Research on Resource Allocation for Device-to-Device Communication Underlaying LTE Network

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Abstract

The idea of the outage probability is introduced into resource allocation in cellular networks, we propose a D2D resource scheduling algorithm for improving the system throughput and decreasing interference. In this paper, a D2D mode selection scheme based on data transfer rate is given when D2D is accessing in the network. Then from the perspective of signal to interference ratio (SIR), we construct outage probability function of D2D access. And a power control mechanism is considered to limit the transmit power within a reasonable range, in order to enable D2D access successfully. The multi-user resource multiplexing scheme proposed in this paper can not only increase resource ultimation, but also reduce the whole interference.

Keywords: Mode Selection; Power Control; Outage Probability; Multi-user Resource Reuse

1 Introduction

In order to effectively achieve the D2D communication, we mainly address from two aspects, first is to look for the dedicated resources and bandwidth for D2D communication, the second aspect is D2D user resource reuse of cellular users [1]. Due to restrictions of communication scenarios, most application scenarios of D2D communication systems are not rich resource scenes, therefore, improve resource reuse efficiency become the focal point of communication quality and the end result. Resource reuse need to solve two problems: First, how to determine D2D access, namely D2D user application access mode selection [2], the second is the next scene in the multiplex interference coordination, reduce system interference [3-5].

In the conventional studies, D2D will reuse resource of a particular cellular user, so that bringing some disadvantages: The UEs (cellular users) are strong interferenced, and severely affect communication of these users. however, some cellular users has absolutely no interference, resulting in reducing fairness of communication effects. In the LTE system, for the receiver design,
the interference from a cellular user is an unnecessary burden. Therefore, we hope to design a disturbance averaging strategy so that some specific users are not always interferenced. And we seek a way to make the interference caused by D2D resource reuse is random, closer to the characteristics of the background noise, easy to design of the receiver and possible to achieve a down-link channel multiplexing. The main objective of the technology is that under the premise of guaranteeing the communication quality of UEs, more D2D pairs can effectively accessed.

When distance-constrained resource reuse scheme, cellular users distribute randomly in a cell, Article [6] derived outage probability of D2D user. It is reasonable to reduce the probability of outage for enhancing system performance. Therefore, the system can achieve the optimization object of minimizing the outage probability, and then maximizing the probability of successfully access. In the resource reuse, the article [7] used traditional access methods, which is simple and easy to implement; In articles [8-10], with the object of maximizing data transfer rate, allocate resource in proportion, to improve resource utilization. Mohammad Zulhasnine [11] consider D2D resource allocation as an integer nonlinear optimization problem with the constraints of minimum target SINR of C-mode UEs (cellular communication) and D-mode UEs (D2D communication). In this paper, from the above perspective, we combine the outage probability and interference averaging, and in the process of resource allocation, we design a power control mechanism, dynamically adjust the transmit power of D2D, to limit the power within a reasonable range to provide access conditions for D2D communication. Under the premise of guaranteeing communication quality of users in the cell, as much as possible to reduce outage probability of D2D pair, to reduce the overall effect of interference, we design a interference averaging algorithm and compare with the traditional access method in D2D successfully access rate system interference and throughput of D2D links and cellular links.

2 Resource Allocation and Mode Selection Model

This paper presents a resource selection strategy, D2D devices can select the appropriate resources multiplexed mode based on the current UEs distribution and resource usage mode. Taking a single cell as a model, there are $N$ UEs for C-mode communication $UE_k \in A = \{UE_1, UE_2, UE_3, ..., UE_M\}$, where $A$ is a set of UEs in a cell. And for D2D communication, there are $M$ pairs, $UE^D_i$ and $UE^d_i$ in $B = \{D2D_1, D2D_2, D2D_3, ..., D2D_N\}$. We consider the following three resource allocation model, shown in Fig. 1.

