular network. It is a proposed technique for the fifth generation wireless network. Here two devices in close proximity can communicate directly using the cellular resources[1] as shown in Fig. 1.

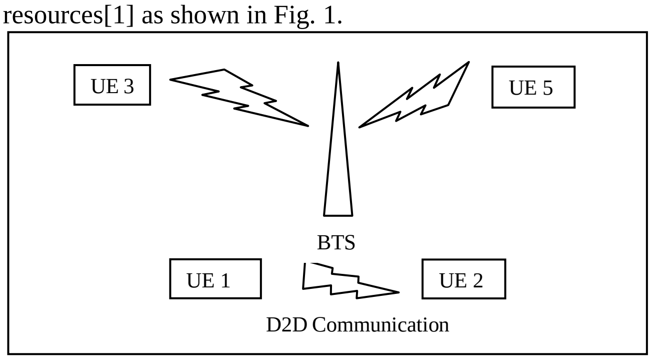

Fig. 1. Device to Device Communication

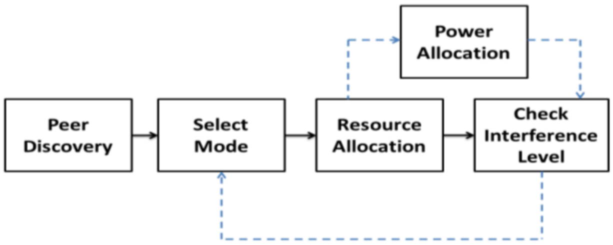

Fig. 2. Challenges in D2D communication

D2D communication replaces the normal 2 hop cellular communication link through a base station to a single hop direct communication link. This reduces the network overhead on the base station and improves the reusability of spectrum. D2D communication mainly addresses five challenges as shown in Fig. 2. They are Peer Discovery for D2D communication, Mode Selection (D2D or Cellular), Resource Allocation and Management, Interference and Power Management. Among them, Peer Discovery and Resource Management play the major role in the success of D2D communication technique.

The common mechanism is to adopt a centralized peer discovery mechanism. In a Centralized peer discovery scheme, peer devices discover each other with the help of a Base Station (eNodeB). Essential information like channel conditions, power control and interference policies based on the network requirements are passed as messages and eNodeB initiates the communication between two devices. Discovering a device which is eligible for establishing D2D link is a tedious task. The devices in a cellular network are expected to be highly mobile in nature. So, two devices in close proximity at a time instant may not be near to each other after some time. Devices may initiate D2D setup and before establishing the connection they may change their position. This situation exhibits the need of proper device discovery with frequent network status verification. That means the procedure needs to be optimized. The eNodeB may completely or partially participate in the device discovery process based on the pre-defined set of practices. It can be a Distributed discovery too, where the devices directly discover a peer for D2D communication.

Mode selection is the guiding factor in resource allocation. The two possible modes are either 2 hop cellular mode, where the devices communicate each other through the base station or the dedicated 1 hop D2D mode where the devices communicate

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* Correspondence Author

Amel Austine*, Department of Computer Science and Engineering, Noorul Islam Centre for Higher Education, Thucklay, India. Email: amelaustine@gmail.com

R. Suji Pramila, department, Department of Computer Science and Engineering, Noorul Islam Centre for Higher Education, Thucklay, India. Email: sujisymon@gmail.com

directly using the cellular resources. Once the peer device is identified and communication mode is selected, next step is to allocate the channel for the D2D link. Number of strategies tried and proposed in many works. Few of them became standards in the cellular network scenario. The selection of channels can be either from licensed band (In-band/Controlled) or from unlicensed band (Out-band/Autonomous). Resources may be Base station (BS) controlled or Device controlled.

Many mechanisms were adopted in many studies for proper allocation of channels for cellular links and D2D links. The resource allocation mechanism is the key factor in managing the interference between different links within a cell. The best mechanism to avoid interference is found to adopt the Overlay mechanism either in the entire cell or in different sectors in a cell. Here the portion of the spectrum is specifically allotted for D2D links. Whereas in an Underlay mechanism the available spectrum in a cell is totally shared among both cellular links and D2D links. Another common approach is the use of different transmit-power for both cellular link and D2D link. Similarly the varying power allocation for different RBs in a sectored cell also can effectively manage interference.

