D2D NEIGHBOR DISCOVERY INTERFERENCE MANAGEMENT FOR LTE SYSTEMS

Y. Zhao, B. Pelletier,
P. Marinier and D. Pani

Globecom 2013

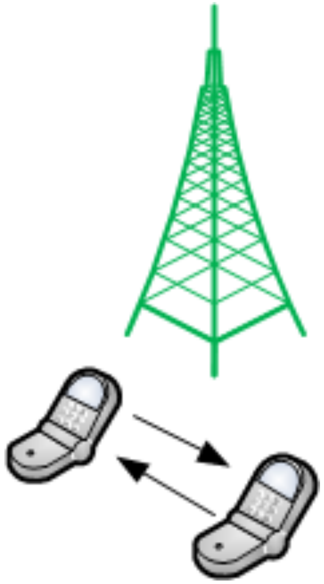
invention | collaboration | contribution

Outline

- Background
- System Model
- Interference Management Techniques
- Methodology
- Experimental results
- Summary and Conclusion

Background

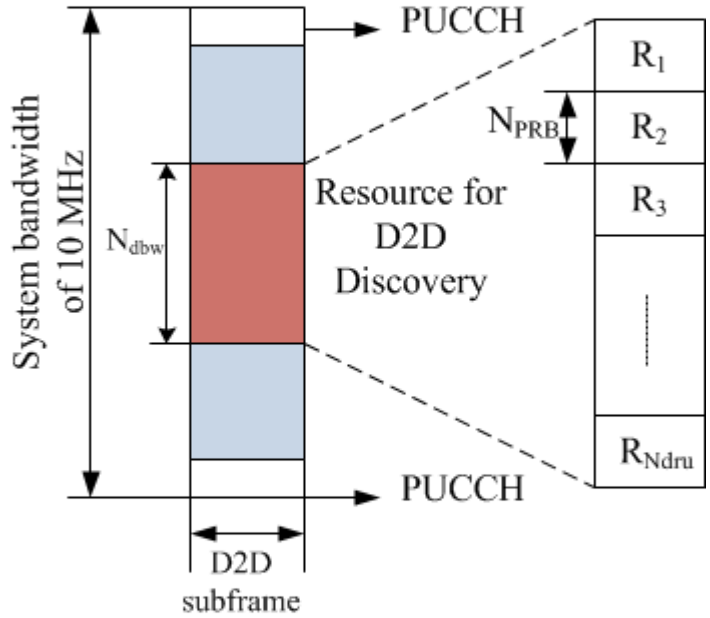
- Proximity detection is motivated by the desire to provide new services to mobile devices targetting:
  - Social applications
  - Advertisement
  - Local-based services
- Current cellular-based systems such LTE do not have mechanisms for precise location information
  - Precise location systems rely on combination of cellular, GPS and WiFi
  - This approach is inefficient from a battery and resource perspective
- In D2D discovery, two or more devices determine their proximity based on direct radio communications
- Implemented in LTE, D2D discovery has the potential to provide energy efficient, low-cost ubiquitous proximity information and further enable D2D communications



INTERDIGITAL

System Model LTE Resource Allocation

- Uplink frequency is used for transmission of D2D discovery signal
- Set of UL resources are reserved for D2D discovery
- Neighbor eNBs use the same resources and are assumed coarsely synchronized
- Individual discovery signals occupy N_{PRB} resource blocks
- Discovery signals are transmitted over specific discovery resource units R_i



