Leveraging Decoupling in Enabling Energy Aware D2D Communications

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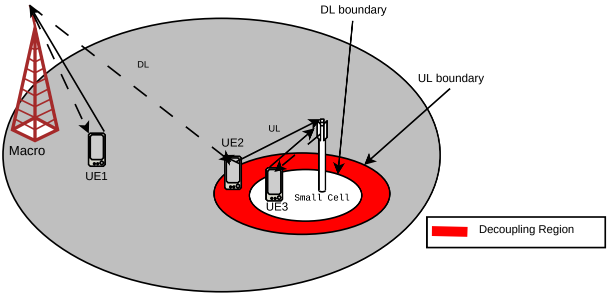
Table of contents

- Introduction to D2D and Decoupling
- Motivation
- Contributions
- Power saving in decoupling
- Enabling D2D through decoupling
- Time spent in decoupling region
- SINR and power consumption comparison for coupled and decoupled
- D2D and Decoupling Results
- Conclusions

What is decoupling

- For UE1, Macro is good for both UL/DL.
- For UE3, Small cell is good for both UL/DL.
- For UE2, Macro is good for DL but small cell is good for UL.

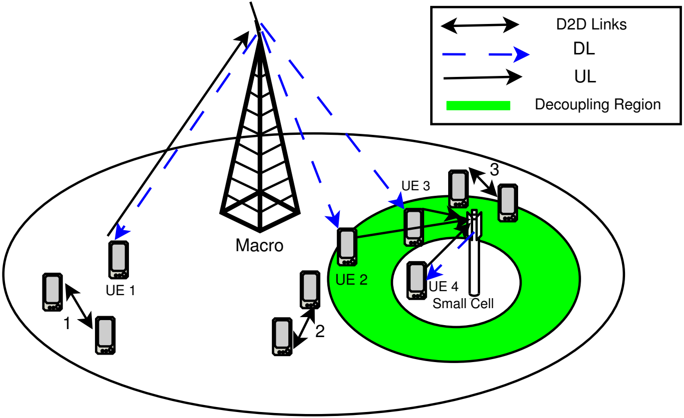


Decoupling Scenario

Advantages of decoupling

- Due to smaller path loss, uplink SNR will increase and transmit power requirement for a device will be lesser for a fixed target SNR.
- Uplink interference condition will be improved due to reduced UL transmit power.
- Increased uplink SNR and decreased uplink interference will result in increased SINR and hence, uplink data rate will be increased.
- UL load on Macro can be pushed towards underutilized small cells.

D2D and decoupling



Typical LTE-A Network Scenario with D2D Pairs and Decoupling Devices

Motivation and contributions

Motivation

- Uplink load on Macro can be reduced due to decoupling of a device.
- More D2D pairs can be enabled due to reduction in interference caused by decoupling devices.

Contributions

- Calculation of total power saved by a mobile UE due to decoupling during its stay in the decoupling region.
- Calculation of the area within which more D2D pairs can be enabled if devices in the decoupling region follows decoupling.
- Estimation of the decoupling region.

Power saving in decoupling scenario

Following notations have been used:

- d_S is the distance of the device from the small cell
- d_M is the distance of the device from the Macro
- ΔP_S is the power saved by the device due to decoupling if UL transmission takes place in decoupling region
- P_{T_M} is the transmit power of the UE with respect to the Macro
- P_0 is the target power which must be received by the Macro or small cell
- α is the power control factor
- $P_{T_{M,i}}$ is the transmit power of the device on its i^{th} transmission to the Macro
- $P_{(T,M)_j}$ is the transmit power of the j^{th} device with respect to Macro
- d_{M_j},d_{S_j} is the location of j^{th} device with respect to Macro and small cell

Power saving in decoupling scenario (contd.)