![Fig. 1: Illustration of three possible resource allocation modes](image)

1. Cell mode: eNB (base station) allocates resources to D2D. In cellular mode, D2D uses a base station for forwarding, and using orthogonal transmission link. Therefore, the resources are
divided into $N + M$ copies, cellular users use $N$ copies, and each user of a D2D pairs use $N/2$ copies.

2. Dedicated mode: D2D devices and cellular users, respectively use separate resources. The resources are divided into $N + M$ copies, cellular users to use $M$-copies, D2D devices for $N$ copies.

3. Reuse mode: D2D devices to share resources with cellular users in a cell.

In combination with resource allocation and throughput, we divide the three modes selection mechanism:

1. Cell mode, D2D communicate in traditional cellular mode.
2. Dedicated mode, D2D device uses resources for communication.
3. Reuse mode, D2D devices communicate by reusing cellular resources.

As shown in Fig. 2, $UE_i^D$ and $UE_i^d$ are respectively sender and receiver of $D2D_i$, and $UE_j$ is cellular user. $g_C^{cNB_j}$ is the channel gain between $UE_j$ and base station. $g_i^D$ is the channel gain of $D2D_i$, $g_{eNBi}^D$ and $g_{eNBi}^d$ are respectively the channel gain between base station and D2D users. $P_i^D$ and $P_i^d$ are transmit power and received power of $D2D_i$. And others are similar.

![Fig. 2: D2D communication as an underlay to a cellular network](image)

3 Mathematical Model

3.1 System model

Assuming that D2D communication reuse up-link resources, in the cellular up-link band D2D generates only interference on the fixed base station, any D2D receiving devices are interferenced by the cellular terminal who share the same resource, the base station dynamically adjust transmission power and reusing UE resources to control the interference, we can also use the power control information in D2D communication control.

As shown in Fig. 2, $UE_i^D$ and $UE_i^d$ are respectively sender and receiver of $D2D_i$, and $UE_j$ is cellular user. $g_{cNB_j}^d$ is the channel gain between $UE_j$ and base station. $g_i^D$ is the channel gain of $D2D_i$, $g_{eNBj}^D$ and $g_{eNBj}^d$ are respectively the channel gain between base station and D2D users. $P_i^D$ and $P_i^d$ are transmit power and received power of $D2D_i$. And others are similar.
3.2 Mode selection

We design a judgment standard for D2D to chose a right mode. When the user is in the cellular mode and dedicated mode, there is no problem of communication between users sharing the same radio resource, and thus will not interfere with each other, so according to the transmission they can transmit in the maximum transmission power to improve system throughput. And when D2D pair is too close to the cellular user, interference between each other is relatively large, is not conducive to communication, then D2D will choose dedicated mode. Assume that the cellular link and D2D communication link respectively get the power $P_C$ and $P_D$. When a user is in the cellular mode, using the Shannon formula and the above resource allocation mode, the total throughput of cellular and D2D communication channel is represented by the following formula:

$$C(cell) = \frac{N}{2(N + M)} \log_2(1 + \frac{g_i^D P_{max}}{N_0}) + \frac{M}{(N + M)} \log_2(1 + \frac{g_{C_{eNBj}}^C P_{max}}{N_0})$$

(1)

In dedicated model, the formula is expressed as:

$$C(ded) = \frac{N}{N + M} \log_2(1 + \frac{g_i^D P_{max}}{N_0}) = \frac{M}{N + M} \log_2(1 + \frac{g_{C_{eNBj}}^C P_{max}}{N_0})$$

(2)

In reusing mode, because of the presence of interference the formula is calculated as:

$$C(reuse) = \log_2(1 + \frac{g_{C_{eNBj}}^C P_k}{P_i^D * g_{cd} + N_0}) + \log_2(1 + \frac{g_i^D P_{max}^D}{P_j^C * g_{dc} + N_0})$$

(3)

$$g_{cd} = \max(g_i^D, g_{ji}^D) \quad g_{dc} = \max(g_{eNBi}^D, g_{eNBj}^d)$$

(4)

