4G++: Advanced Performance Boosting Techniques in 4th Generation Wireless Systems and Beyond

Khaled Fouad Elsayed
Cairo University

www.4gpp-project.net

Opportunity Knocks Again!

- We are in the midst of the fifth major technology cycle of the past half a century.
- The era of the **Mobile Internet**

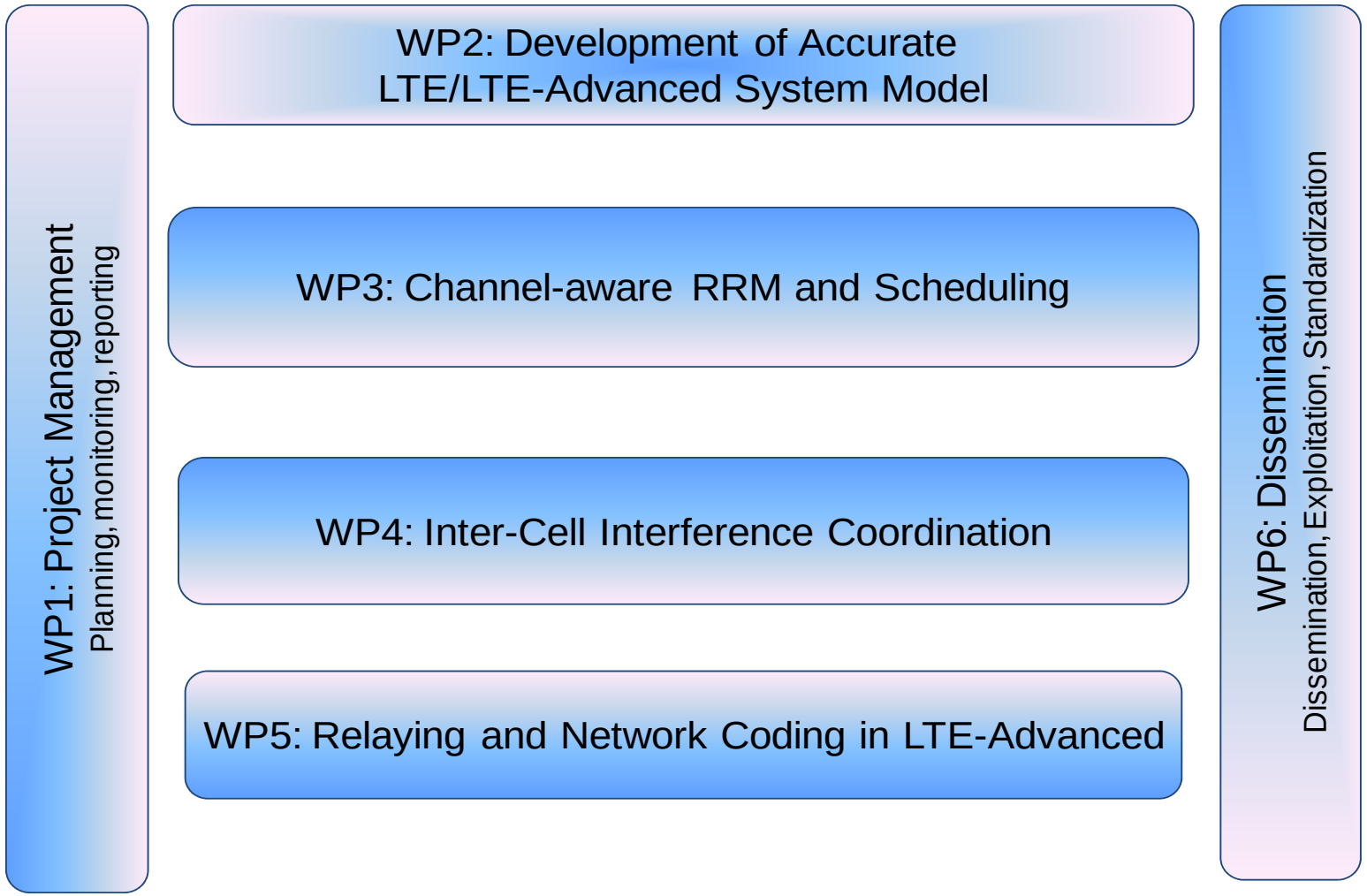
The 4G++ Research Project

- An ambitious project tackling a multitude of radio resource management techniques with goal of enhancing spectral efficiency in terms of bits/sec/Hz in LTE/LTE-A.
- Classical single-cell and multi-cell (resource allocation/power control).
- More challenging scenarios:
  - Carrier-aggregation
  - CoMP
  - D2D Underlay
  - Femto/PicoCells
  - Relays
  - HetNet
- Self-Organizing Networks (SoN) Concepts.