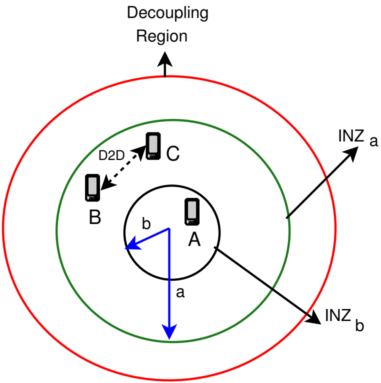
- For a device in a decoupling region, $d_S < d_M$
- $$\Delta P_S = P_{T_M} * (1 - (\frac{d_S}{d_M})^{3\alpha P_0})$$
- Total power saved by the UE, moving with v velocity in a straight line in the decoupling region and makes n number of transmissions each in t time-intervals, because of having a decoupled connection:

$$\sum_{i=1}^{n} P_{T_{M,i}} * (1 - (\frac{d_S - (i-1)vt}{d_M + (i-1)vt})^{3\alpha P_0})$$

- If there are m number of static devices located in the decoupling region having one time UL transmission then total power saved by the total number of devices can be written as follows:

$$\sum_{j=1}^{m} P_{(T,M)_j} * (1 - (\frac{d_{S_j}}{d_{M_j}})^{3\alpha P_0})$$

Enabling D2D through decoupling



Interference Zones of D2D Pair with respect to a Decoupling Device.

The boundary with radius a (denoted by INZ_a) and the boundary with radius b (denoted by INZ_b) show the interference zones of device A when it was uplinkly attached with Macro and small cell respectively.

Enabling D2D through decoupling (contd.)

Following notations have been used:

- λ is the interference threshold
- a and b are the radii of the interference zones of a device.
- P_{L_a} and P_{L_b} are the path-loss of device A at distance a and b when it is transmitting to Macro and small cell
- ΔA is the excess area which can be used to enable more D2D pairs
- ΔA_T is total excess area
- D is the number of devices communicating in the decoupling region
- a_i and b_i are the radii of interference zones of device i

Enabling D2D through decoupling (contd.)

- $$\lambda = P_{T_M} + P_{L_a} = P_{T_S} + P_{L_b} \tag{1}$$

- $$b = (a^{30} - 10^{(35\alpha-1)}(d_M^{30\alpha} - d_S^{30\alpha}))^{\frac{1}{30}} \tag{2}$$

- $$\Delta A = \pi(a^2 - b^2) \tag{3}$$

- If we assume that interference zones of any two devices will never overlap and a D2D pair is under the interference of single decoupling device then:

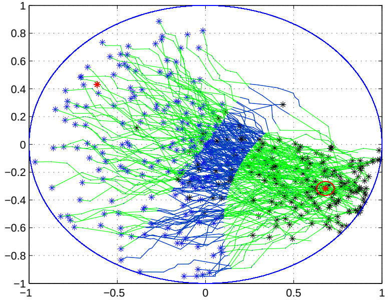
$$\Delta A_T = \sum_{i=1}^{D} \pi({a_i}^2 - {b_i}^2) \tag{4}$$

Time spent in decoupling region

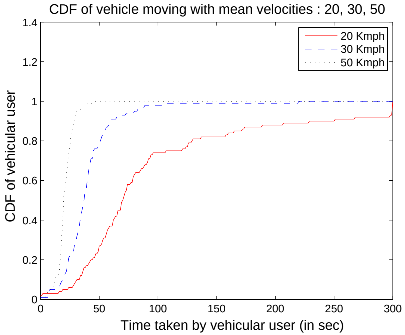
Simulation Parameters For Mobility Model

Parameter	**Model**	**Model-Parameter**
Distance	Half Normal Distribution	Mean $=$ 0.01 Km, Variance $=$ 0.01 Km
Rotation Angle	Uniform Random	Range $= [\theta - \pi/4, \theta + \pi/4]$ where, θ is angle between user and Femto cell with $+$ve x-axis.
Velocity: Vehicular	Half Normal Distribution	Mean $=$ (20, 30, 50) Kmph, Variance $=$ 10 Kmph

Time spent in decoupling region (contd.)