The paper is structured as follows. Section II discusses related works on device to device communication. the base for our proposed methodology is stated in Section III. Section IV discusses the system model. The experimental results are discussed in Section V. Finally, the conclusion is presented in Section VI.

II. RELATED WORKS

Many previous works took effort to efficiently identify the peer for D2D communication in a distributed manner. Huan Tang et al. [2] develop a D2D neighbour discovery method where the peer discovery of a potential partner by a UE is done by listening to cellular uplink channels. Bentao Zhang et al. [3] proposed a social-aware peer discovery scheme for D2D communications. Here the social network characteristics are exploited in device centric peer discovery.

In the cellular and D2D modes, the resource allocation is centralized that means it is controlled by the eNodeB. Kun Zhu and Ekram Hossain [4] proposed a mode selection framework, potential D2D UE can select a mode itself considering the noticed performance and the cost. Xingqin Lin et al. [5] proposed a tractable hybrid network model and a unified performance analysis approach for D2D communication. In this work they had considered distance based D2D mode selection. G, Nardini et al. [6] proposed a framework where an aggregator is used to assist the mode selection. Yanru Zhang et al. [7] proposed an innovative social aware approach to optimize the Direct communication between devices. The two layers called the social network layer and the physical wireless network layer used to do this. Wentao Zhao et al. [8] studied a resource sharing pattern for D2D communication in an undelaying cellular network. In this case, it is allowed to share subchannels among both multiple D2D pairs and multiple cellular users. Setareh and Slawomir [9] suggested a centralized and distributed channel allocation scheme for D2D communication. For cellular user, data stream is transmitted with fixed average power. Whereas each D2D user selects an integer valued power valued some a predefined set.

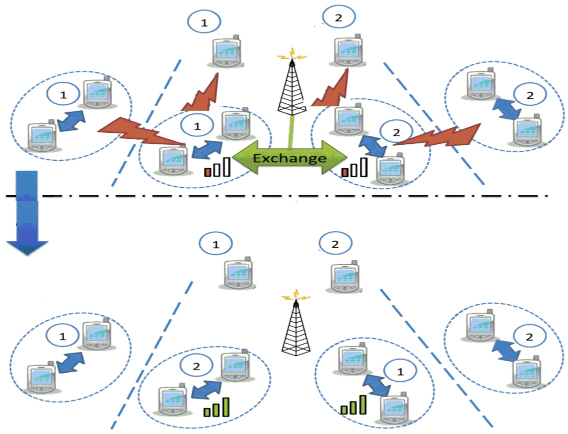

Fig. 3. Cellular Resource Exchange

III. RESOURCE EXCHANGE

The mobility of devices in cellular network imposes many hurdles in maintaining a connection. In cellular mode, if the signal strength reduces with the mobility of devices, usually the system initiates a hand off procedure. In the D2D mode the risk of interference is high as each cell reuses its own channels for spectrum efficiency. In D2D mode hand off is not a feasible solution, ie, to provide a new channel. In basic mechanism when the signal strength reduces below a threshold the D2D connection breaks. So in D2D Communication instead of switching the mode to cellular mode, in this system it checks the possibility of exchanging the resources of nearby links without affecting the communication in the cell.

Fig. 3 shows the representation of the proposed resource exchange framework in the cellular network. The resource reuse in the same cell will introduce interference due to the movement of mobile devices in the cell. In normal situation this interference will badly affect the communication. A solution for this situation is by exchanging the RBGs between possible links as shown in the figure 3. It is seen in the upper diagram that the introduction of the D2D link with RBG 1 in the centre portion introduces interference to the D2D link at the LHS with RBG 1 and the cellular device on top with the same RBG. If we can found any other link with a different RBG which will not introduce any interference in the affected area we can initiate an exchange of RBGs between these links. It should be noted that the RBG 1 should not introduce any interference in the new area. The lower diagram shows the network status after the RBG exchange.