Using Eq. (1), (2), (3), we derived the up-link resource sharing model selection mechanism proposed by the following formula.

$$R_{max} = \text{Max}\{R(cell), R(ded), R(reuse)\}$$

(5)

4 Resource Allocation

4.1 Outage probability

Assume that $D2D_i$ can reuse multiple cellular user resources, denoting as $\sum_{j=1}^{N} a_{ij}$. And cellular users respectively occupy bandwidth: $(W_1, W_2, ..., W_N)$. The same cellular user resource can not be occupied by more than two users.

$$\sum_{j=1}^{N} a_{ij} \leq N, \forall j, \quad a_{ij} \in (0, 1)$$

(6)

Spectrum resources used by is followed as:

$$\forall_i = \sum_{j} a_{ij} W_j$$

(7)
Define the proportion of resource reused by in all spectrum resource of as:

\[ b_{ij} = \frac{a_{ij}W_j}{\sum_{j=1}^{M} a_{ij}W_j}, \quad 0 < b_{ij} \leq 1 \] (8)

Only considering the impact of the path loss on the signal, the transmit power of \( D2D_i \) is \( P_i^D \); H is the channel fading. So the received power of \( D2D_i \) can expressed as:

\[ P_i^d = p_i^D H_i^D \] (9)

Similarly, set the transmit power of cellular user is \( P_j^C \), calculate the interference caused by \( UE_j \) on as:

\[ I_{ji} = P_j^C H_{ji} \] (10)

And the interference generated by \( D2D_i \) on \( UE_j \) is followed as:

\[ I_{ij} = P_i^D H_{ij} \] (11)

The received power of \( UE_j \) from base station is represented as:

\[ P_j^C = P_j^C H_{eNBj} \] (12)

Due to the randomness of the signal, we use Rayleigh fading model. Assuming that there is one D2D pair \( D2D_i \) and \( D2D_i \) only reuse source of \( UE_j \). The outage probability based on SIR can be expressed as follow:

\[ P_{out}^{UE_j} = Pr(T_0 > SIR) \] (13)

Formula (15) can be converted as:

\[ P_{out}^{UE_j} = Pr(T_0 > \frac{P_j^C F_j}{I_{ji} f_{ji}}) = Pr(I_{ij} F_{ij} T_0 > P_j^C F_j) \] (14)

\[ P_{out}^{D2D_i} = Pr(T_i > \frac{P_i^D f_i}{I_{ji} f_{ji}}) = Pr(I_{ji} f_{ji} T_i > P_i^D f_i^C) \] (15)

Where \( T_0 \) is the presented \( SINR \) threshold of cellular; \( T_i \) is the minimum communication \( SINR \) of D2D; Rayleigh fading coefficient is \( F, f \).

When selecting Rayleigh fading model, random variables on both sides of the inequality are independent exponentially distributed. So the above formula satisfies the following formula:

\[ E[P_i F_i] = P_i \] (16)

**Theorem 1**: Assume two random variables \( z_1, z_2 \), they are independent exponentially distributed, and \( EZ_i = \frac{1}{\lambda_i} \), then \( Pr(z_1 < z_2) = \frac{\lambda_1}{\lambda_1 + \lambda_2} \).

**Proof 1**: Set \( x1, x2 \) is independent exponentially distributed random variables. The probability density function is expressed as \( f(x) = \begin{cases} \lambda e^{-\lambda x}, & x \geq 0 \\ 0, & x < 0 \end{cases} \).
The expectation function is \(Ex = \int_0^\infty xf(x)dx\), after integration, we can conclude it.

\[
P_{out}^{UE} = \frac{I_{ij}T_0}{I_{ij}T + F_j}
\]

(17)

\[
P_{out}^{D2D} = \frac{I_{ij}T_i}{I_{ij}T + F_i}
\]

(18)

**Corollary 1:** Suppose there are \(n\) random variables \(z_1, z_2, \ldots, z_n\), they are independent exponentially distribute, and \(E(Z_i) = \frac{1}{\lambda_i}\), then \(Pr(z_1 > \sum_{i=2}^n z_i) = 1 - \prod_{i=2}^n \left(\frac{1}{1 + \lambda_i} \right)\).