Main Techniques

- Optimization Techniques (Convex, ILP, MILP, SDP)
- Graph Theory
- (Approximation) Algorithms Design
- Linear Algebra
- Heuristics
- Interference and wireless capacity (basics of information theory).

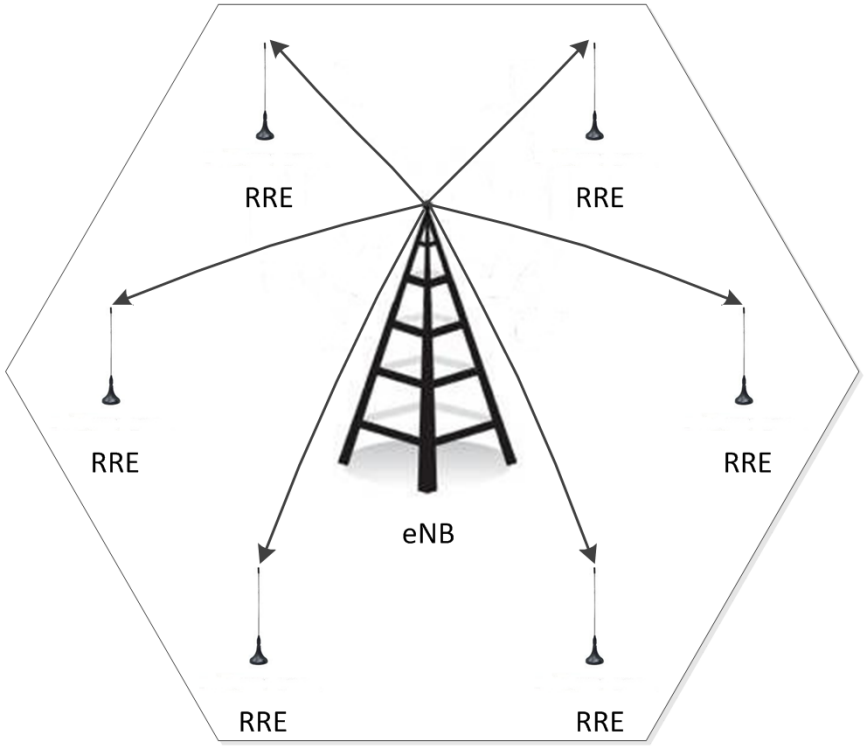
4G++ WP Structure



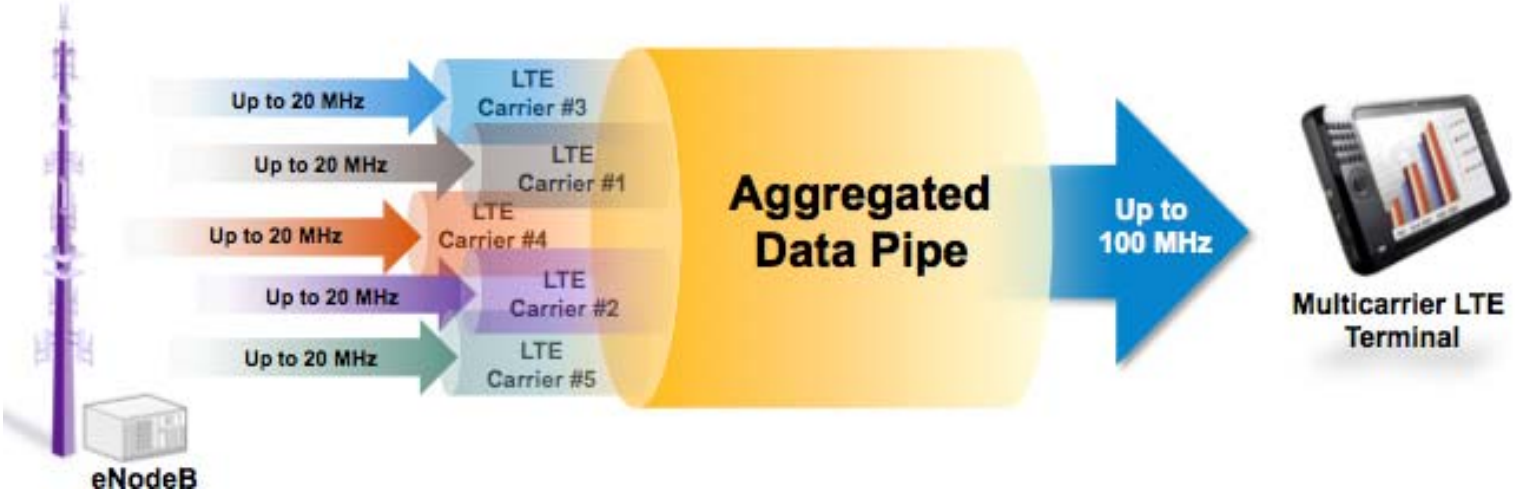
Coordinated Multi-point (CoMP)

