Robust Randomized Resource Allocation for Device-to-Device Communications

Christoforos Vlachos and Vasilis Friderikos

King’s College London
Strand, WC2R 2LS, London - UK

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Motivation

- Significant number of mobile devices with increasing set of capabilities.
- Booming demand for spectrum use.
- Need to retain/improve UEs’ Quality of Service (QoS).
- Increased data rates requirements.

Figure 1: Cisco forecasts 15.9 exabytes per month of mobile data traffic by 2018

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1 Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update. 2013-2018
Main D2D characteristics

In this emerging communication paradigm, two close-ranged UEs are eligible to connect directly and communicate with each other by utilizing either the cellular spectrum (i.e. inband) or the unlicensed spectrum (i.e. outband), unlike the traditional communication via the BS.

- Close proximity.
- Frequency reuse gain.
- Traffic offloading.
- Power saving.
- Higher data rates.

Figure 2: Cellular traffic path with data
Device-to-Device communications
State of Art (1/2)

Figure 3: D2D communications taxonomy
Figure 4: Existing literature on D2D-based resource allocation
Device-to-Device communications

Challenges

- Standardization of D2D communications to emerging wireless networks.
- Spectrum sharing.
- Power efficiency and interference management.
- Ameliorated data rates in respect to power and QoS constraints.
Assumptions

1. Underlay DL scenario,
2. D2D & CUs uniformly distributed,
3. Fractional Frequency Reuse (FFR)\textsuperscript{2,3}
   - FRF = 1 for inner users
   - FRF = 3 for outer users
4. Fixed D2D transmission power.

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D2D Resource allocation
Problem / Scenario description (2/2)

Figure 6: CU and D2D UEs resource availability (ex. cell 1)
Algorithm 1 Randomized D2D RRA algorithm

1: for $l = 1$ to $L$ do
2: Allocate one RB $\forall U_l \in C_l$ from $\{N_{Inner_l}\}$ or $\{N_{Outer_l}\}$, depending on location.
3: end for
4: for $i = 1$ to $K$ do
5: for $l = 1$ to $L$ do
6: $S \leftarrow \{N_{Inner_l}\} \cup \{N_{Outer_l}\}$
7: Randomly allocate RB to $U_l \in D_l$ from the corresponding $S$ available RB pool.
8: Subtract assigned $RB_{U_l,l}$ from the available pool: $S \leftarrow S - RB_{U_l,l}$.
9: end for
10: Compute $\forall U_l \in l$ its achievable rate $R_{U_l,l}$.
11: Compute $AT(i) \leftarrow \sum_{l=1}^{L} \sum_{u=1}^{|U_l|} R_{u,l}$
12: end for
13: $M = \max AT \rightarrow$ Maximum estimated Aggregate Throughput
Allocate $C$ orthogonal resources to CUs

Random resource allocation for each D2D pair / cell (location dependent)

Update available resources’ pool for each cell

Estimate Aggregate Throughput ($AT_n$)

Iterative Algorithmic Block ($N$ iterations)

Choose RA corresponding to maximum $AT$

Figure 7: Algorithmic block representation
D2D Resource allocation
Results (1/3)

Figure 8: Mean Aggregate System Throughput comparison with fixed number of D2D pairs.

Results acquired after 1000 algorithmic iterations:

1. 9.8% performance gain compared to the baseline study.
2. 12.5% improvement of baseline study’s worst case.
3. D2D rate performance significantly increased.

* 1: random allocation, 2: strict-FFR based allocation, 3: differentiated FFR allocation, 4: proposed scheme
D2D Resource allocation
Results (2/3)

Figure 9: Aggregate System Throughput behaviour for different number of D2D pairs.

1. Proportional increase with the number of D2Ds.

2. Main difference/gain observed for high density scenarios.

3. 14.5% highest achieved improvement compared to the baseline work.
Table 1: Sensitivity analysis related to location uncertainty

<table>
<thead>
<tr>
<th>Location information error</th>
<th>Estimated aggregate throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate location</td>
<td>$5.58 \times 10^2$ [Mbps]</td>
</tr>
<tr>
<td>1 meter</td>
<td>$5.51 \times 10^2$ [Mbps]</td>
</tr>
<tr>
<td>2 meters</td>
<td>$5.58 \times 10^2$ [Mbps]</td>
</tr>
<tr>
<td>3 meters</td>
<td>$5.56 \times 10^2$ [Mbps]</td>
</tr>
<tr>
<td>4 meters</td>
<td>$5.61 \times 10^2$ [Mbps]</td>
</tr>
<tr>
<td>5 meters</td>
<td>$5.59 \times 10^2$ [Mbps]</td>
</tr>
</tbody>
</table>
Concluding remarks

- Iterative randomized algorithm
- Low complexity
- After $K = 100$ iterations, almost 99% of best performance solution ($M$) is achieved
- Robust to uncertainty scenarios
- System throughput improvement
- Add-on feature in FFR-based wireless systems.

**Future work:**

1. Efficient resource allocation for non-stationary users.
2. Re-utilize the uplink resources of cellular spectrum to achieve limited interference.
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\(^4\)http://gain.di.uoa.gr/crossfire/
Any questions?

Christoforos Vlachos
Marie Curie Early Stage Researcher
Centre for Telecommunications Research (CTR)
Department of Informatics
School of Natural and Mathematical Sciences
King’s College London (KCL)
Strand, WC2R 2LS, London - UK

Contact:
email: christoforos.vlachos@kcl.ac.uk