**Proof 2:** Let exponential coefficient of \(n\) exponentially distributed random variables are accordingly \(\lambda_1, \lambda_2, \ldots, \lambda_n\), \(f(t_i) = \left\{\begin{array}{ll}
\lambda_i e^{-\lambda_i t_i}, & t_i \geq 0 \\
0, & t_i < 0.
\end{array}\right.\)

Specific derivation process is as follows:

\[
Pr(z_1 > \sum_{i=2}^n z_i) = \left\{\begin{array}{l}
\int_0^\infty ... \int_{t_n=0}^\infty Pr(z_1 > \sum_{i=2}^n z_i) \prod_{i=2}^n \lambda_i e^{-\lambda_i t_i} dt_2 ... t_n \\
\int_{t_2=0}^\infty ... \int_{t_n=0}^\infty \lambda_i e^{-\lambda_i (t_2 + ... + t_n)} \prod_{i=2}^n \lambda_i e^{-\lambda_i t_i} dt_2 ... t_n \\
\prod_{i=2}^n \int_{t_i=0}^\infty \lambda_i e^{-(\lambda_1 + \lambda_i)} t_i dt_i \\
\prod_{i=2}^n \frac{1}{1 + \lambda_i}
\end{array}\right.
\]

then using 1 minus the above formula will get the result. According to the above formula, we can conclude as:

\[
Pr(Z_1 \leq \sum_{i=2}^n z_i) = 1 - \prod_{i=2}^n \left(\frac{1}{1 + \lambda_i} \right)
\]

(19)

\[
Pr(Z_1 \leq \sum_{i=2}^n a_i z_i) = 1 - \prod_{i=2}^n \left(\frac{\lambda_i}{\lambda_i + a_i \lambda_1} \right)
\]

(20)

With \(D2D\), reusing multiple cellular resources, the interference caused by \(UE_i\) on \(D2D\) denote as \(b_{ij}I_{ij}^C\), and \(a_{ij}I_{ij}^D\) shows the interference caused by \(D2D\) on \(UE_i\). Using the above assumption, we can conclude the outage probability \(UE_j\) of \(D2D\) and:

\[
Pr_{out}^{UE_j} = \text{Prob}(T_0 > \sum_{i=1}^N \frac{P_i^C F_j^C}{b_{ij} F_j^C}) = 1 - \prod_{i=1}^N \frac{P_i^C}{b_{ij} F_j^C}
\]

(21)

\[
Pr_{out}^{D2D_i} = \text{Prob}(T_i > \sum_{j=1}^M \frac{P_i^D f_{ij}^D}{a_{ij} f_{ij}^D}) = 1 - \prod_{j=1}^M \frac{P_i^D}{a_{ij} f_{ij}^D}
\]

(22)

When \(Pr_{out}^{D2D_i}\) is stationary, from the above formula, if set other value stationary, \(P_i^d\) is bigger, in other words \(P_i^D\) is bigger, \(Pr_{out}^{D2D_i}\) is smaller. Therefore, we consider maximizing the received
power of $D2D_i$ as a approximation. To achieve the outage probability is minimized, i.e., to maximize the number of D2D access successfully, we assume a scene: multiplexing proportion transmit power keep stationary when a new D2D access. Assuming $D2D_1, D2D_2, ..., D2D_{N-1}$ are accessed successfully, $D2D_N$ is a new access one, while other conditions known. The objective function is followed as:

$$
Pr_{out}^{UE_j} = 1 - \prod_{i=1}^{N} \frac{P_c^i}{b_{ij}I_{ij}T_0 + P_c^i} \\
1 - \frac{P_c^j}{b_{ij}I_{ij}T_0 + P_c^j} \frac{P_c^j}{b_{ij}I_{Nj}T_0 + P_c^j} \leq \Delta_j
$$

