WCDMA and OFDMA coexistence with device-to-device communication overlaying cellular networks

SDR - WInnComm 2013

January 8st, 2012

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Introduction

Motivation:

- Increasing demand for rich multimedia services;
- New solutions required to improve network capacity;
- D2D is a promising technique to small areas solution.

Objectives:

- Propose a new reuse method to D2D links overlaying cellular networks;
- Maximize resource sharing probability through OFDMA/WCDMA characteristics;
- Design allocation algorithms based on WCDMA spectrum decay.

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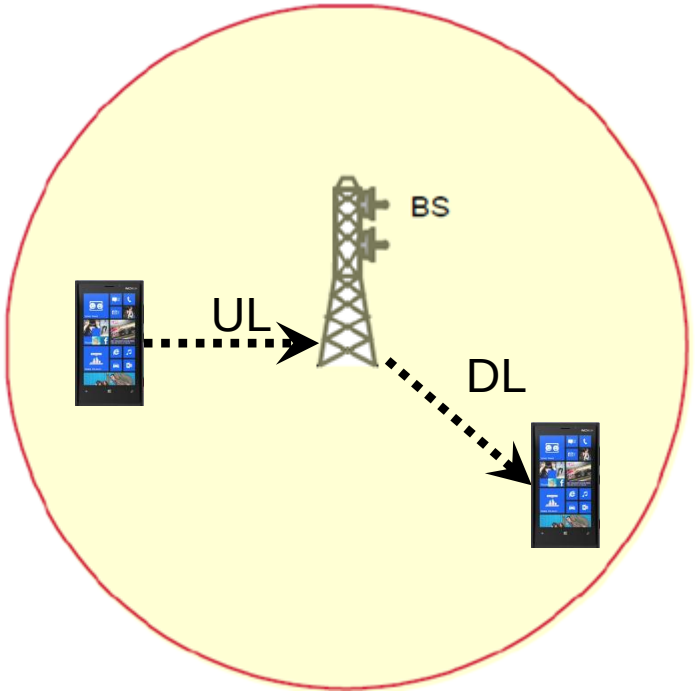
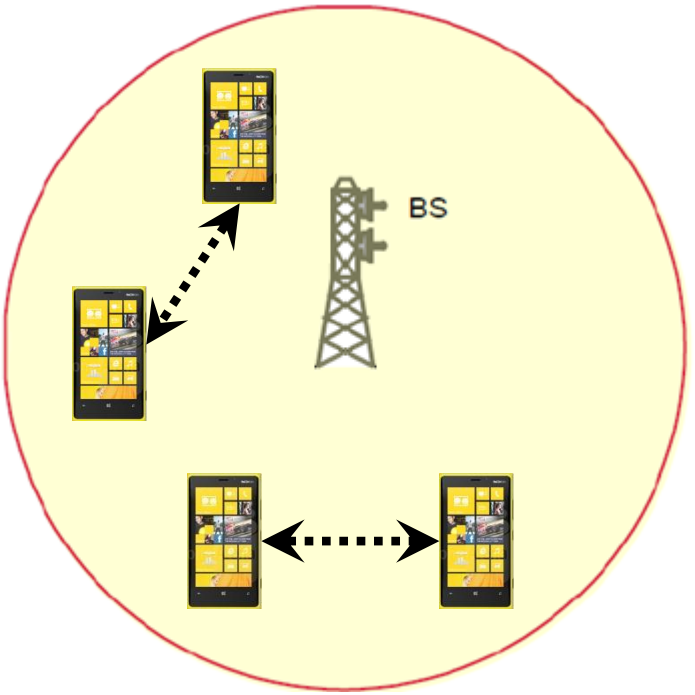
Cellular Networks and D2D Communication

Cellular Network



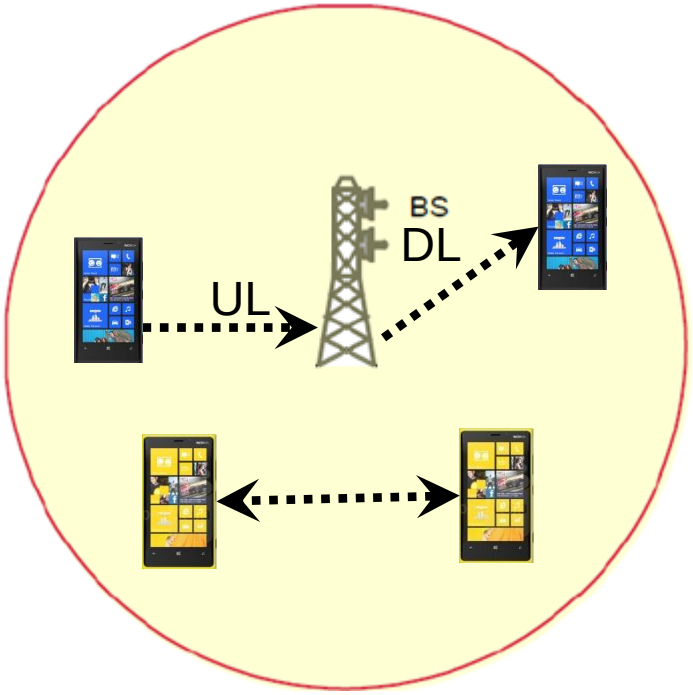
- Central Node Coordination
- Licensed Spectrum
- TX and RX don’t need to be in the same cell
- Information flows in two hops (UL and DL)