Decoupling Region



CDF of Decoupling Time of Devices Having Speeds 20, 30 and 50Kmph

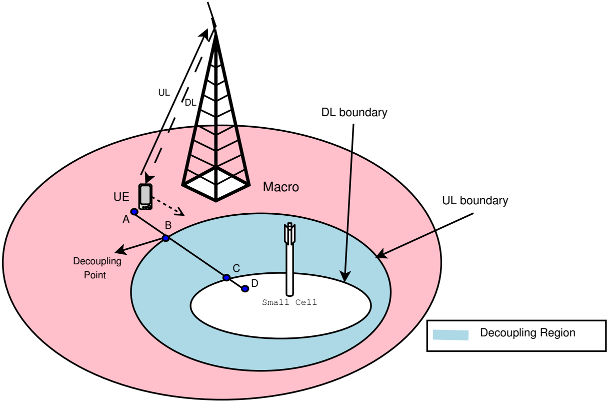
1. Decoupling time decreases with increasing speed.
2. Decoupling time is order of tens of second.

SINR and power consumption comparison

Simulation Parameters

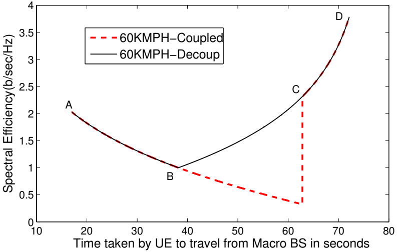
Parameter	**Value**
Macro and small cell downlink transmit power	40, 20 dBm
Maximum UE uplink transmit power	23 dBm
Number of RBs	10
Macro and small cell power control parameter (α) and (β)	0.7, 0.7
Macro and small cell coverage radius	1 Km, 0.035 Km
Scheduling algorithm	Round-Robin

SINR and power consumption comparison (contd.)

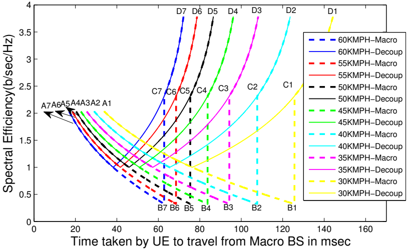


Decoupling Points

SINR and power consumption comparison (contd.)



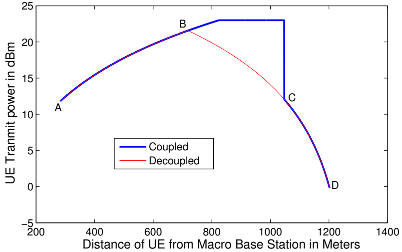
Spectral Efficiency Comparison for Coupling vs Decoupling in Mobility Scenario.



Spectral Efficiency Comparison for Different Velocity

- Spectral efficiency improves in case of decoupled connection.
- As speed of the device increases, rate of decrement of spectral efficiency increases for coupled connection while rate of increment of spectral efficiency increases for decoupled connection.

SINR and power consumption comparison (contd.)



Comparison of Transmit Powers for Coupled and Decoupled Scenario

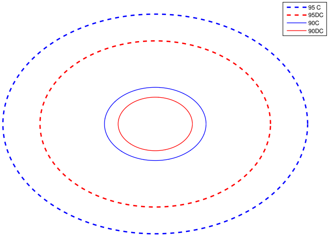
- Energy consumption per device decreases in case of decoupled connection.

D2D and decoupling results

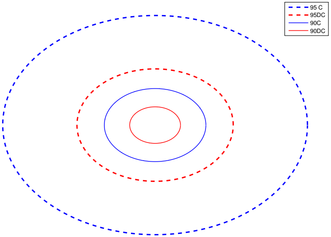
D2D Simulation Parameters

Parameter	Value
Macro coverage radius	800 Meters
Maximum transmit power of UE and D2D device	23 dBm
D2D interference threshold	90, 95 dBm
Distance of decoupling device from Macro	0.6, 0.73 KM

D2D and decoupling results (contd.)



Interference zone of a decoupling device farther from small cell.



Interference zone of a decoupling device nearer to small cell.

Conclusions

- Decoupling between Macro and small cell is possible only in a particular area.
- Transmit power of a device reduces in decoupling region.
- Spectral efficiency of the system increases due to decoupling.
- More D2D can be enabled due to reduction in interference zone of a decoupling devices.

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Thank You !!!