- A CoMP refers to a system where several geographically distributed antenna modules coordinate to improve performance of the served users in the coordination area
- RRE/RRH: Remote radio equipment/head connected with Radio over Fiber (RoF) to base station (eNB)

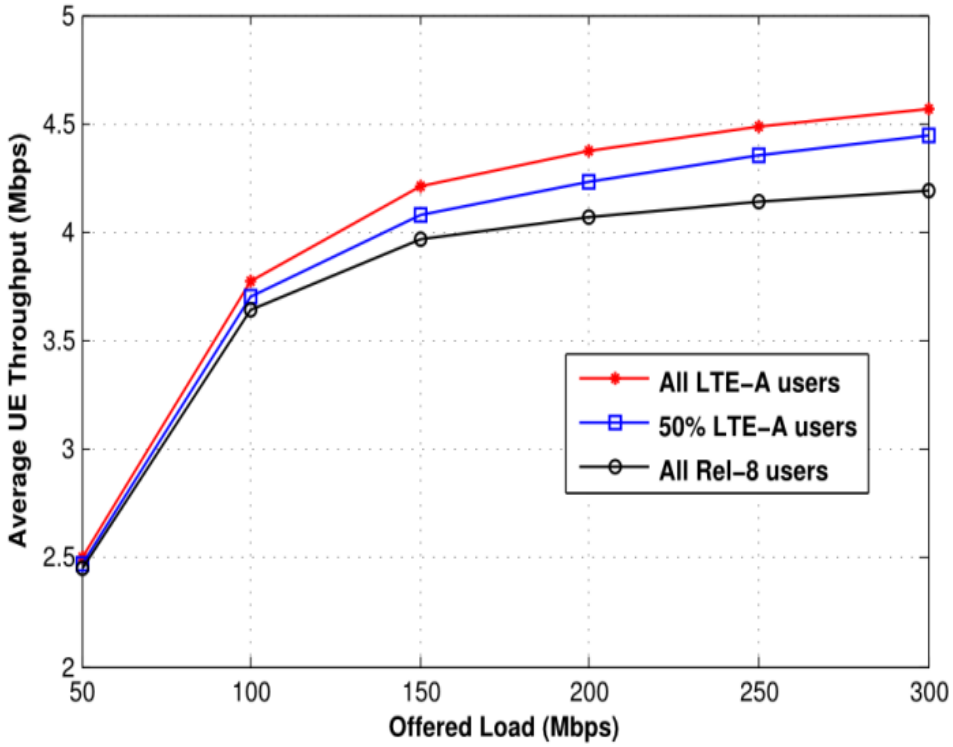
- Multi-cell coordinated transmission:
  - Coordinated Scheduling (one at a time).
  - Joint Processing/BF
- Multi-cell reception considered for beyond Rel. 10