(23)

Where $\Delta_j$ is the threshold value of the outage probability. $I_{Nj}$ and $P_D^j$ show linear, we can get the following formula:

$$
b_{Nj}P_D^j \leq \Omega_j \quad (24)
$$

$$
b_{Nj} \forall N = a_{Nj}W_j, \forall j \quad (25)
$$

The outage probability of shows as:

$$
P_{out}^{D2D_i} = Prob(T_i > \frac{P_iF_i}{\sum_{j=1}^{M} a_{ij}I_{ij}^Df_{ji}}) = 1 - \frac{P_D^j}{a_{Nj}I_{Nj}T_i + P_D^j} \quad (26)
$$

$P_D^j$ is bigger, the smaller $P_{out}$; When $i$ gets different value, $a_{Nj}$ are not relevant. So $a_{Nj}$ is bigger, the smaller $P_{out}$. We can conclude that maximizing the transmit power, or allocate more spectrum resource, the smaller outage proportion will be gotten. The final objective function expresses as:

$$
min \prod_{j=1}^{M} (1 + \frac{a_{Nj}I_{Nj}T}{P_D^j}) = min \prod_{j=1}^{M} (1 + \frac{k_jb_{Nj}\forall N}{P_D^j})
$$

(27)

Where $k_j = I_{Nj}P_D^jT/W_jP_D^j$, due to the known rate, it must reach $\forall N \geq \Lambda$, $\Lambda$ is the minimum bandwidth for D2D communication. Because $\frac{k_jb_{Nj}\forall N}{P_D^j} \ll 1$, high-order components are not important than low order components in the above minimization problem. We consider $\sum \frac{k_jb_{Nj}\forall N}{P_D^j}$ as a design strategy: values from small to large, when $\sum \frac{k_jb_{Nj}\forall N}{P_D^j}$ reaching the minimum, calculate $b_{Nj}$.

### 4.2 Interference control based on power control mechanism

Due to the transmit power of $D2D_i$, it will interference with the communication of $UE_i$. Under the premise of eliminating interference, in order to ensure the normal communication between D2D pair, D2D should ensure the received signal strength to meet certain conditions. For D2D communication in the up-link frequency band, the received signal strength is expressed as:

$$
R_i^d = P_i^D H_i^D + P_j^C H_{ji}^C + N_0
$$

(28)
The SINR is shown as
\[ \beta_{th}^D \geq \text{SINR}^d_i = \frac{P_i^D \cdot H_i^D}{P_j^C \cdot H_j^C + N_0} \geq \beta_{min}^D \] (29)

Where \( \beta^d \) is the minimum SINR of D2D for communication connection. According to (15), the interference caused by cellular user on D2D link follows as:
\[ I_{ij}^c = P_i^D \cdot H_{ji}^C \] (30)

Then the minimum transmission power is calculated as:
\[ P_i^D = \frac{\beta_{min}^D (P_i^D H_{ji}^C + N_0)}{H_i^D} \] (31)

The interference caused by UE \( j \) on D2D, can be derived as:
\[ I_{ij}^c = \frac{\beta_{min}^D (P_i^D H_{ji}^C + N_0)}{H_i^D} H_{ki} \leq I_{min} \] (32)

When D2D communication is started, dynamically adjusting the transmission power of D2D can effectively reduce interference caused by D2D communication system on the cellular communication system. For this purpose, in the known state of the channel, adjusting the transmission power to exclude base station and cellular users out of D2D communication coverage, avoiding the interference:
\[ g_i^D = R_i^D - P_i^D \] (33)
\[ g_i^d = R_i^d - P_i^d \] (34)

Where \( R_i^D \) and \( R_i^d \) are received signal strength of D2D, users
\[ P_i^D = \min(P_{max} - g_i^D), (P_{max} - g_{eNB_i}) \] (35)
\[ P_i^d = \min(P_{max} - g_i^d), (P_{max} - g_{eNB_i}) \] (36)