INTERDIGITAL

System Model — Signal Design

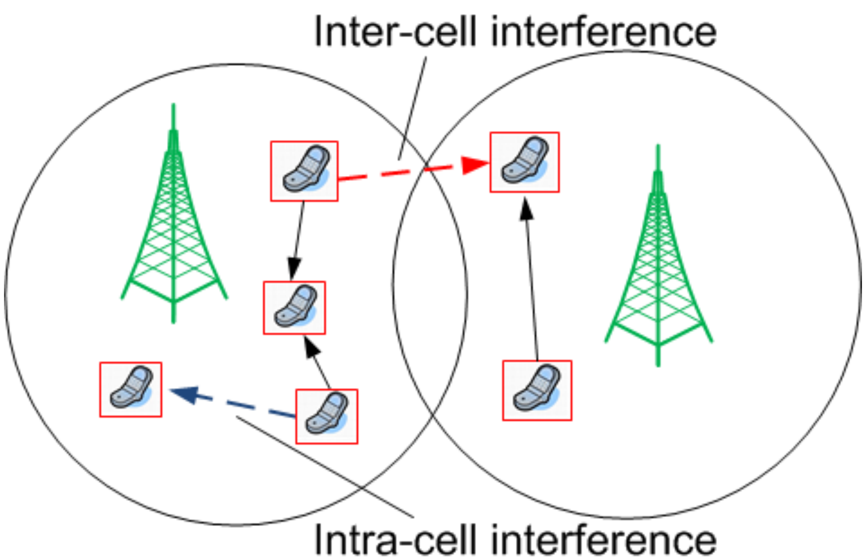
- Assume a signal-based discovery carrying no payload
- Signal based on Zadoff-Chu (ZC) sequences of a specific length N_{zc}
- Discovery signals $x_k(n+\sigma)$ is characterized by root (k) and cyclic shift (σ) combination, with correlation property $\rho_{k,q}(\sigma)$ such that:

$$\rho_{k,q}(\sigma)=\begin{cases}\sum_{n=0}^{N_{zc}-1} x_k(n)\,x_q^*(n+\sigma)=\delta(\sigma) & k=q\\ \sum_{n=0}^{N_{zc}-1} x_k(n)\,x_q^*(n+\sigma)=1/\sqrt{N_{zc}} & k\neq q\end{cases}$$

- Interference between discovery signals caused by:
  1. Signals with same ZC roots and same cyclic shift (collision)
  2. Signals with different ZC roots, regardless of cyclic shifts
- Up to N_{zc} cyclic shifts can be allocated for each ZC root

System Model Interference Model

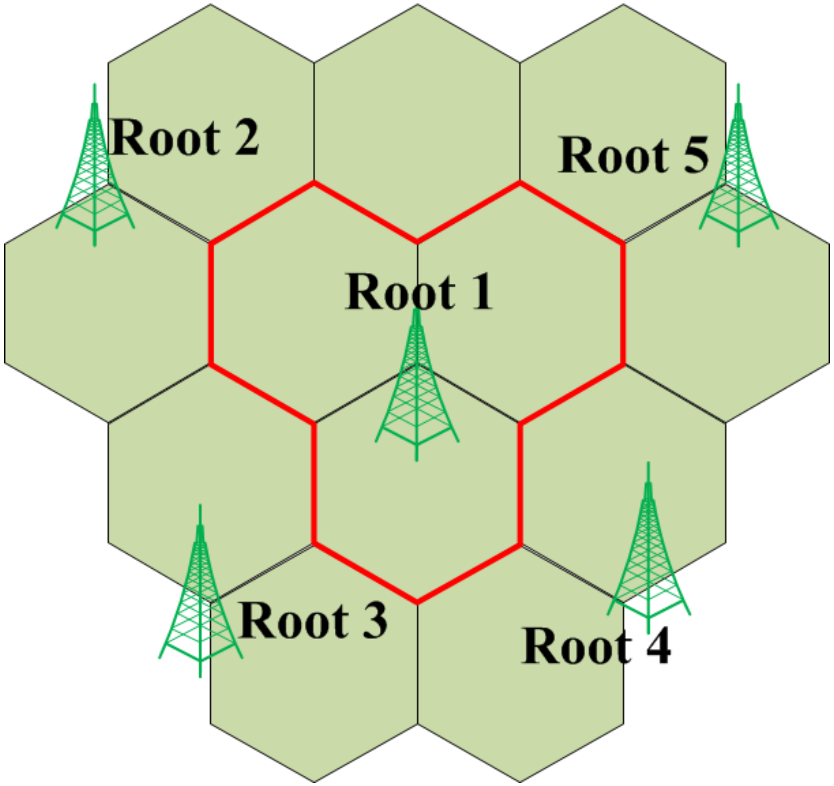
- In practice a limited number of discovery resource units are allocated
- Baseline assumption: each eNB assigns a different set of root sequences
  - Inter-cell interference arises from all D2D UEs transmitting in the other cell over the same discovery resource unit
  - Intra-cell interference arises from UEs allocated with a different root sequence (due to e.g. running out of cyclic shifts for a given root) also transmitting in the same discovery resource unit