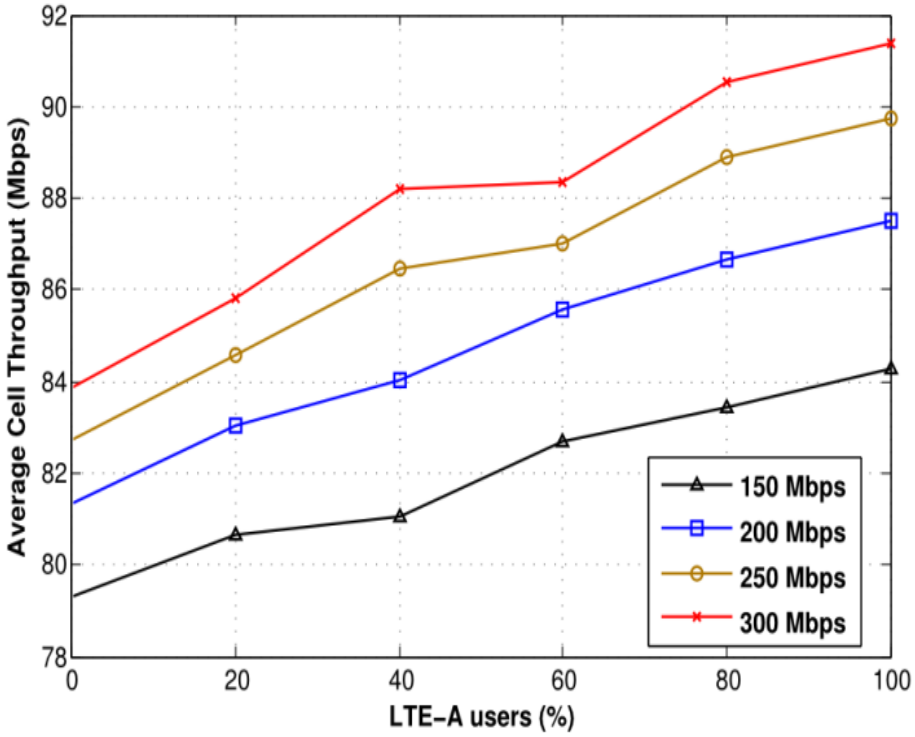


Why Carrier Aggregation



- To increase the data rate to 1 Gbit/s, LTE-A requires a high bandwidth of 100 MHz.
- This requires several LTE carriers to be aggregated.