Where \( P_{max} \) denotes the power threshold of D2D on one RB, which determines the communication coverage of D2D. Combined with section A in IV, resource allocation problem of D2D can be transferred into solving the following problem:

\[ \text{Determine} \quad b_{Nj}, \forall j \]

\[ \text{ToMinimize} \quad \sum_{j=1}^{M} \left( \frac{k_j b_{Nj}}{P_N^D} \right) \]

\[ \text{Subjecting to} \quad b_{Nj}P_N \leq \Omega_j \]
\[ P_N^D = \min(P_{max} - P_N^D), (P_{th} - P_{eNB}) \]
\[ \sum_{j=1}^{M} b_{Nj} = 1 \] (37)
5 Algorithm Description

To solve planning problem showing in (37), we design a method from mode selection, power control and resource allocation based on outage probability. First, in order to satisfy with the minimum communication requirement, building a D2D alternative set. And in order to achieve maximum number of D2D access successfully, we use a power control mechanism, mainly limit the transmit power of D2D within a reasonable range. Then with the objective of minimizing outage probability, deciding spectrum resources for D2D, that is to solve the problem D2D reusing which cellular user resources.

Algorithm

1. \( M \) : number of cellular users
2. \( N \) : number of D2D pairs
3. \( I \) : the interference
4. \( Pr \) : outage probability
5. \( \text{begin} \)
6. \( c \leftarrow 1 \)
7. \( \text{set } V = \Lambda \)
8. \( \text{calculate the throughput in various modes} \)
9. \( R\max = \text{Max}\{ R nosotros, R(ded ), R(reuse ) \} \)
10. \( \text{estimate the SINR of all D2D meet the requirement} \)
11. \( \beta_i^n \preceq \text{SINR}_e = \frac{P_i^n R_i^n}{P_i^n R_i^n + N_0} \)
12. \( \text{if } I_e > I_{out} \text{ then} \)
13. \( \beta_i^n = \min ( (I_{out} - I_{out}^0 )P_{out} - P_{out} ) \)
14. \( \text{end} \)
15. \( \text{if } \beta_i^n > \lambda_y \text{ then} \)
16. \( \text{find } b_{kV} \text{ when } \sum_{i} k_i V_i \rightarrow \text{reach the minimum} \)
17. \( \text{end} \)
18. \( \text{end} \)

6 Formulation Analysis

We use LTE system-level simulator of C++ for proposed resource allocation algorithm. The proposed algorithm is mainly to study mode selection, power control and resource allocation. Detailed simulation parameters shown in Table 1. We compare performance of the proposed algorithm with the traditional control mechanism.

Table 1: Simulation parameteres

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell radius</td>
<td>500m</td>
</tr>
<tr>
<td>Cellular link path loss mode</td>
<td>PL=128 + 1.37 * 6*log10(R)</td>
</tr>
<tr>
<td>D2D link path loss model</td>
<td>PL=148 + 40*log10(R)</td>
</tr>
<tr>
<td>Distance between D2D</td>
<td>20m</td>
</tr>
<tr>
<td>Number of D2D links</td>
<td>15-20</td>
</tr>
<tr>
<td>Noise strength</td>
<td>-174dBm/HZ</td>
</tr>
<tr>
<td>Transmission power of cellular user</td>
<td>100mW</td>
</tr>
<tr>
<td>Transmission power of D2D</td>
<td>0.1mW</td>
</tr>
<tr>
<td>Transmission power of base station</td>
<td>45dBm</td>
</tr>
<tr>
<td>Tolerable outage probability</td>
<td>0.2</td>
</tr>
<tr>
<td>System bandwidth</td>
<td>10MHz</td>
</tr>
<tr>
<td>Target SINR(β)</td>
<td>-3, 3, 9, 12, 15</td>
</tr>
</tbody>
</table>
6.1 Simulation scene I