INTERDIGITAL

Interference Management Techniques – Option 1

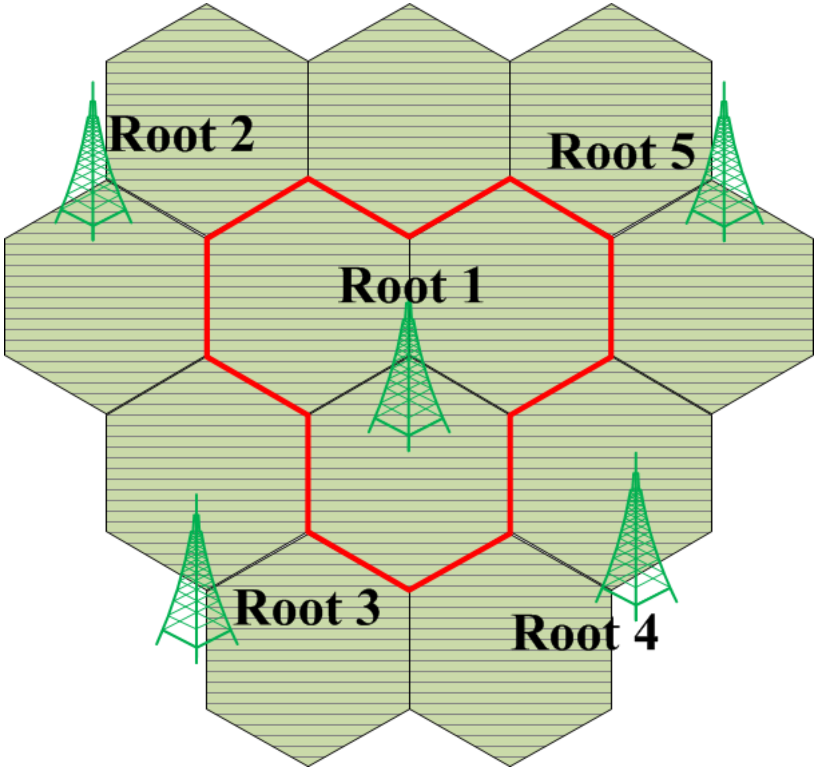
- Each eNB assigns the discovery resources and uses a different pool of root sequences
- All cyclic shifts of a given root sequence are allocated before a new discovery resource unit is allocated
- All discovery resource units are allocated before a second root sequence is allocated on an already allocated discovery resource unit



INTERDIGITAL

Interference Management Techniques – Option 2

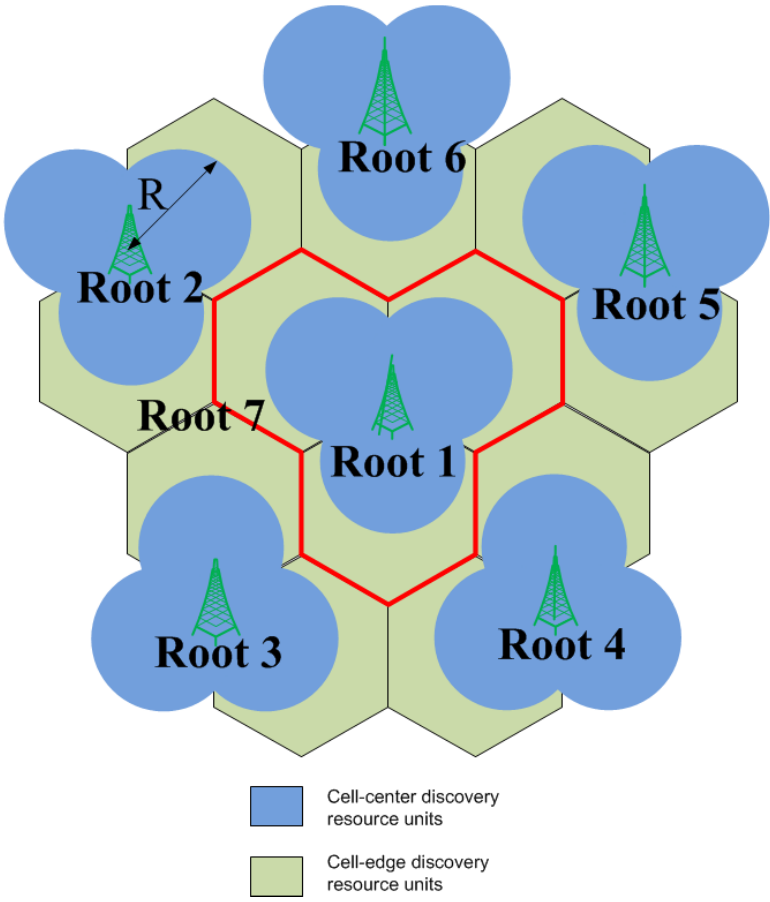
- Similar to Option 1:
  - Each eNB assigns the discovery resources and uses a different pool of root sequences
  - All discovery resource units are allocated before a second root sequence is allocated on an already allocated discovery resource unit
- Discovery resource unit are assigned in alternance to randomize interference in frequency