In an existing work Chih-Yu Wang et al. [10] demonstrated a concept of resource exchange, which was performed based on a trader assisted mechanism. In that work it is assumed that UE compete for RBGs with based on their preference. A preference matrix is created and based on that a resource exchange graph was created. In each iteration, the UE's preference is granted to remove cycles from the graph. This operation performed until all the UEs acquire the desired RBG. It is found that the mechanism is based on overlay resource allocation. In their framework they allocate a set of RBGs dedicated for D2D communication only. It is applied

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for a small service area too. But it is found that the framework fails to consider the entire cellular system. They were only focusing on the resource exchange mechanism, considering their own experimental setup, where few D2D pairs were considered in a small service area. The concept is not applicable in a broad view of a cellular system as the preference of each UE cannot be granted as they will be many UEs competing for the same RBG.

Resource exchange can ensure more consistency of a link between two devices in direct link. Here comes the need of adapting the concept in a broader way. That is to the entire cell with both cellular links and D2D links. We cannot consider the preference of UEs in resource allocation. Resource allocation need to be done by the eNodeB by analyzing the current status of the cell. At this point we are not specifying the resource selection mechanism. Any conventional resource allocation technique can be followed. We are focusing on the possibility of introducing resource exchange to a cellular system and maintain D2D links with minimum interference and maximum life time.

IV. SYSTEM MODEL

In this paper the resource exchange idea is adopted to a complete cellular framework. A cell with one base station, P D2D pairs and Q cellular links are considered here. As shown in Fig. 3. both the D2D pair and cellular devices are considered. The framework is based on a base station (eNodeB) controlled mechanism. The decision on mode selection, (that is communication through D2D link or normal cellular link), resource allocation, channel monitoring etc are governed by the base station itself. In the proposed framework, we define an underlay mode, where the available spectrum in a cell is shared by both the D2D links and cellular links. Even though in the existing work, it adopts an overlay mode, which is mainly applied for special purpose services using a dedicated spectrum for direct device services holding multiple contiguous or non-contiguous narrowband spectrum licenses. But it will not ensure the spectrum efficiency as the availability of resources for reuse will be limited.

Apart from the trader assisted mechanism, in this work we consider two factors. The interferences due to the increasing number of D2D pairs in a cell and the number of RBGs assigned to a cell in order to initiate the resource exchange. Figure 4 shows the system architecture of the proposed system.

In this system, cell is managed by the base station (eNodeB) itself. So the eNodeB will be having enough information regarding the spectrum and devices under the corresponding cell. So the peer identification can be easily done with the help of eNodeB, which is more advantageous than peer discovery by the UE itself.

A distance based mode selection is adopted here for the formation of the D2D association. A mode selection threshold µ is initialized and depends on the distance between the peer devices of D2D communication D, either conventional infrastructure mode or D2D mode is selected. That is, if D > µ infrastructure mode is selected else it will go for D2D mode. We have selected the value of µ as 10m for simplicity. To calculate the distance between two user equipment (UE) to establish D2D link, we need to identify the position of the device in the cell.

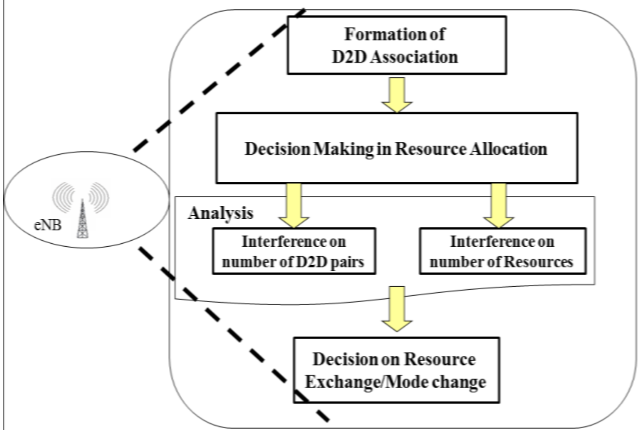

Fig. 4. System Model

Many techniques are available to locate the position of user equipment in LTE. Several techniques like GPS, Cell ID, Time of Arrival, Angle of Arrival etc can be applied to locate the devices. Once the location is identified the eNodeB can easily find the distance between two devices in the cell and can allow direct communication between them. Now resource (resource group blocks - RBG) is allocated to both cellular user and D2D user as the LTE-A scheme.

