Route Discovery and Power Allocation in D2D Communications

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September 27, 2014

Outline

What is D2D

- Direct communication between devices without traversing the core cellular network
- *Inband* D2D: Communication over licensed spectrum
- *Outband* D2D: Communication over unlicensed spectrum

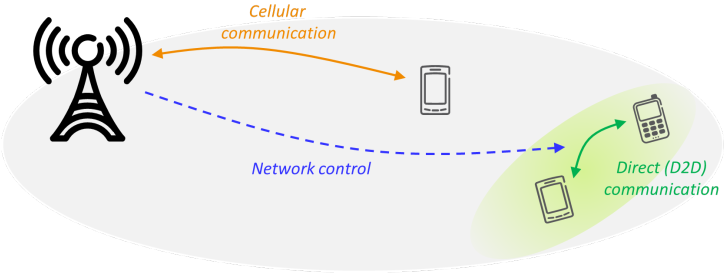


Figure: Simplest illustration of D2D communication

How is it different?

- Unlike CRNs, D2D is expected to be controlled by a central entity sometimes called the eNB
- M2M refers to wireless or wired technologies
- M2M does not take distance into account
- The devices that employ M2M may or may not require human interaction

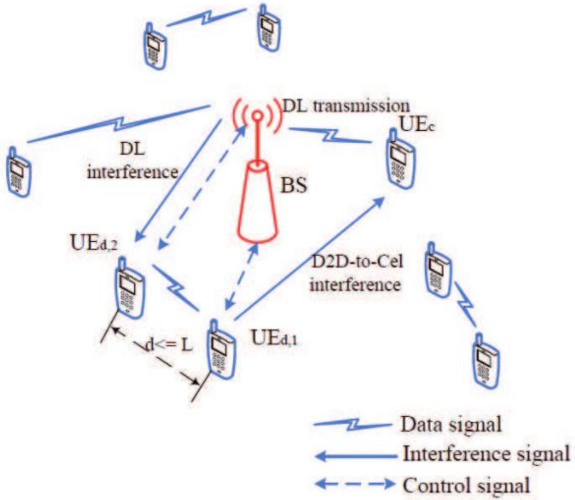
Major challenges in D2D

- Interference Avoidance/Cancellation
- Device Discovery
- Resource Management
- Mode Selection

System Model

- *Underlay Inband* D2D
- N BSs and M D2D devices
- D2D users reuse Downlink frequencies
- Two types of interference in the system :
    1. Base Station to D2D receiver
    2. D2D transmitter to cellular receiver
- Cellular users given priority
- Reliability(γ,γ_b) and Interference constraints(γ_d)
- D2D links rendered feasible only if they cause intolerable interference to the cellular users

Types of Interference



- All BSs assumed to transmit at the same power P
- Aim: To find all the feasible D2D pairs
- Algorithm
  1. Find the interference($P_{int}^{d_R}$) at a D2D device (d_R) due to all BSs
  2. Find the transmit power required by d_T to communicate reliably with d_R and repeat for all d_Rs and d_Ts

$$P_{d_T}^{d_R} = P_{int}^{d_R} + \gamma$$

  3. Find the region around the BSs in which the SNR for the cellular users is at least γ_b dB.

$$P - 10\alpha \log(d) \geq \gamma_b$$

$$d_{max} = 10^{\left(\frac{P-\gamma_b}{10\alpha}\right)}$$

4. Shut down all the D2D transmitters in the region
5. Find the max power that d_T can use without causing intolerable interference to the cellular users

$$P^{max}_{d_T,BS_i} = \gamma_d + 10\alpha \log(D_{d_T,BS_i} - d_{max})$$

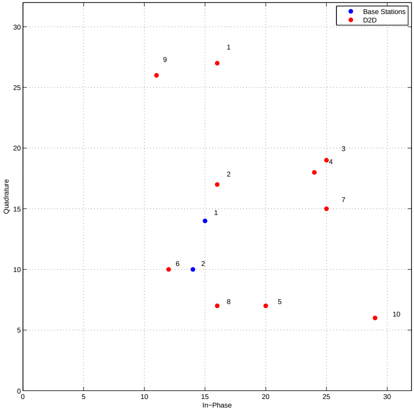
$$P^{max}_{d_T} = \min_{1 \le i \le N} P^{max}_{d_T,BS_i}$$

6. Declare the link $d_T \longrightarrow d_R$ *infeasible* if $P^{d_R}_{d_T} > P^{max}_{d_T}$.

- We have the feasible links and the transmit powers required for reliable communication on those links

Simulation Results

- 2 BSs and 10 D2D devices
- Locations uniformly random
- Total 45 D2D pairs and 90 D2D links



