Post-Resource Sharing Power Allocation in Cellular Networks to Coexist with D2D Underlay

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***Abstract*—Device to Device communications (D2D) is considered as a key technology component in fifth generation (5G) of mobile communication, which anticipates higher user density and traffic volume than in present. D2D communication aims to offload base station from traffic routing by enabling direct link between communicating devices in proximity. D2D underlay allows a D2D pair to reuse resources with a cellular link, leading to better spectrum utilization. However, D2D transmission causes significant interference to cellular link with which it reuses physical resource block (PRB), thereby hindering cellular performance. Regulating D2D transmissions to mitigate the aforementioned problem would mean sub-optimal exploitation of D2D communications. As a solution, post-resource allocation power control at cellular users is proposed in this paper. Three schemes namely interference aware power control, blind power control and threshold based power control are discussed. Simulation results show reductions in dropping of cellular users due to interference from D2D transmissions, improvement in throughput at base station (uplink) while not hindering the D2D performance.**

***Index Terms*- 5G, D2D communication, power control, resource allocation, context awareness**

I. Introduction

Mobile communication is one of the most ubiquitously used technologies in the world, evolving towards its fifth generation (5G). Wireless data traffic is anticipated to be in order of 1000 times more in 2020 as opposed to 2010 and the number of connected devices will be 10 to 100 times more [1]. Management of such large density of users and traffic volume are major concerns for network operators in 5G.

Device to Device (D2D) communication is a concept where mobile users in close proximity can communicate over a direct link between them without routing their traffic via base station [2]. D2D is treated as an important technology in 5G, capable of managing high user density and data volume [1]. D2D communication can be carried out in two major ways, namely: 1) Overlay: D2D communication takes place over dedicated spectrum [2]. 2) Underlay: D2D links and conventional cellular links share the available spectrum in a cell for their transmissions [2]. D2D underlay allows for better spectrum utilization but, mutual interference among D2D pairs and cellular users (CUE) would hamper the SINR at receivers, there by reducing the performance.

There are several resource allocation schemes in literature that discuss resource reuse between D2D pairs and CUEs that would cause minimum interference to each other [2][3]. Further, several proposals are made to regulate transmission power of D2D users to mitigate interference[3][4]. Some proposals emphasize on selection of either D2D or conventional modes of transmission based on constraints of SINR, throughput etc,[3][5], and some allow the usage of D2D only in a specified region [6] fairly away from base station. However, majority of these schemes impose restrictions on usage of D2D communications, hence maximum benefit cannot be reaped from D2D communications at all times. On the contrary, D2D links would pose high interference to cellular links with which they reuse PRBs and cause significant dropping of cellular connections due to interference.

In this work, we propose post-resource allocation (RA) power control for cellular users as a solution against interference caused by D2D transmissions on shared PRBs. Three post-RA power control (PC) schemes namely: Interference aware PC, blind PC and threshold based PC are introduced. Simulation results demonstrate that proposed schemes reduce dropping of cellular connections, improve cellular throughput while not hindering D2D performance.

II. Post-Resource Allocation Power Control

A. Interference Aware Power Control

This scheme is carried out on the CUEs sharing PRBs with D2D users. CUEs which have their SINR lesser than target SINR due to interference, will be boosted with power levels sufficient to overcome the interference. Equations 1 and 2 are similar to LTE open loop power control [7], but has been designed to overcome interference from D2D transmission along with pathloss compensation. The logic of the scheme is described in algorithm 1. Denotations of terms used in algorithm 1 are as below,

- $SINR_{cue} \Rightarrow$ SINR of relevant CUE
- $SINR_t \Rightarrow$ intended target SINR
- $\alpha \Rightarrow$ path loss compensation factor
- $PN_0 \Rightarrow$ average noise power per PRB
- $NF \Rightarrow$ noise figure at base station
- $M_0 \Rightarrow$ number of PRBs
- $PL \Rightarrow$ pathloss of the CUE w.r.t base station
- $P_{cue} \Rightarrow$ power allocated to CUE
- $\tilde{I}_{D2D} \Rightarrow$ estimated interference from D2D pair

