Quality of Service Tradeoff in Device to Device Communication Underlaid Cellular Infrastructure

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Device-to-device (D2D) communications underlaid cellular infrastructure is an competitive local area services technology to promote spectrum usage for next generation cellular networks. These potential can only be tap through efficient interference coordination. Previous works only concentrated on interference from D2D pairs whiles interference from CUs to D2D pairs were neglected. This work focus on solving uplink interference problem emanating from multiple CUs sharing its resource with multiple D2D pairs. The base station (BS) acting as a supervisor selfishly institute a pricing scheme to manage the interference it experience from D2D pairs based on its Quality of service (QoS) requirement. D2D pairs following the supervisor make power allocation decisions considering the price from the BS in a non-cooperative game fashion. In order for the D2D pairs to also meet their QoS requirement, they suggest a price to the BS called discount price which reflects the interference they receive from the CUs. Finally, we analyze the proposed approach.

Index term: discount price, power control, game theory, interference management.

Ⅰ. Introduction

Device-to-device communication is a local area technique to allow device in close range to communicate without passing through the BS. It is key integral part of the third generation partnership project (3GPP) long term Evolution-Advanced (LTE-A) systems. CUs sharing radio resource with D2D pairs brings about interference from D2D pairs to CUs and also from CUs to D2D pairs. Failing to handle this interference problem could tend to damage the QoS of users. Therefore, a robust interference management scheme is required to manage the interference from D2D transmission.

Recently, various interference management technique has been developed to allow multiple D2D pairs to reuse the radio resource of multiple cellular users while managing the interference from D2D transmission. In [1], [2], a selfish pricing scheme was developed at BS to control the interference from D2D transmission however, interference from CUs to D2D pairs was not accounted for. In [3], the author proposed a merge-and-split scheme to develop an overlapping coalition game with the objective of maximizing the system sum-rate, nevertheless the performance is damped by high signalling amongst D2D pairs.

In this work, we designed a distributed interference management scheme for D2D system to obtain a balance between the QoS of CUs and D2D pairs. Interference from D2D transmission is handled selfishly via a pricing scheme. On the contrary, D2D pairs compete for the subchannels in a non-cooperative game way. In order to ensure a balance between the QoS of CUs and D2D pairs, we adopted an idea of discount pricing scheme to design efficient pricing scheme to tackle the interference.

Ⅱ. System Model

An uplink orthogonal frequency division multiple access (OFDMA) for device to device communication underlaid cellular network is designed. The system is made up of cellular tier and D2D tier. There are N subchannels, D D2D links and M cellular links. Subchannels are exclusively assigned to the cellular users so there is no interference amongst CUs. D2D pairs reuse the subchannel of CUs therefore there exist interference from D2D pairs to CUs and from CUs to D2D pairs. let $D2D_d$ be D2D pairs and CU_m be cellular users. Let $D2D_{Tx}$ and $D2D_{RX}$ be D2D transmitter and receiver respectively. let p_d and p_m be the transmit power vector of $D2D_d$ and CU_m respectively. The signal to interference plus noise (SINR) ratio of the both D2D pairs and cellular users are formulated as

$SINR_d^n = \frac{p_d^n h_{d,d}^n}{p_m^n h_{m,d}^n + \sum_{d \neq j}^{D} p_j^n h_{j,d}^n + 1}$ and $SINR_m^n = \frac{p_m^n h_{m,o}^n}{\sum_{d=1}^{D} p_d^n h_{d,o}^n + 1}$ respectively while the rate of $D2D_d$ and CU_m are expressed as $R_d = \sum_{n=1}^{N} \log_2(1 + SINR_d^n)$, and $R_m = \sum_{n=1}^{N(m)} \log_2(1 + SINR_m^n)$.

Ⅲ. Problem Formulation

In the uplink D2D communication scenario, the victim of the interference from D2D transmission is BS hence the BS manage the interference by imposing a price on reused subchannels based on its QoS with no consideration of the QoS of D2D pairs. The QoS of CU_m is formulated as

$$R_m \geq r_m \ , 1 \leq m \leq M..$$

D2D pairs acting as followers, adapt their power levels in a non-cooperative game way.

3a. Non-cooperative game amongst D2D pairs

Each D2D pair player solve the optimization below to update their power

$$\max_{p_d \in P_d} \ U_d = R_d - \lambda^n \sum_{d=1}^{D} p_d^n h_{d,o}^n.$$

The convexity of the above problem permits us to obtain the optimal solution by adopting KKT systems. therefore, the optimal solution is obtained as

$$p_d^n = \frac{1}{\ln 2 \lambda^n h_{d,o}^n} - \frac{\sum_{d \neq j}^{D} p_j^n h_{j,d}^n + p_m^n h_{m,d}^n + 1}{h_{dd}^n}.$$

For equilibrium analysis of the game refer to reference[1].