D2D Communication



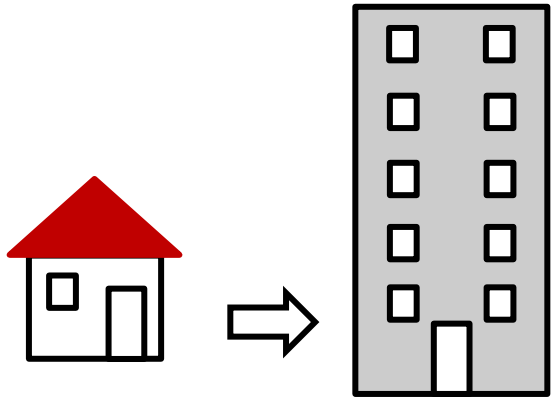
- Direct Communication
- Low power consumption
- Small Areas
- High Resource reuse

Overlaid Communication



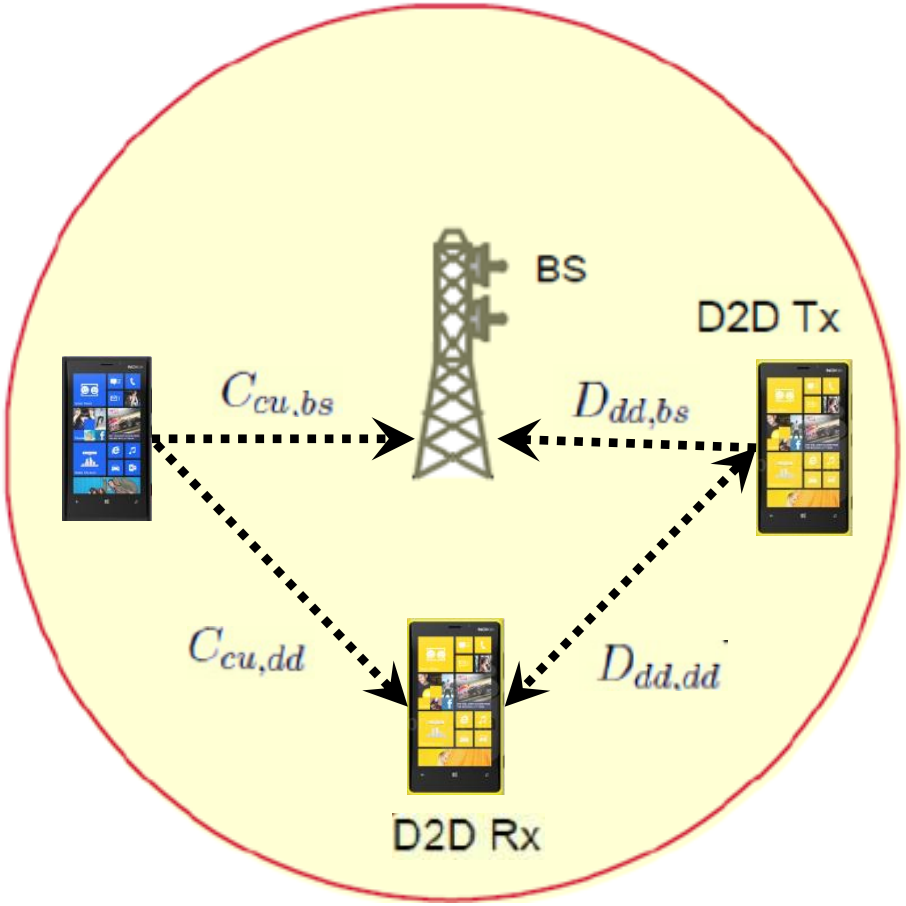
- Coordinated by the central node
- Reuse licensed spectrum
- D2D Low Power -> Low Interference

Advantages: Resource Sharing leads to Capacity Gain!