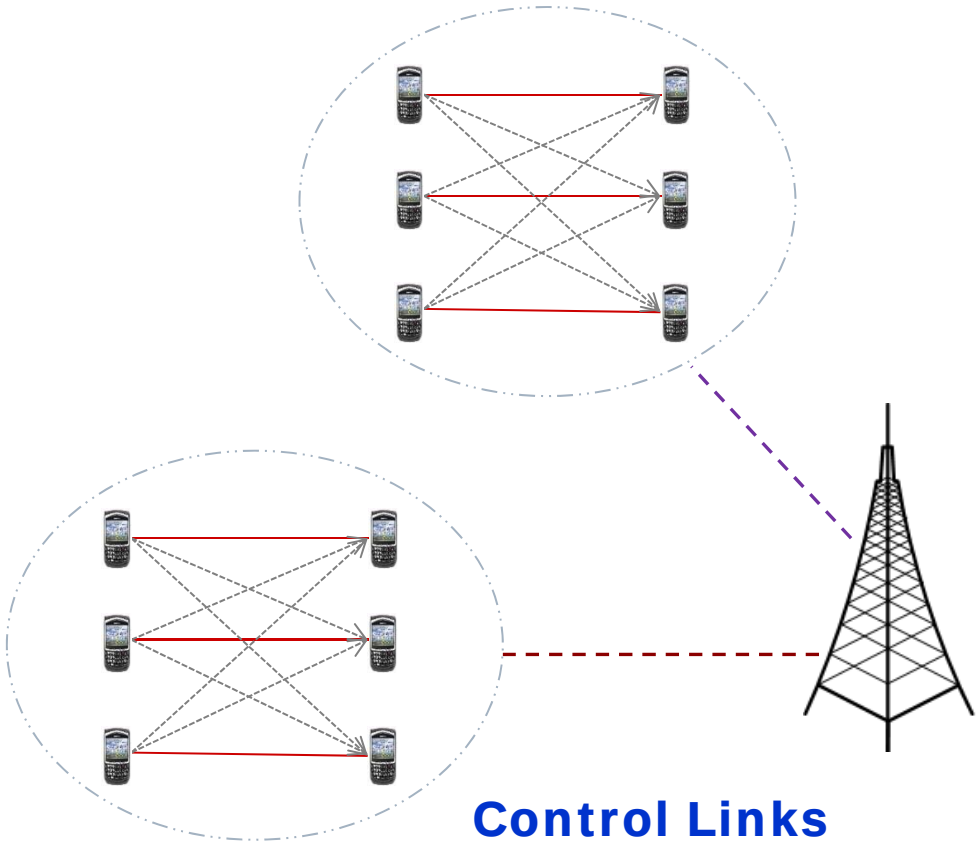

Average UE Throughput (Mbps)
Offered Load (Mbps)
All LTE-A users
50% LTE-A users
All Rel-8 users
5
4.5
4
3.5
3
2.5
2
50
100
150
200
250
300


Average Cell Throughput (Mbps)
LTE-A users (%)
150 Mbps
200 Mbps
250 Mbps
300 Mbps
92
90
88
86
84
82
80
78
0
20
40
60
80
100