	Tx1	Tx2	Tx3	Tx4	Tx5	Tx6	Tx7	Tx8	Tx9	Tx10
Rx1	0	0	1	1	0	0	0	0	1	0
Rx2	0	0	0	0	0	0	0	0	0	0
Rx3	1	0	0	1	0	0	1	0	1	1
Rx4	1	0	1	0	0	0	1	0	0	1
Rx5	0	0	0	0	0	0	0	0	0	1
Rx6	0	0	0	0	0	0	0	0	0	0
Rx7	0	0	1	1	0	0	0	0	0	1
Rx8	0	0	0	0	0	0	0	0	0	0
Rx9	1	0	1	0	0	0	0	0	0	0
Rx10	0	0	1	1	0	0	1	0	0	0

Table: Feasibility Matrix

Observations

- d_6 is at a disatnce less than d_{max} from BS 2. Hence it cannot transmit to any of the users.
- d_2, d_5 and d_8 cannot transmit because the power required by each of them to transmit to any other user is more than what is allowed by the γ_d constraint.
- The interference caused by the Base Stations to the users d_2, d_6 and d_8 is very high. Hence they cannot be the receivers in any feasible D2D link.
- The links $d_3 \longrightarrow d_4$ and $d_4 \longrightarrow d_3$ are both feasible. But the transmit power required by d_4 to communicate with d_3 is less than the transmit power required by d_3 to communicate with d_4.

We have the feasible D2D links.

What's next ?

Fixed Rate Scheme

- Consider a device d_S which has some data for some other device d_D in the above system
- Data should reach the destination ASAP
- The D2D SNR constraint γ determines the rate of all the D2D links
- Effective rate on the link $d_S \longrightarrow d_D$

$$R_{\text{eff}} = \frac{\log(1+\gamma)}{\text{Number of hops}} \text{ bps per Hz}$$

- As γ varies, the structure of the directed graph G may also change.
- The shortest path $d_S \longrightarrow d_D$ may change

- Since the 'number of hops' term figures in the expression of R_{eff}, it is not true that as γ increases, R_{eff} should always increase.
- Illustration :
  Let $\log(1+\gamma_1) = 25$ bps/Hz and $\log(1+\gamma_2) = 50$ bps/Hz.

  The shortest path
  γ_1 - 3 hops
  γ_2 - 8 hops

  R_{eff} for the γ_2 case is less than that for the γ_1 case.
- This motivates the problem:

  Find the (γ_{opt}) using which the devices d_S and d_D can communicate incurring the minimum delay.

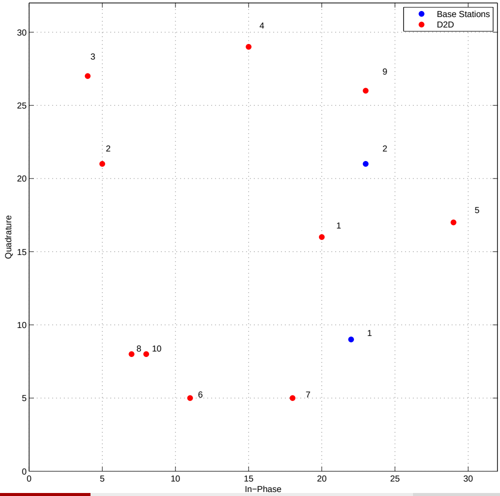
The problem is summarized below:

1. Set an SINR threshold (γ) and find the feasible D2D pairs
2. Fix the source and destination devices
3. Find the shortest path for this SINR and calculate R^{γ}_{eff} for this SINR threshold
4. Vary the SINR threshold to maximize R^{γ}_{eff} to get γ_{opt}

$$\gamma_{opt} = \max_{\gamma} R^{\gamma}_{\text{eff}}$$

Simulation Results

Source: d_6 Destination: d_4



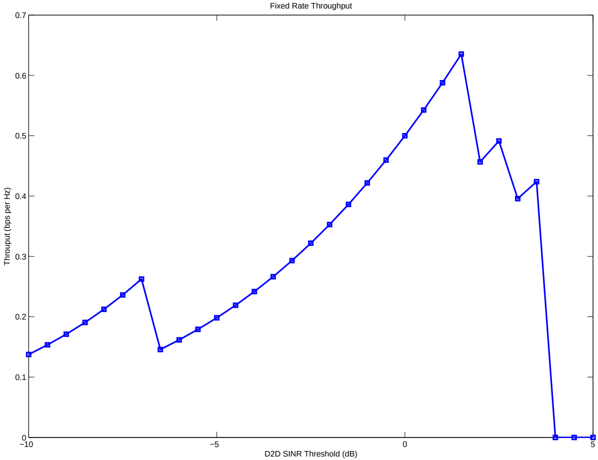


Figure: Throughput vs D2D SINR threshold

Coming up in the next presentation

- Algorithm to find the peaks in the previous graph
- Fixed Power Scheme
- Analysis

THANKS!!!