The planned RBG is allotted to a new link if and only if it will not introduce any sort of inconsistencies in the network. Here we are considering the interference level. For that the channel quality indicator (CQI) is used here. CQI is a 4-bit integer and it is calculated based on the observed value of signal to interference plus noise ratio (SINR) at the UE. The value of SINR is calculated for each set of RBs using the received reference signal power for each cell and the total interference in every period of measurement. It is calculated using the equation (1);

$$CQI_{dB}(n) = \Delta_Q \lfloor SINR_{dB}(n)/\Delta_Q + 0.5 \rfloor \quad (1)$$

where Δ_Q is the reference signal power of the RBG n.

The CQI is measured as integer multiples of transmission time interval. The CQI measurement typically consists of four basic steps: 1) measure the SINR over the bandwidth of interest. It can be sub-band or wideband. 2) Introduce measurement error to the measured SINR 3) convert the SINR value to discrete CQI values and 4) finally report the CQI using PUCCH or PUSCH. The reported CQI values are used by the eNodeB for the link allocation. Based the value of CQI, usually between 2>CQI<15, the user equipment used to prepare a preference matrix and which was used for the resource exchange in an existing work. In this work, as it is a more centralized approach, if the CQI is low, the eNodeB first tries to find out another channel with better CQI. It can be a channel which is already allocated to a cellular user or another D2D pair. If it will not affect the existing link the eNodeB initiates a resource exchange and the new link will not affect the consistency of the cellular system. If no such pair is found for exchange the communication mode between those two devices will change to the normal cellular link, where the devices communicate through the base station. The CQI is analyzed frequently to maintain the cell status without affecting the system efficiency and consistency through proper resource exchange.

V. RESULT AND DISCUSSION

The proposed technique is simulated in NS3. The Interference is the main factor used to analyze the reusability of resources in a cellular system. In a normal scenario interference will increase with an increase in the number of D2D pairs with a fixed number of RBGs in a cell and it will reduce the interference with the increasing number of RBG. These two scenarios are analyzed and compared with an existing work [10] where the resource exchange only in a D2D environment was considered. The resource exchange was purely based on the preference matrix of the UEs. In this paper the scenario is adapted to an entire cellular system.

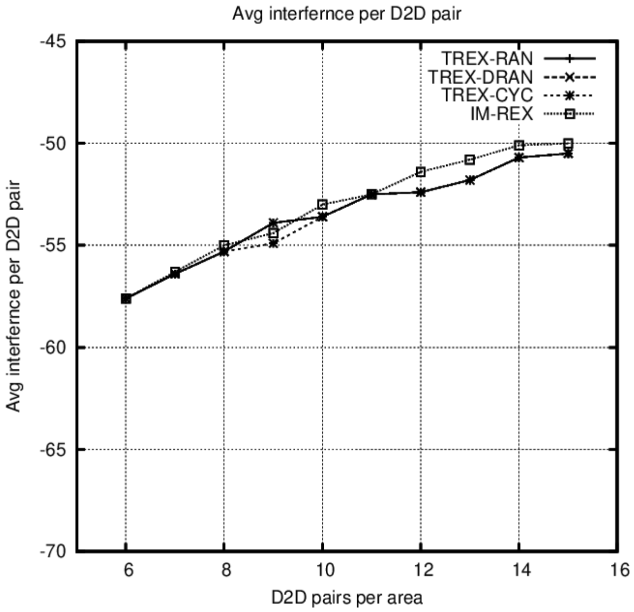

Fig. 5. Interference Vs D2D pairs per area.