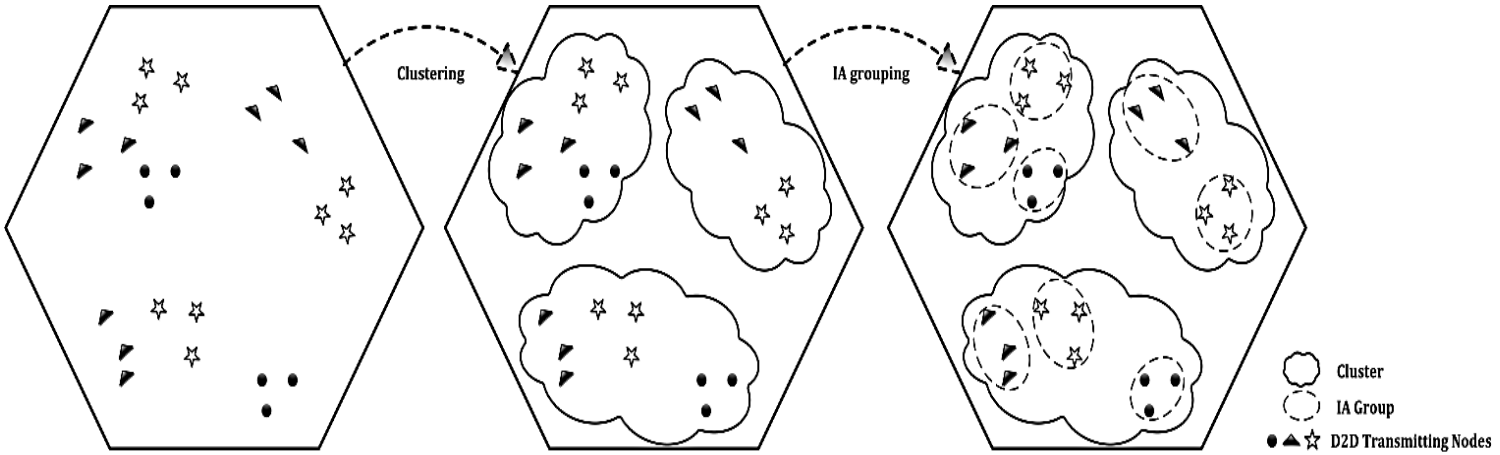
IA in D2D Uderlay Cellular Networks

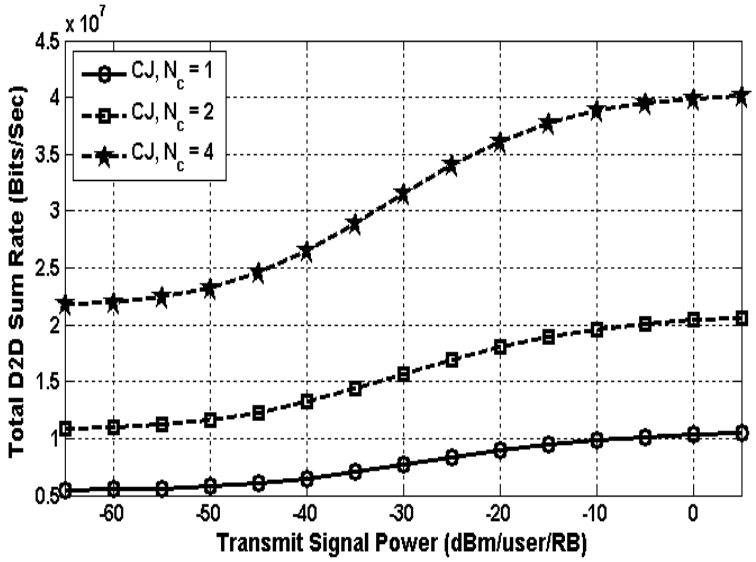
- UE units may communicate directly with each other over the D2D links.
- The UE in D2D connections remains controlled by the eNBs and continue cellular operation.
- Reuse of resources between cellular and D2D and among D2D clusters/groups.

5G Technology ☺



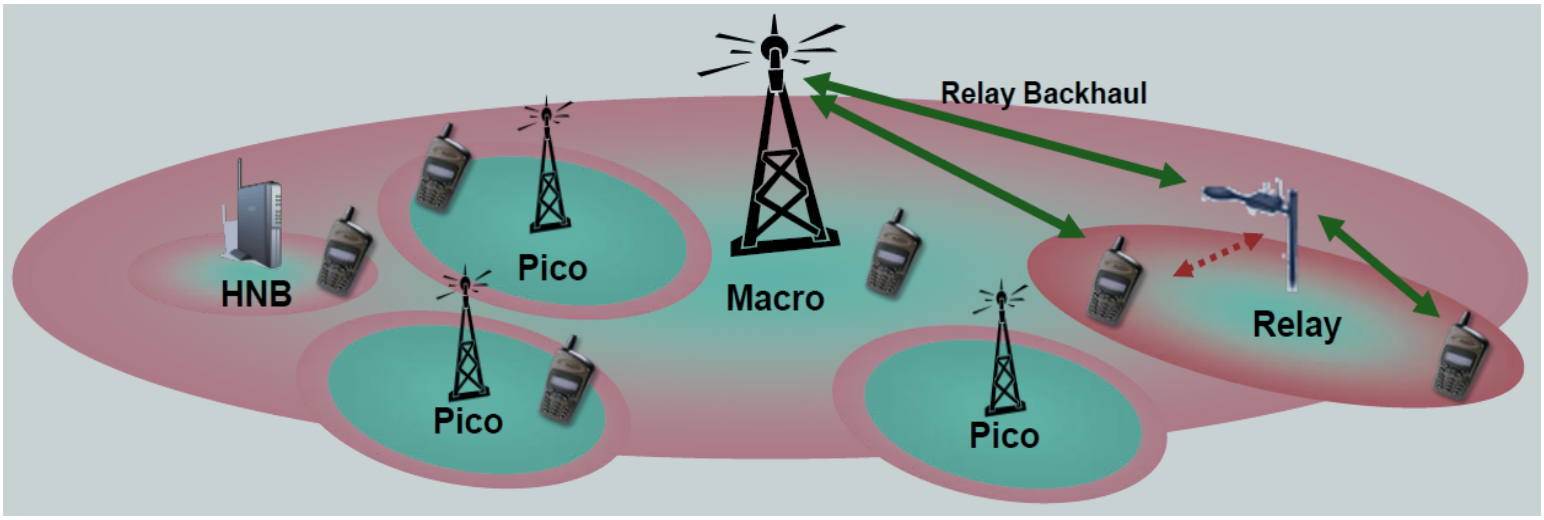
Shrinking the Re-use Distance





Heterogeneous Networks (HetNet)

- Radio link performance is approaching theoretical limits with 3G enhancements and LTE.
- Next performance leap in wireless networks will come from the network topology.
  - Shrinking reuse distance of wireless resources.
  - Improving bits/sec/Hz/ per unit area.



Other Work

- Internet of Things: Web of Objects
  - IPv6 based WSN
  - ITEA2 Project with France, Spain, Korea
- Mobile calls/data variable pricing

Questions?

khaled@ieee.org

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