Sharing: individual accept controled losses to maximize group objectives – INTERFERENCE

Resource Sharing Policy



1. Based on model proposed on [1] .
2. Uplink Resource Sharing
3. CU (Cellular User): Primary User
4. Interference Margin: κ

$$SINR_{CU} \geq (1+\kappa)\beta_{cu}$$

5. Limited distance for D2D LINK:

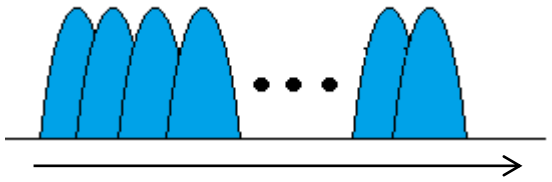
$$d_{crit} = D_{dd,bs}\left\{\frac{\kappa}{\beta_{dd}\left[1+(\kappa+1)\beta_{cu}\left(\frac{C_{cu,bs}}{C_{cu,dd}}\right)^{\alpha}\right]}\right\}^{1/\alpha}$$

Challenge: Reduce the cross-interference!

WCDMA: Technique known by the narrowband interference mitigation.

WCDMA Vs OFDMA

OFDMA Spectrum



Multiple Narrowband Subcarriers

WCDMA Spectrum

Wideband spread spectrum
Processing Gain (G)

WCDMA for D2D Overlaying OFDMA cellular network:

- One D2D Link interferes in several narrowband channels;
- Each OFDMA channel can be allocated to a different CU;
- Several narrowband channels interferes in one D2D Link;
- Narrowband mitigation on WCDMA side.

$$d_{crit} = D_{dd,bs}\left\{\frac{\kappa T_c}{\beta_{dd}\max_n\left(\left|S_h\left(n/T_{ofdm}\right)\right|\right)\left[1+X\right]}\right\}^{1/\alpha}$$

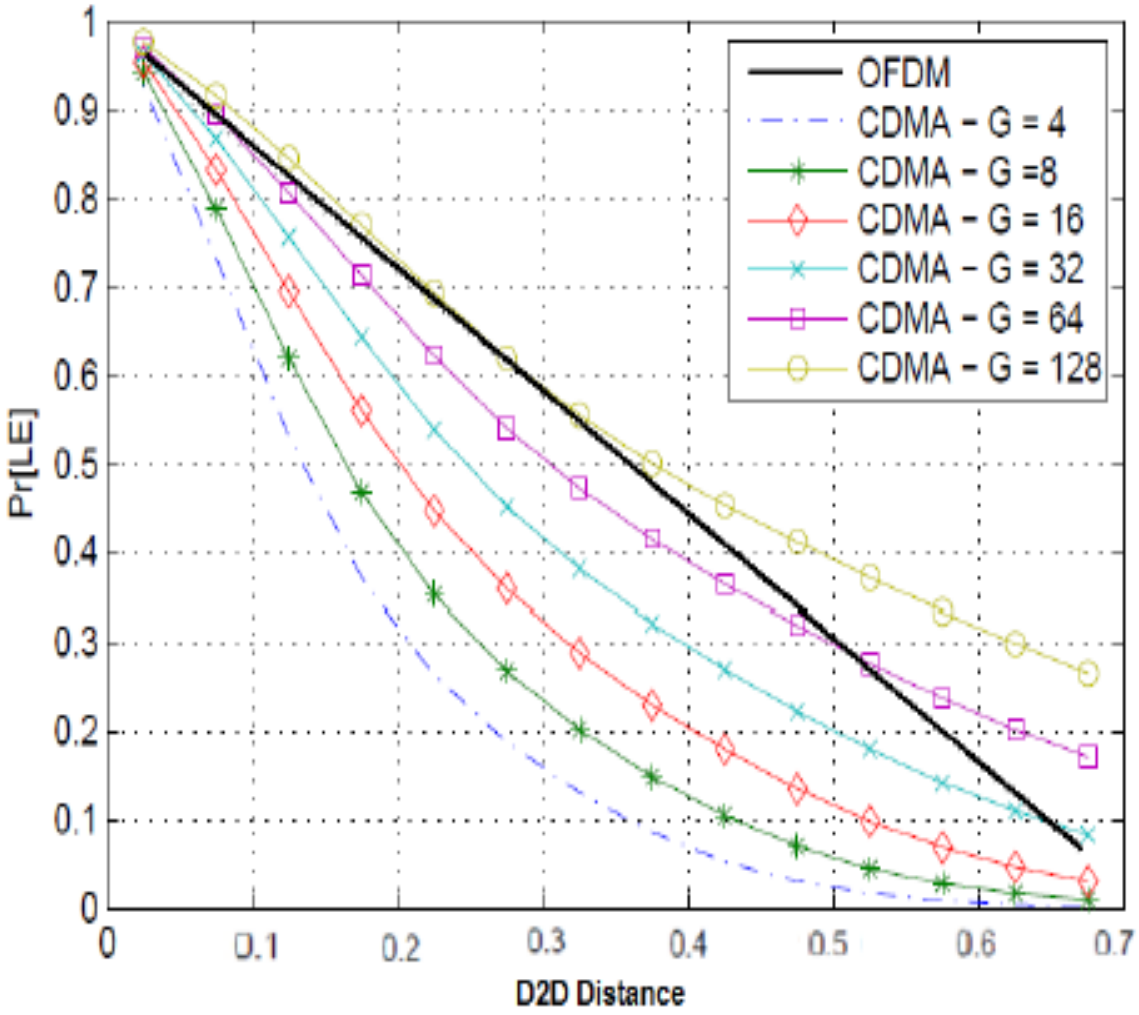
$$X = \beta_{mu}(1+\kappa)\sum_{n=0}^{N_{sc}-1}\left(\frac{C_{uc_n,bs}}{C_{uc_n,dd}}\right)^{\alpha}\left|S_h\left(n/T_{ofdm}\right)\right|$$