INTERDIGITAL.

Interference Management Techniques – Option 3

- Option 3 is motivated by the observation that the cell-edge UEs suffer more from inter-cell interference than cell-center UEs
- Discovery resource units are seggregated between cell-edge UEs and cell-center UEs
- Resources are assumed to be assigned by a centralized controller



Methodology

The experiment consists of a set of system-level simulations where:

- N_{TX} transmitting and N_{RX} monitoring UEs are dropped uniformly in each sector
- The path loss between each transmit-receive UE pair (l,m) is calculated ($PL_{l,m}$)
- The resource allocation according to one of the option is carried out
- The SINR at receiver l for a given target transmit UE m with TX power $P_{TX,m}$ is calculated as follows:

$$SINR_{l,m} = \frac{P_{TX,m}/PL_{l,m}}{P_{I,l}+\sigma_w^2}$$

where σ_w^2 is the thermal noise power and $P_{I,l}$ is the interference term derived from the discovery signal properties as follows:

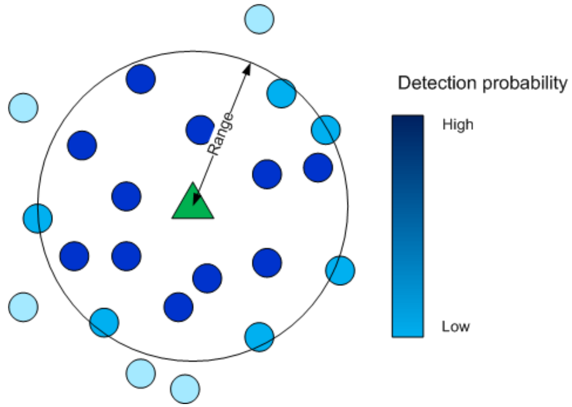
$$P_{I,l} = \sum_{m\in\mathcal{U}(l)} \rho_{\mathcal{R}(m),\mathcal{R}(l)}\left(\mathcal{C}(m)-\mathcal{C}(l)\right) P_{TX,m}/PL_{l,m}$$

$\mathcal{C}(m)$ and $\mathcal{R}(m)$ are the cyclic shifts and root sequences of UE m, respectively.

- Statistics are accumulated over multiple drops to emulate UE mobility

Methodology

- Probability of missed detection (P_m):
  - In this experiment P_m is determined analytically based on the properties of the discovery signal and the characteristics of each drop
  - This model assumes that the total interference is spectrally white
- False alarm probability (P_{fa}):
  - The false alarm probability is the probability that a UE detects the presence of another UE in proximity, where in fact there is no such UE present
  - P_{fa} is also determined analytically
- Range:
  - The distance for which 95% or more of the discovery signals are discovered at a target false alarm probability of 0.1%



