Advanced radio access solutions for the new 5G requirements

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Identified 5G scenarios and services

- Multimedia services will require more and more bandwidth
- Mobile cloud services are growing rapidly
- Augmented/virtual reality services will become common
- Social networking services will be expanded with rich contents
- M2M devices proliferate and high data rate M2M service will grow
- Personalized services will be integrated into daily life
Devices’ number increase
Wireless networks legacy and new challenges

3G (HSPA)

WCDMA

3G: Data

2G: Voice
Wireless networks legacy and new challenges

3.9G (LTE)

OFDMA

UE

eNodeB (LTE)

MME

SGW (Serving Gateway)

PGW (PDN Gateway)

IP

4G: Mobile data
3G: Data
2G: Voice
Wireless networks legacy and new challenges

**4G (LTE-A)**

- Massive MIMO
- MU-CoMP

![Diagram](image)

**Carrier Aggregation**

LTE-A (100 MHz = 5 x 20 MHz)

**Summary**

- 4G: Mobile data
- 3G: Data
- 2G: Voice
Wireless networks legacy and new challenges

4G (LTE-A)

eICIC

HetNet

Dr. Soumaya Hamouda
Wireless networks legacy and new challenges

4G (LTE-A)

Ultra Dense Small Cells

New Radio Access Challenges

Dr. Soumaya Hamouda
Wireless networks legacy and new challenges

• Accommodate traffic and bandwidth explosion
  – Traffic volume will be increased 1000 times (Video traffic portion will be major)

• Handle the interference explosion and optimize the radio resources allocation
  – Enhance the interference coordination between the ultra-dense small cells
  – Manage the hotspots of traffic and high mobility

• Accommodate signaling explosion
  – Mobility signaling explosion by Small Cell
  – Massive connectivity due to increased number of devices
  – Bearer control caused by ‘always-on-apps’ services
  – Higher paging complexity caused by heterogeneous wireless and wire-line accesses

• Satisfy operator‘s requirement of profitable network infrastructure
  – Legacy network can hardly reduce CAPEX and OPEX
  – Need to accommodate new services in the same physical network
5G requirements

- R1: Peak Data Rate [Gbps]
- R2: Cell Edge Data Rate [Mbps]
- R3: Cell Spectral Efficiency [bps/Hz]
- R4: Mobility [km/h]
- R5: Energy & Cost Efficiency
- R6: Simultaneous Connection
- R7: Latency [msec]
## Mapping new technologies with 5G requirements

<table>
<thead>
<tr>
<th>Enabling technologies</th>
<th>R1</th>
<th>R2</th>
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<tbody>
<tr>
<td>Massive MIMO and beamforming</td>
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<td>New multiple access technique (SCMA) or new waveforms (f-OFDM, FBMC…)</td>
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Enhancing Energy Efficiency with CRAN/ H-CRAN
Enhancing Energy Efficiency with CRAN/ H-CRAN
Enhancing Energy Efficiency with **CRAN/ H-CRAN**

- With a virtualized control plane, the C-RAN/ H-CRAN help:
  - better coordinate the inter-cell interference
  - better coordinate the MU-CoMP
  - enhance the traffic balancing
  - coordinate the traffic offloading

- But also:
  - Better handle the Small Cell sleep and wake up
  - A few number of VMs is processing for the whole network.

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**Improve SE and EE**

**Reduce operational expenditures (OPEX)**
D2D reduces latency, increases throughput and batteries life, but...!

How to increase D2D communications while respecting the quality of service of cellular users’ communications?
Proposed noise-rise based D2D Communication mode selection

Interference impact:

\[ I_i = A \frac{d_i}{D_i} \log_{10}(R_i) \]

Noise rise:

\[ \eta_i = \frac{N + I_i}{N} = \frac{N + A \frac{d_i}{D_i} \log_{10}(R_i)}{N} \]

Optimization problem:

\[ \max \sum_{i=1}^{U_D} \log_2 (1 + \gamma_i) \]

s.t. \( \eta < \eta_{\text{Thresh}} \)

Proposed noise-rise based **D2D**
Communication mode selection

**Total system throughput**

A good tradeoff between the number of D2D users and the system radio capacity
Proposed noise-rise based D2D Communication mode selection

Impact of the mobiles’ distribution

Impact of the noise rise threshold

- D2D mode selection is more efficient when it is applied at the cell edge.
Cognitive radio for **D2D** communications

Considering the **underlay mode**, how to enhance a D2D communication performance while reducing the interference caused in the network?
Proposed bargaining games for D2D communications

Cooperative Bargaining Games $G=\{I,S,U\}$

- Players: the SUs Tx (D2D TX-UE)
- Strategy: the SUs’ transmit powers set
- New objective function

Constraint taking into account PU’s quality of service.

$$U_i(p_i, p_{-i}) = N \log(R_i) - \beta p_i - \alpha \sum_{i=1}^{N} h_{im} p_i$$

Optimization problem (Non Cooperative game):

$$\max_{p_i} U_i(p_i, p_{-i})$$

s.t. $$\gamma_i \geq \gamma_{\text{min}}$$ $$\sum_{i=1}^{N} h_{im} p_i \leq I_{\text{Thres}}$$ and $0 \leq p_i \leq P^{\text{max}}$, $i = 1, ..., N$

Proposed bargaining games for **D2D communications**

Pareto-optimal convergence

The Utilitarian Game Solution achieves the best EE
Saving energy with multi-cast caching

Backhaul

How to download the required content at the edge while reducing the power cost?

Graph Theory

S. Mrad, S. Hamouda, H. Rezig, «Graph Theory Based Multicast Caching for Better Energy Saving in Dense Small Cell Networks», accepted in IEEE International Wireless Communications and Mobile Computing Conference (IWCMC’17), Spain, June 2017
Saving energy with multi-cast caching

Energy Efficiency

![Energy Efficiency Graph]

EE gain boundary

![EE Gain Boundary Graph]

A tradeoff between the number of the small cells involved in the graph and the cache size in order to guarantee an efficient energy system.
Thank you