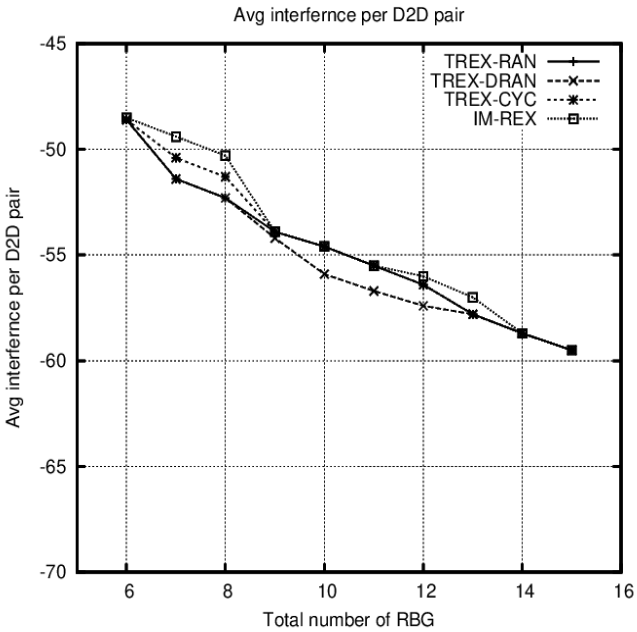

Fig. 6. Interference Vs Total number of RBG

The resource exchange is based on the interference values. It is found that, comparing with the existing work the complexity is increased because of more aspects are considered and the number of devices also increased in this work. Still the performance is close to the existing work. The results for the two scenarios are depicted in Fig. 5 and Fig. 6. The simulation results are compared with three similar approaches where resource exchange technique was implemented. They were based on a Trader Assisted Resource Exchange (TREX) mechanism. Techniques were Random, D2D Random and Cyclic. In the first scenario a liner increase in interference is occurred, and when it reaches the maximum, that is the corresponding CQI value is less than 2 the link breaks and the communication mode will switch back to the normal cellular mode. In the second scenario a dynamic resource allocation scenario is represented. Here the interference is measured for various number of RBGs. It is found that the interference reduces with the increasing number of RBGs as the possible resources for reusability is increasing. Thus more D2D links can be maintained with minimal interference.

VI. CONCLUSION

We tried to adapt the concept of resource exchange in cellular network in this paper in order to maintain the consistency of links in a cell, especially the D2D links. We applied the concept in both cellular user as well as the D2D pairs. The distance between the two devices is the initial guiding factor to establish a D2D link. Simply considering the CQI reported by the UE may not be effective in resource exchange. So the eNodeB can properly measure the quality of link and the measured interference can be the guiding factor for resource exchange. Interference experienced by the D2D links was assessed. Since we considered both cellular and D2D links we could not achieve a great improvement in the performance. Still the results shows that the mechanism can contribute a lot to the proximity based communication especially in the D2D communication in a diverse dynamic cellular system. By proper D2D association and proper analysis of network metrics we can improve the performance to a great extent. Instead of relaying in metric reported by the UE we can use algorithms like Ant Colony Optimization to properly assess the channel quality in order to allow the direct communication by devices.

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AUTHORS PROFILE

Amel Austine, is pursuing his PhD from Department of Computer Science and Engineering at Noorul Islam Centre for Higher Education, Tamil Nadu INDIA. He completed his M.Tech in Software Engineering from Karunya University Coimbatore, India in the year of 2011. He Completed his BE from APIIT, Panipat, India in the year of 2008. He had published 7 papers in International Journals. His area of interest includes Mobile Computing, Computer Networks and Software Engineering.

R Suji Pramila is working as an Associate professor in the Department of Computer Science and Engineering at Noorul Islam Centre for Higher Education Tamil Nadu INDIA. She obtained her PhD. Degree in Security Enhanced Automated Patient Monitoring System from Noorul Islam Centre for Higher Education and ME degree from SRM University in the year of 2005. She did her BE degree from St.Xavier's Catholic College of Engineering in the year of 2003.She had published numerous papers and few books. Her research interest includes Wireless sensor Networks, E-Healthcare, Wireless networks, and Mobile communications.