Data: Obtain CUEs sharing PRBs with D2D pairs

if $SINR_{cue} < SINR_t$ **then**

$$P_0 = \alpha * (SINR_t + IN) + (1-\alpha) * (P_{max} - 10log_{10}(M_0)) \quad (1)$$

where, $IN = (PN_0 + NF)_{dB} + \left(\tilde{I}_{D2D}\right)_{dBm}$

$$P_{cue} = P_0 + \alpha * PL + 10log_{10}(M_0) \quad (2)$$

else

Continue without changing P_{cue}

end

Algorithm 1: Post-RA Interference Aware Power Control

Interference from a D2D pair on a PRB shared with a CUE is given as,

$$\tilde{I}_{D2D} = P_D - \tilde{P}L_{Dbs} \quad (3)$$

$P_D \Rightarrow$ Power level of D2D transmitter

$\tilde{P}L_{Dbs} \Rightarrow$ Estimated pathloss between D2D transmitter and base station

B. Blind Power Control

This algorithm doesn't require estimation of interference caused by D2D transmissions, thus highly reducing complexity. However, if $SINR_{cue} < SINR_t$, then predefined power step ($step_{blind}$) is blindly added to transmission power of CUE. The idea of the scheme is similar to algorithm 1, but eq. 1 and eq. 2 are replaced with eq. 4 and eq. 5 respectively.

$$P_0 = \alpha * (SINR_t + PN_0 + NF) + (1-\alpha) * (P_{max} - 10log_{10}(M_0)) \quad (4)$$

$$P_{cue} = P_0 + \alpha * PL + 10log_{10}(M_0) + step_{blind} \quad (5)$$

C. Threshold Based Power Control

This approach neither requires interference estimation nor chooses power step blindly. The algorithm design is similar to blind power control but the power step is not blind and is derived based on certain logic. The principle of algorithm is same as blind PC, but eq. 5 is replaced with eq. 6.

$$P_{cue} = P_0 + \alpha * PL + 10log_{10}(M_0) + step_{th} \quad (6)$$

Unlike blind power control, power step chosen in this algorithm is correlated with SINR of corresponding CUE. An example logic to derive power step ($step_{th}$), based on SINR thresholds is described in algorithm 2. The resolution of SINR thresholds and power steps corresponding to different interference situations can be customized by network operators as required, by monitoring D2D scenario and resulting SINR degradations over a period of time.

if $(SINR_t - 3) \leq SINR_{cue} < SINR_t$ **then**

$step_{th} = 1\ dB$

else if $(SINR_t - 6) \leq SINR_{cue} < (SINR_t - 3)$ **then**

$step_{th} = 4\ dB$

else if $(SINR_t - 9) \leq SINR_{cue} < (SINR_t - 6)$ **then**

$step_{th} = 7\ dB$

else if $SINR_{cue} < (SINR_t - 9)$ **then**

$step_{th} = 10\ dB$

else

$step_{th} = 0\ dB$

end

Algorithm 2: Example SINR-threshold based power step deduction

III. Simulation Results

A single cell scenario is considered with a base station at center, enabled with LTE radio access technology. The cell radius is $500m$ and has 10 MHz bandwidth (50 PRBs) [8]. 50 cellular users (CUEs) and 50 D2D users (25 D2D pairs) are uniformly distributed in the cell. The resource reuse factor is 1, which means a D2D pair can reuse a PRB from only one unique CUE. A simple distance based resource allocation [2] is implemented. The simulation parameters are listed in table I. The key parameters for power control are chosen as $\alpha = 1$, $M_0 = 1$ and $PN_0 = -121dBm$ [7].

TABLE I

Simulation Assumptions

Parameter	Value (C-Mode)	Value (D-Mode)
Max Transmit Power (UEs)	24 dBm	24 dBm
Min Transmit Power (UEs)	-40 dBm	-40 dBm
Power Control	Open Loop [7]	Open Loop [7]
Noise Figure	5 dB	7 dB
SINR Target (Rx)	-4 dB (eNB)	2.5 dB
Channel Model	3GPP [8]	3GPP [9]

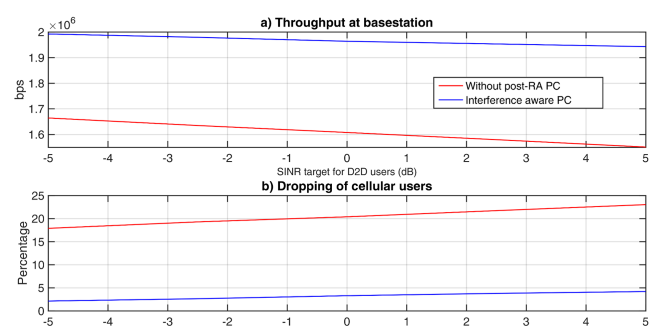

Fig. 1. Improvements after interference aware PC

In each case, simulations are executed for 100 runs and average performance metrics are obtained.