D2D WCDMA Overlaying Cellular OFDMA

Parameter	Value
κ	1
β_{CU}	10 dB
β_{dd}	7 dB
α	3.5
T_{ofdm}	$0.1ms$
Chip rate	$2.3Mcps$
T_c	$1/(ChipRate)$
T_{ofdm}/T_c	230
Number of Subcarriers	450
Resource Blocks	25
System Bandwidth	4.5 Mhz

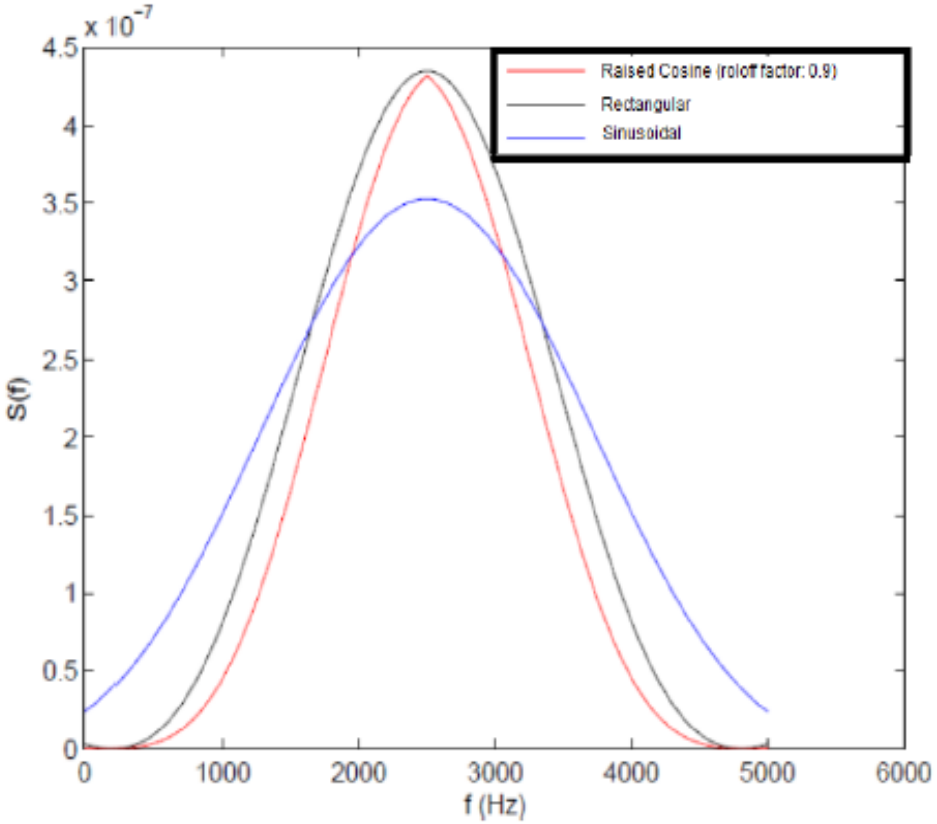
- Pr[LE] is higher for secondary link using OFDMA technique.