3b. Cellular Link Interference Coordination (CLIC)

For each cellular link to update the price the BS solve the optimization below

$$\min_{p_m \in P_m} \lambda^{n,m} \sum_{d=1}^{D} p_d^n h_{d,d}^n$$

$$s.t$$

$$R_m \geq r_m$$

$$p_d^n = \frac{1}{\ln 2 \lambda^n h_{d,o}^n} - \frac{\sum_{d \neq j}^{D} p_j^n h_{j,d}^n + p_m^n h_{m,d}^n + 1}{h_{dd}^n}$$

By solving the above problem the optimal reuse price is obtained as

$$\lambda^{n,m} = \frac{D}{\frac{p_m^n h_{m,o}^n}{2^{r_d} - 1} - 1 + \frac{h_{d,o}^n (\sum_{d \neq j}^{D} p_j^n h_{jd}^n + p_m^n h_{m,d}^n + 1)}{h_{d,d}^n}}.$$

However, the above price does not reflect the QoS of D2D pairs. Therefore, for the $D2D_d$ to also meet their QoS they suggest a price to BS to take into consideration when updating the reuse price. This price reflects the QoS of D2D pairs. The QoS of D2D pairs is expressed as

$$R_d \geq r_d \ , 1 \leq d \leq D.$$

At nash equilibrium, upper bound of the suggested price by each D2D pair on subchannel n can be formulated as

$$\pi_d^n \leq \frac{h_{d,d}^n}{h_{d,o}^n (2^{r_d} (p_m^n h_{m,d}^n + \sum_{d \neq j}^{D} p_j^n h_{j,d}^n + 1)) \ln 2}.$$

When the BS receive the suggested price, it selects the minimum price as follows

$$\pi_{d,\min}^n = \arg\min_{d \in D} \pi_d^n.$$

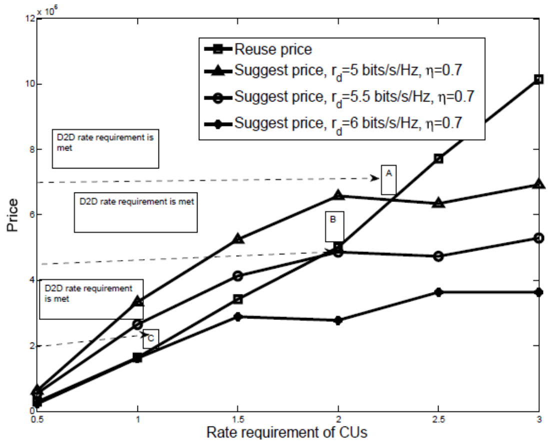
The BS then update the price by finding a balance between the reuse price and suggested price via a weight scheme μ which represents the balance between the QoS of $D2D_d$ and CU_m.

$$\lambda^n = \mu \lambda^{c,m} + (1 - \mu) \pi_{d,\min}^n.$$

When only QoS of CUs is under consideration, the BS set the $\mu = 1$ else the weight is set a predetermined value $\mu = [0,1]$.

Ⅳ. Results

We compare the evolution of the suggested price against the optimal reuse price. Increasing the data requirement of D2D pairs leads to decrement of the suggested price hence D2D pairs needs higher data requirement. At point A, B and C, both the rate requirement of D2D and CU is met which shows that a tradeooff exist between data rate of D2D pairs and that of CUs.



Ⅴ. Conclusion

In this work, a QoS tradeoff in D2D communication is analyzed. Using the idea of discount pricing an efficient pricing scheme which consider both the QoS of CUs and D2D pairs was developed. The proposed scheme is flexible, robust with low computational complexity and signaling.

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References

[1] G. Yu, L. Xu, D. Feng, R. Yin, G. Li, and Y. Jiang, "selection and resource allocation for device-to-device communications,"Communications, IEEE Transactions on, vol. 62, no. 11, pp. 3814 - Nov 2014.

[2]Yin R, Yu G, Zhang H, Zhang Z, Li G. Pricing-based interference coordination for d2d communications in cellular networks. Wireless Communications, IEEE Transactions on March 2015; 14(3):1519 - /TWC. 2014.2368151.

[3] Xia XS C, Kwak KS. Overlapping coalition formation games-based resource allocation for device-to-device communication in lte-a network. trans. emerging tel. tech., 26: 12951305. doi: 10.1002/ett.2958., 2015;