INTERDIGITAL

Simulation assumptions

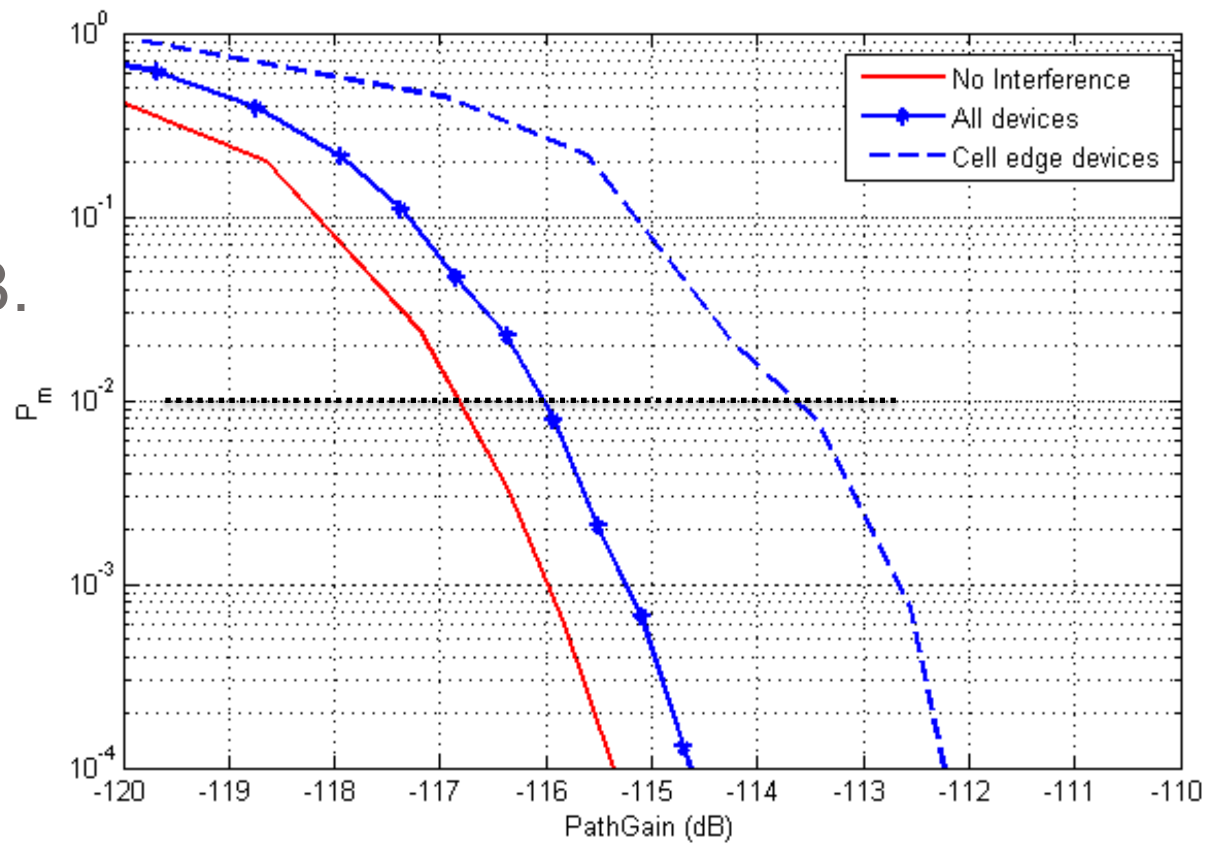
Cat.	Parameter	Value
Deployment	ISD	500 m
	Distribution of devices	Uniformly
	Mobility	3 km/hr
	Centre carrier frequency	2 GHz
	System bandwidth (BW)	10 MHz
Channel model	Path loss model	Indoor Hotspot NLOS
	Shadowing standard deviation	4 dB
Device params.	Antenna gain	0 dBi
	Noise figure	9 dB
	Antenna height	1.5 m
	Number of Tx and Rx antennas	1 Tx / 2 Rx

Cat.	Parameter	Value
Discovery signal parameters	Length of discovery signal	800 µs
	Length of cyclic prefix	12.5 µs
	D	12.5 µs
	NRB	6 RBs
	Ndru	2
	Discovery bandwidth Ndbw	12 RBs
	Ncs	64
	Target false alarm rate	0.1%
	Target detection rate	95%
	Target detection range	200 m
	NTx	30 / sector
	NRx	60 / sector

InterDigital

Experimental Results P_m for cell-edge devices

- Cell-edge devices are those worst 10% UEs w.r.t. the distance to the eNB.
- Cell-edge device suffer a 2dB loss at $P\downarrow m = 1\%$ compare to the cell average