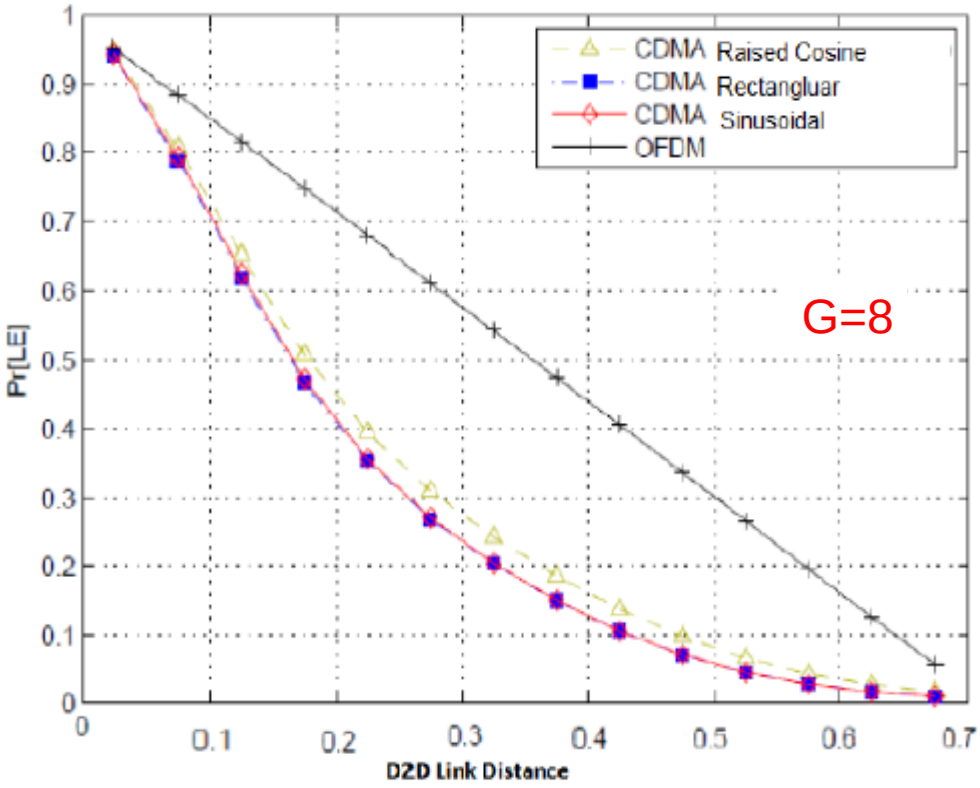
How we can use WCDMA characteristics to improve Pr[LE]??



WCDMA Pulse Waveform

Different WCDMA waveforms



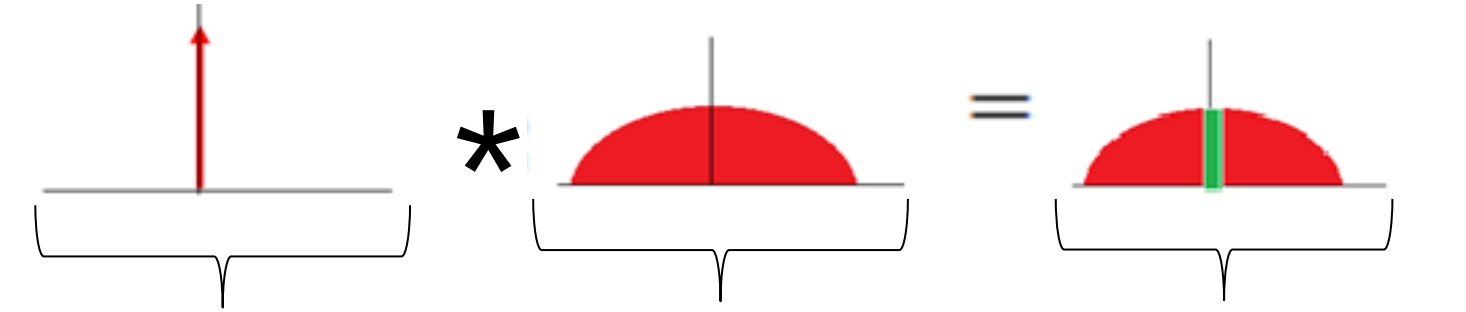


Few gain observed. The side decay on WCDMA spectrum is not used properly.

Is it possible to improve this gain?