Performance of interference aware PC at CUE is evaluated against D2D SINR targets ranging between -5 dB to +5 dB. Figure III a) shows enhancement in throughput at base station resulting from interference aware PC at CUEs. It can been seen that with increasing SINR target at D2D, throughput at base station declines due to interference. However with interference aware PC, throughput performance proves to be stabilized. It can be seen from figure III b) that interference aware PC reduces cellular dropping by around 20% for whole range of considered D2D SINR targets. It was also observed that rise in interference at D2D receivers due to interference aware PC at CUE, is so low that there is no negative impact on performance of D2D transmissions.

In order to evaluate the performance of blind PC, power steps ranging from 0 to 5 dB are chosen. Figure III a) depicts that with increase in value of power step, throughput at base station increases. However, for the considered simulation parameters, target data rate would have been reached (indicated in green) at power step value of 3 dB. The power steps above this are unnecessary and are used here to reflect wastage of power resources. Therefore, choice of power step is a key concern in blind power control. Figure III b) indicates that blind PC reduces dropping by only 2-3% for all the considered range of power steps. This is because blind PC would add power in surplus than required for some users, where as in some cases added power would not be sufficient to overcome high interference and CUE would still be dropped.

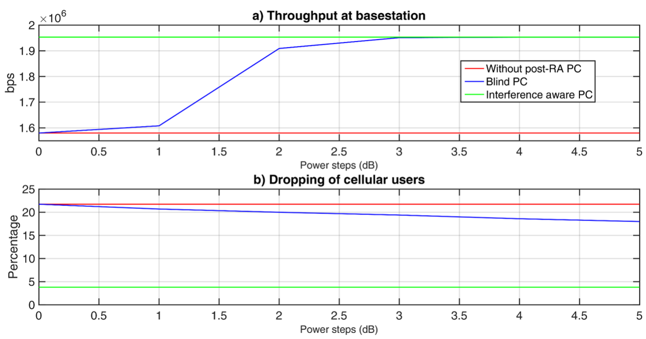

Fig. 2. Improvements after blind PC

Finally, threshold based PC is incorporated and compared with interference aware PC and blind PC. Based on the results in figure III, power step of 3 dB is chosen for blind PC. It could be seen from figure III b) that dropping of CUEs are reduced by around 8% . Figure III a) compares the throughput at base station. It could be seen that post-RA power control improves cellular performance without hampering D2D transmissions. Further, interference aware PC outperforms rest of the PC schemes. However, it is suggestible to use interference aware PC when there is room for efficient interference estimation (cost and complexity wise) and switch to threshold based dynamic power control if not. Whenever, neither interference estimation nor efficient SINR estimation is possible, system can fall back on blind PC.

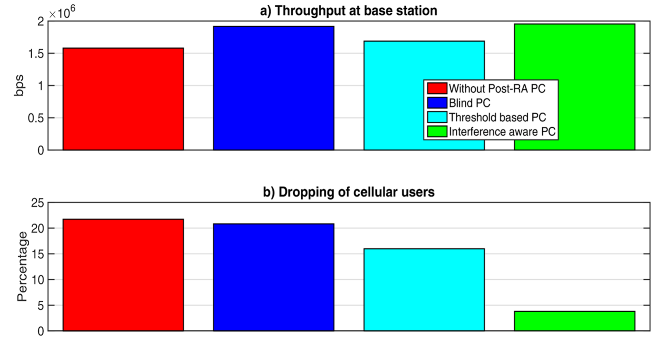

Fig. 3. Improvements after threshold based PC

IV. Conclusion and Future Work

D2D communication is considered a key technological component in 5G. Allowing D2D underlay leads to better spectrum utilization, but high interferences from D2D transmissions reusing same PRBs as uplink transmissions of CUEs, hinder the performance of CUEs. In this paper, we presented post-resource allocation-power control at CUEs as a viable solution. Three discrete schemes namely, interference aware PC, blind PC and threshold based PC were presented. Simulation results demonstrated, reduction in dropping of CUEs and improvement in throughput at base station, while not hindering the D2D performance. One of the key directions for future work is to investigate further on efficient interference estimation techniques to obtain interference estimate from D2D transmitters.

V. Acknowledgment

Part of this work has been performed in the framework of H2020 project METIS II, which is partly funded by the European Union. The authors alone are responsible for the content of the paper.

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