As Fig. 3 shows, there is a D2D pair and a cellular user in a cell. Assume that the radius of the cell is 500 meters, the position of D2D is stationary and keep the distance 20 meters, cellular user can move randomly. According to the mode selection function, we performed the corresponding simulation. Fig. 4 shows that when UE move randomly, D2D can select the best communication mode. By analyzing the simulation results, we find that when UE is far from D2D, the reuse mode should be selected, and when the distance is closer, in order to avoid significant interference, the optimal resource allocation is dedicate mode, and when the distance between D2D users is larger than the distance between D2D and base station, the best solution is to select cell mode. When UE is near the cell edge, in order to ensure quality of system service, does not allow D2D to reuse the UE resource.

6.2 Simulation scene II

In this simulation, D2D access sequentially. We mainly analyze the factors causing interference on system throughput interference and the number of D2D access successfully. Fig. 5(a) shows that the minimum SINR of D2D increases, the number of D2D access successfully drops and Fig. 5(b) shows that as the SINR increases, however, system interference increases. Combing Fig. 5(a) with Fig. 5(b), we can conclude that as the SINR of D2D increases, system performance turns bad, which interferes significantly access of D2D. Another example Fig. 5(c), with the interference threshold is increased, system interference increases. On the end, in order to achieve the best performance of the system, selecting the interference threshold of the minimum SINR for D2D is very important.

Fig. 5: SINR threshold and interference threshold of D2D cause interference on average system interference and number of permitted D2D access
Fig. 6 shows total throughput of C-mode and D-mode, and all UEs in a cell as varying P-max of D-mode UEs for proposed power control mechanism. In Fig. 6(a), total throughput of C-mode UEs in proposed algorithm decreases as Pmax increases since increase in transmission power of D-mode UEs causes more interference to C-mode UEs. On the other hand, because the proposed algorithm dynamically controls transmission power of D-mode UEs to reduce interference to others, the average total throughput of C-mode UEs in the proposed scheme is larger than traditional algorithm. In Fig. 6(b), total throughput of D-mode UEs with the proposed control scheme increases as their Pmax increase. The traditional algorithm can guarantee more throughput than the traditional algorithm for Pmax larger than 3dB. Because D-mode UEs with the existing scheme But, the total throughput of traditional algorithm cannot increase constantly. On the other hand, the proposed algorithm always has high throughput, because it use power control scheme to control transmission power of D-mode UEs to certain level and minimize interference to C-mode UEs using same resource. use larger transmission power on average than the proposed algorithm. Fig. 6(c) shows that total throughput in the traditional algorithm increases as $P_{max}$ increases.

![Figure 6: Total throughput of the proposed power control and traditional algorithm](image)

As Fig. 7. shows that the abscissa indicates the number of D2D access sequentially, and the ordinate denotes the outage probability. As can be seen from the figure, for traditional algorithm, the probability of successful access is relatively stable in the first ten. However, the probability decreases significantly after more than ten.

![Figure 7: Comparison of D2D access probability between different algorithms when D2D access sequentially](image)

The proposed algorithm also dropped obviously, but compared with traditional algorithm, the decline is relatively stable. And observing the chart, in the entire dimension the proposed algorithm is superior to the traditional algorithm.
7 Summary

In this paper, a resource allocation algorithm based on outage probability is presented. In this algorithm, we propose an optimization algorithm based on minimizing outage probability through deriving interference ratio problem caused by D2D reusing cellular user resources. And reduce the number of variables and calculation of dimensions of the algorithm, so that simplify the complexity of the algorithm. In the process of D2D access, we use a power control method, limiting the transmit power of D2D within a reasonable range, providing favorable conditions for D2D access successfully. It has been shown via simulation that the proposed algorithm is superior to the traditional in the performance. In addition, the proposed scheme can be applied not only LTE and the subsequent, WiMax using B3G and 4G can also apply it due to similarity of the link layer design. And the parameters can be set according to the specific scene, not changing the effectiveness and feasibility.

References