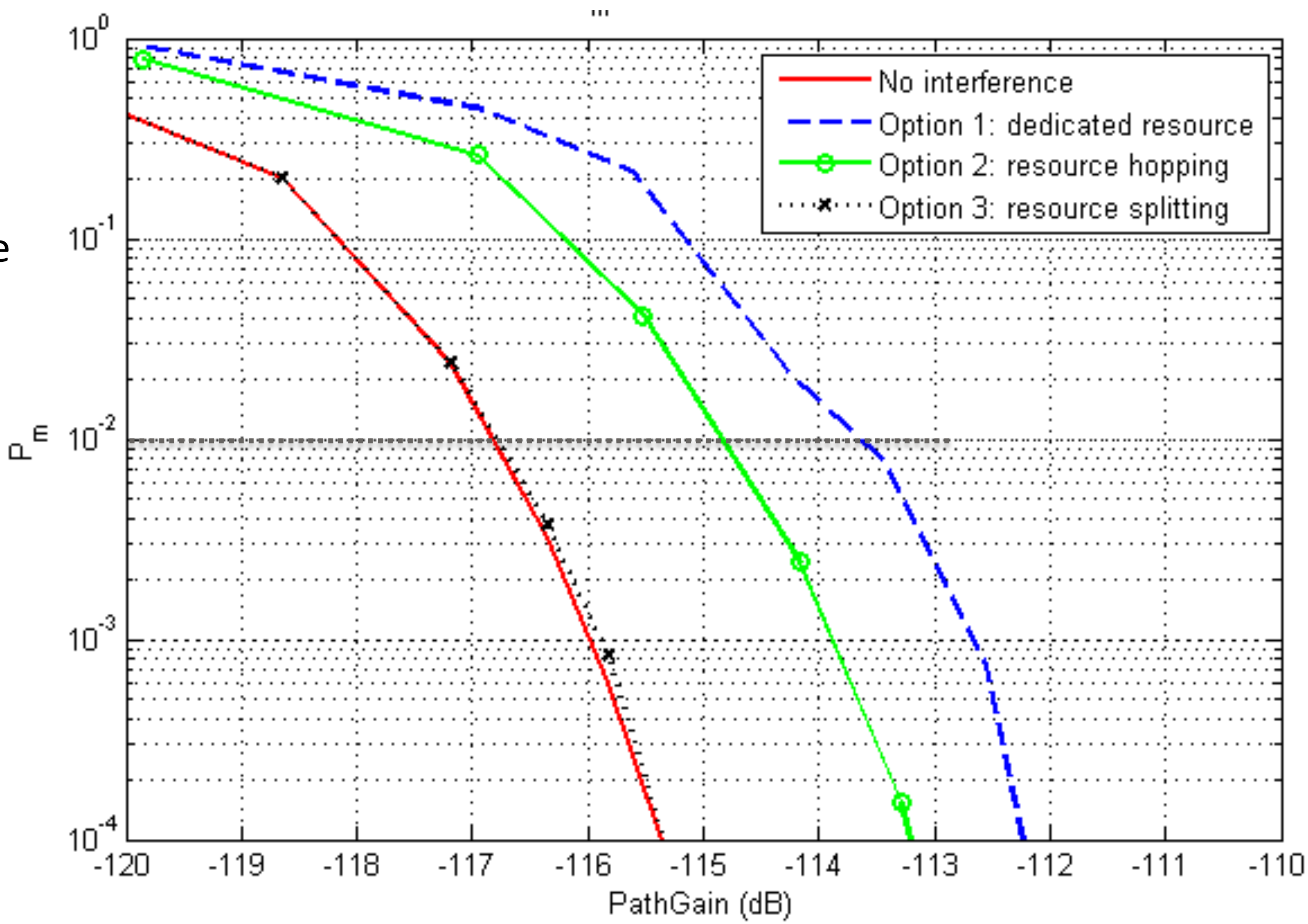
INTERDIGITAL.