Narrowband Interference in WCDMA Signal

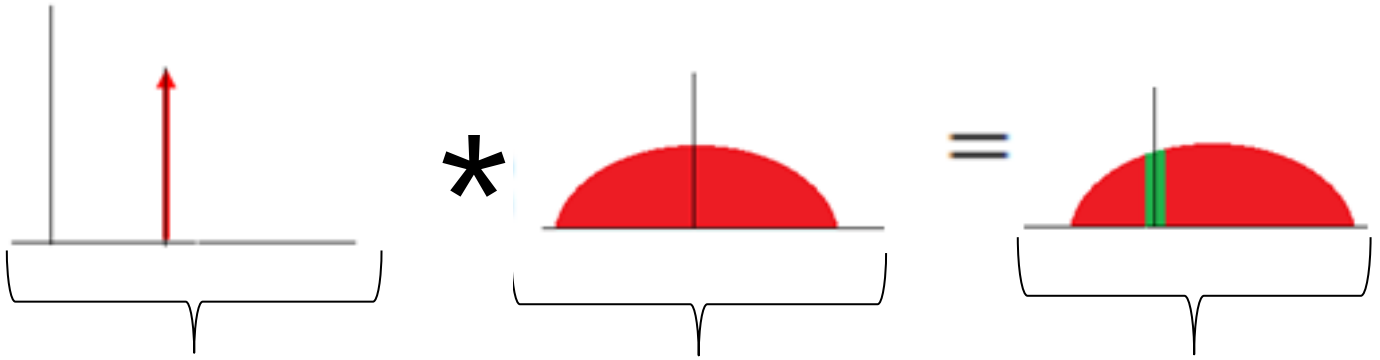
WCDMA Reception



Narrowband Interference in central frequency

WCDMA Despreading Sequence

Interference Power after low-pass filtering.



Narrowband Interference in side frequency.

WCDMA Despreading Sequence

Interference Power after low-pass filtering.

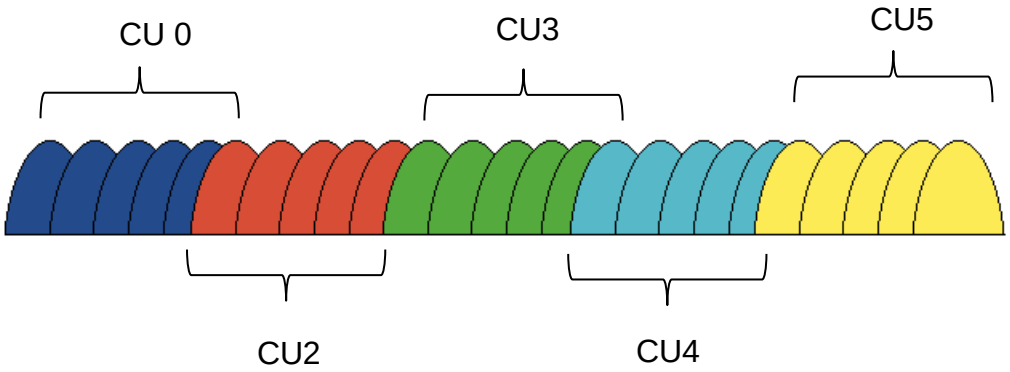
The farther from the center frequency the greater the attenuation.

Primary User Reassignment Strategy

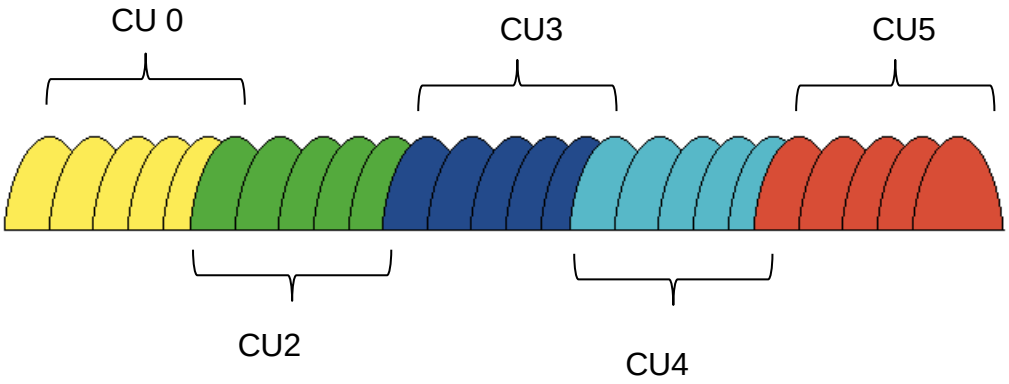
$$d_{crit} = D_{dd,bs}\left\{\frac{\kappa T_c}{\beta_{dd}\max_n(|S_h(n/T_{ofdm})|)\,[1+X]}\right\}^{1/\alpha}$$

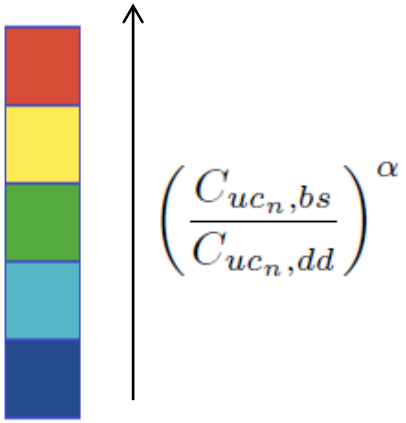
$$X = \beta_{mu}(1+\kappa)\sum_{n=0}^{N_{sc}-1}\left(\frac{C_{uc_n,bs}}{C_{uc_n,dd}}\right)^{\alpha}|S_h(n/T_{ofdm})|$$