Experimental Results

P_m for Options 1-3

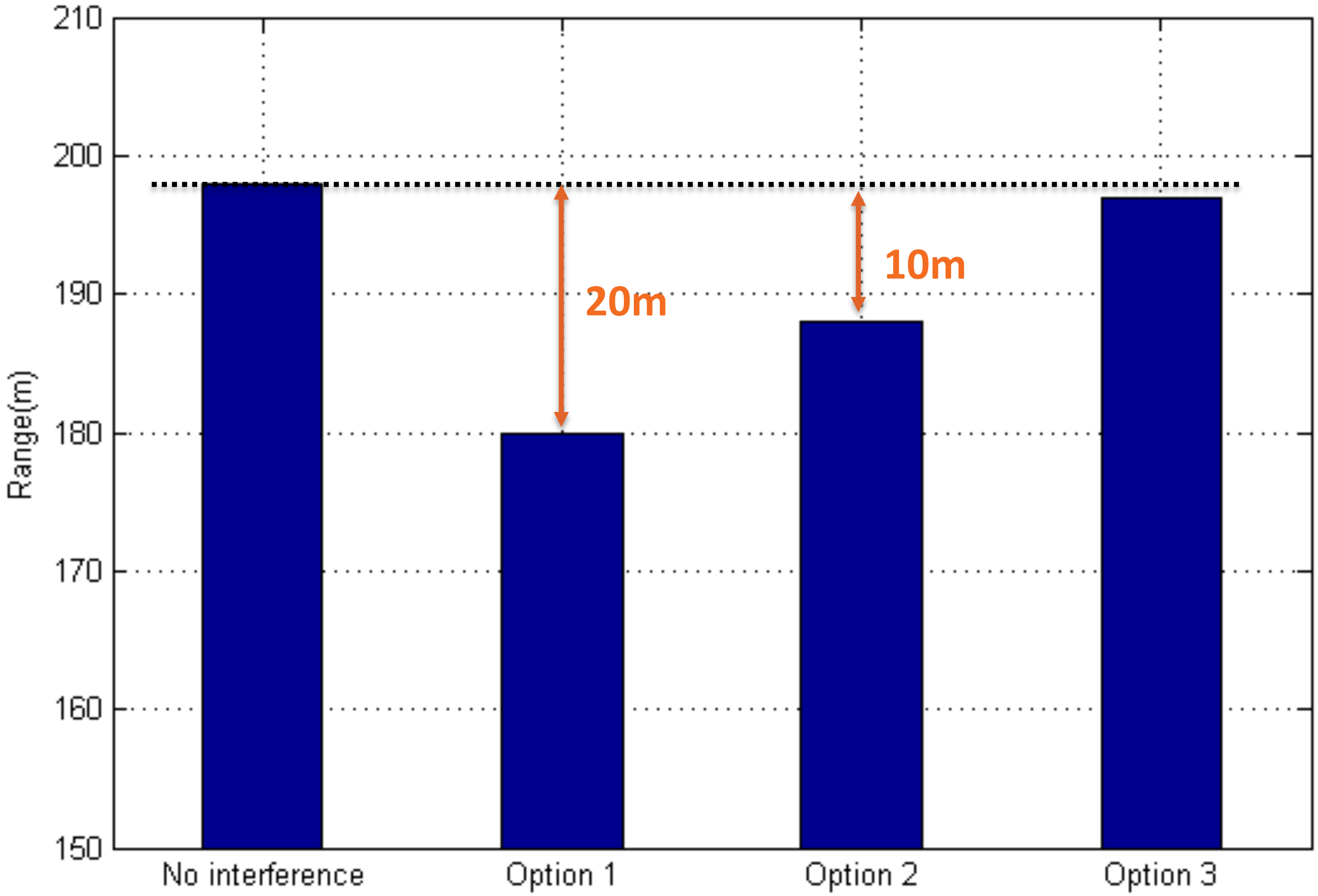
Impact of Interference at Pm=1%

Opt.	Loss
1	3dB
2	2dB
3	0dB



INTERDIGITAL

Experimental Results Range for Option 1-3



INTERDIGITAL

Summary and Conclusions

- This studies interference management for D2D discovery in the context of LTE systems
- Various practical options for resource allocations are studied
- The experimental results show that:
  - D2D discovery signal inter-cell interference has the potential to significantly impact the D2D discovery detection range
  - allocating the D2D discovery resources for cell-edge UEs using a centralized approach has to potential to (almost) eliminate the loss in D2D discovery detection range due to inter-cell interference