Before Channel Reassignment

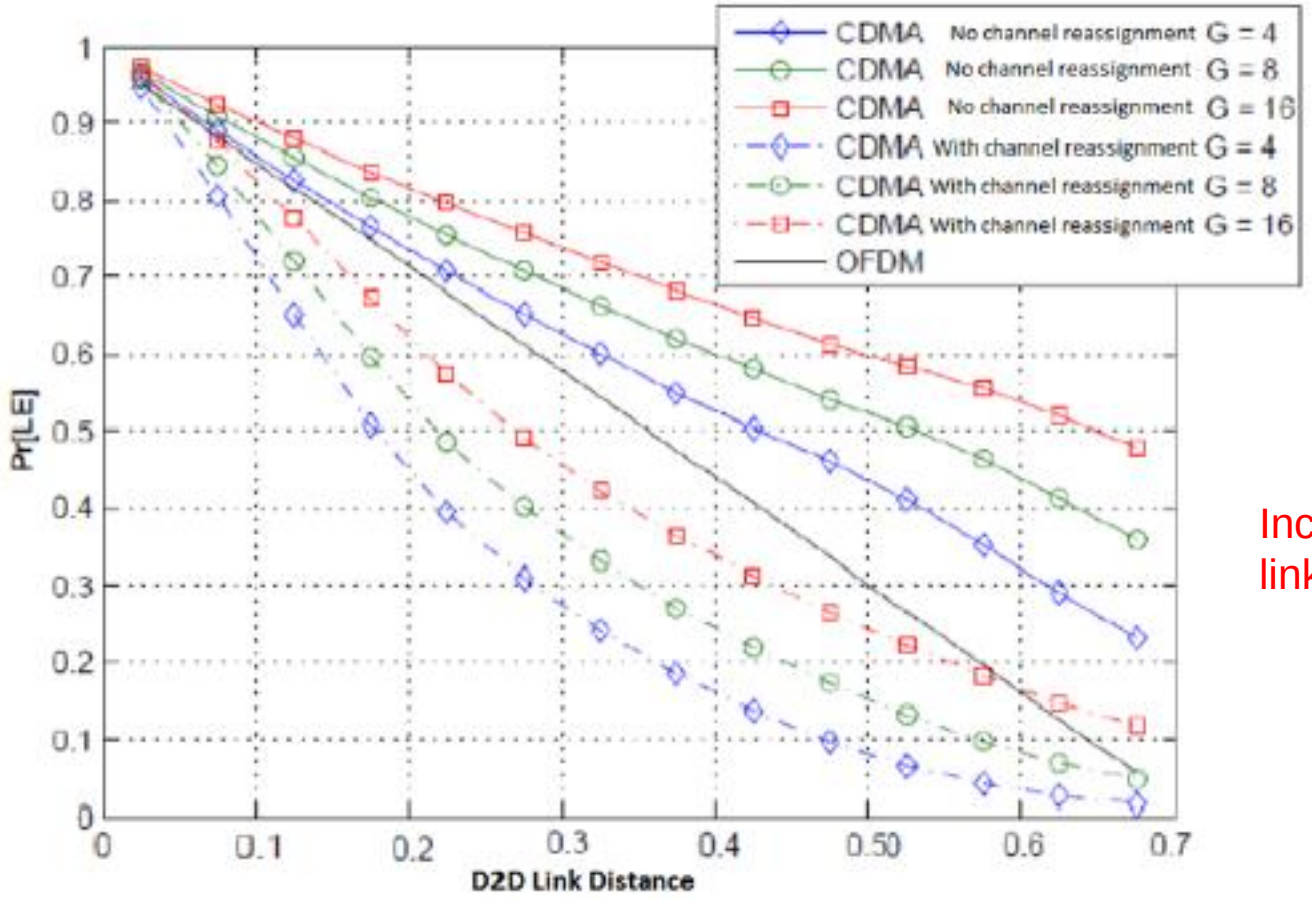


After Channel Reassignment





Reassignment Strategy Result



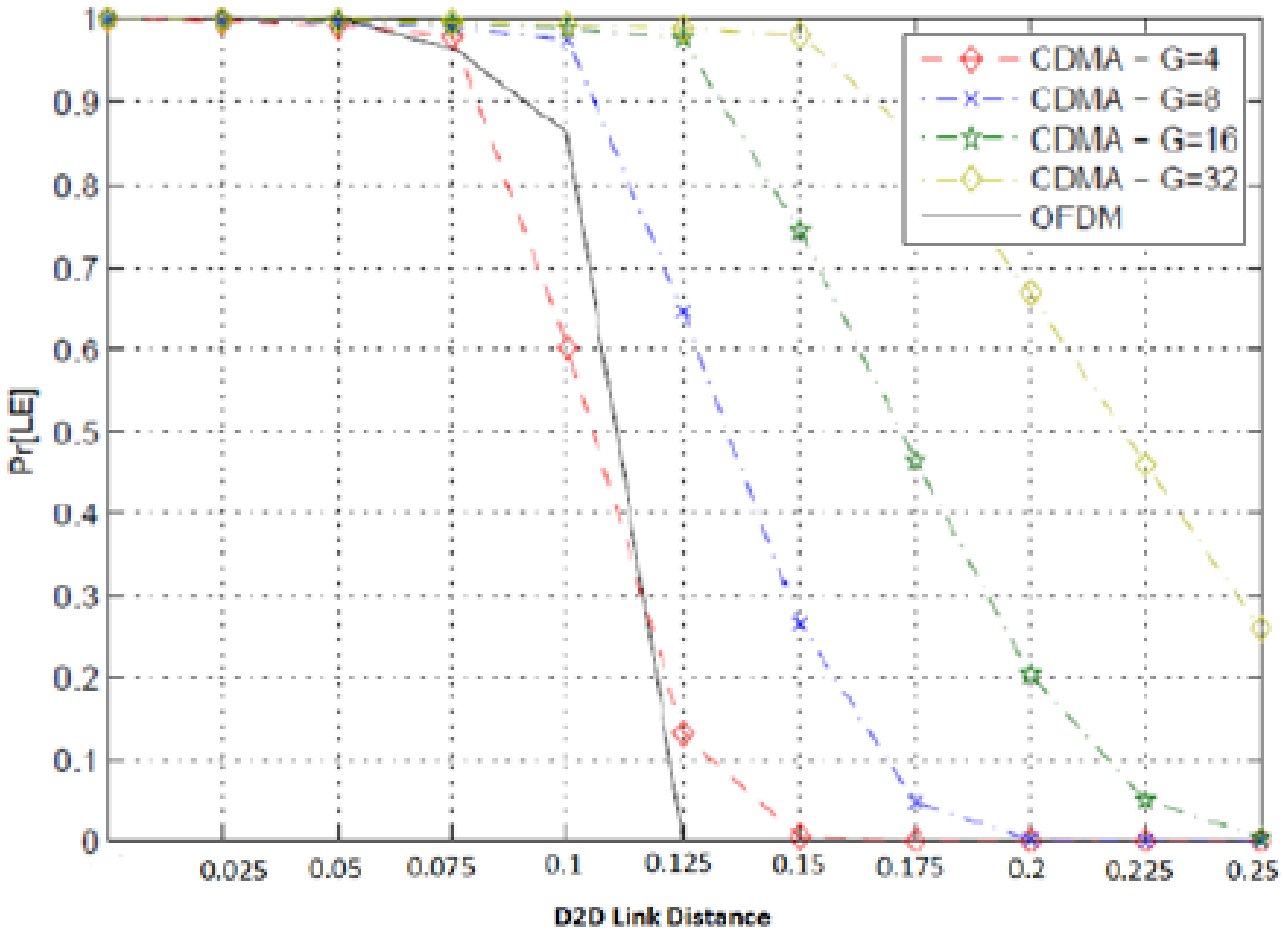
$\uparrow d_{crit}$ $\uparrow$ Pr[LE]

Under same conditions

Increase in D2D maximum link distance !!!

Reassignment Strategy Result

$D_{dd,bs} = 0.125$



$\uparrow d_{crit}$ $\uparrow$ Pr[LE]

Increase in D2D maximum link distance !!!

Conclusion

- WCDMA link overlaying OFDMA networks:
  - Same D2D link interferes in all CU. And Vice-Versa.
  - Interference mitigation can be achieved through proper coordination.
  - Resource Sharing gain is introduced by channel reassignment algorithm.
  - Flexibility in D2D link interference controled by the spread factor (G).

- Major Contributions:
  - Development of WCDMA and OFDMA spectrum sharing strategy for D2D communication.
  - Channel Reassignment Algorithm as an interference mitigation tool.

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Reference

[1] B. Kaufman and B. Aazhang, “Cellular networks with an overlaid device to device network”, in *42nd Asilomar Conference on Signals, Systems and Computers,* 2008