Next Generation Radio Communication Technologies

Angeliki Alexiou
University of Piraeus, Greece
Chair of WGD on Radio Communication Technologies, WWRF
 alexiou@unipi.gr
Outline

• ‘5G’ visions and expectations
• Technology trends
• System concept evolution paths
• Key Enabling Radio Technologies
7 trillion wireless devices serving 7 billion people by 2020

- All people will be served with wireless devices
- Affordable to purchase and operate
- Calm computing: technology invisible to users
- Machine to machine communications
  - Sensors and tags: e.g. in transport and weather systems, infrastructure, to provide ambient intelligence and context sensitivity
- All devices are part of the (mobile) internet

WWRF
Vision in a nutshell
Radio Communications in 2020s become pervasive

Pervasive Communication Systems consist of a very large number of computer-communication devices, often of small size and/or embedded in the environment, which are able to:

• interact with each other and with mobile users,

• dynamically form telecommunication networks and

• probe the environment in order to adapt and optimize, in a context-aware fashion, the networks performance and the user experience and QoS.
Capacity scaling with user demands

Present: Capacity decreases with increasing node density. The total system capacity remains constant, while per-user capacity decreases.

Future: Capacity increases with increasing node density. The total system capacity increases, while per-user capacity remains constant.
Wireless connectivity beyond IoT - "Thingbook"
.. or is it all about control?

“The Tactile Internet” ensures ‘real-time’ user experience

[The Tactile Internet] ensures ‘real-time’ user experience, which is crucial for applications that require immediate feedback and interaction, such as autonomous vehicles and industrial automation. The Tactile Internet is expected to enable a new era of communication where the latency is minimized, allowing for more responsive and efficient systems.

Technology trend #1
Ultra Dense Deployments or the disappearing cell

- OFDMA
- Advanced antenna technology (MIMO)
- Relaying
- CoMP
- CDMA
- Power control
- Turbo coding
- Frequency reuse
- Discontinuous transmissions
- Handover

Multiuser multicell optimization
Multiuser single-cell optimization
Single link single-user optimization

GSM  UMTS  HSPA  LTE-(A)
Wireless Sensor Networks interact with the physical world in “Things 2.0”: Where EveryThing is connected in the M2M communities networking.
Technology trend #3
Distributed versus centralized or the rising Clouds

Cloud Computing to address exponentially growing demand for real-time, reliable data processing in the IoT
System concept evolution path#1: *Cell-less architecture*

Distributed-Input-Distributed-Output (DIDO) wireless technology allows each user to use the full data rate of shared spectrum simultaneously with all other users, by eliminating interference.

System concept evolution path #2: M2M over wireless infrastructure

Capillary parts of the network collect data and aggregate info through the M2M gateways towards the wireless infrastructure

[source: ICT-EXALTED fp7 project, 2011]
System concept evolution path #3: RAN Virtualization

All baseband functions/intelligence is moved to the virtual substrate (cloud), making use of shared virtual resources.
New technology challenges...
..may require a little revolutionary radio-communications thinking

New technology challenges:
• Manage huge number of nodes: interference management, resources allocation, aggregation
• Latency, tactile response time and large dynamic range of delay constraints
• Energy efficiency, often too stringent constraints
• Backhaul and over the air signaling design

..may require a whole new approach to:
• physical layer, air interface and spectrum usage
• resources management
• optimization
Enabling Radio Technology #1
Combining cooperation and coordination with Network MIMO

David Tse in his 2007 IEEE Trans on Inf. Theory paper showed that “Hierarchical Cooperation Achieves Optimal Capacity Scaling in Ad Hoc Network” by keeping interference constant as the number of nodes increases.
Enabling Radio Technology #1

Combining cooperation and coordination with Network MIMO

- a1) 3D MIMO/BF
- a2) massive MIMO in higher freq. bands
- b1) advanced RX
- b2) non-orthogonal multiple access using SIC
Enabling Radio Technology #1
Combining cooperation and coordination with Network MIMO

Efficient partitioning needs to be applied in order to maximize the effective throughput of Network MIMO, taking into account the bandwidth resources spent on overhead signaling.
Enabling Radio Technology #2

Combining wide and local areas, scheduled and random access

[“Future steps of LTE-A – Evolution Toward Integration of Local and Wide Area Systems”, IEEE Wireless Communications, Feb 2013]
Scheduled access is optimized for cellular

Wireless sensor networks use random access based on contention (CSMA)

New hybrid approaches (e.g. Funneling MAC) can offer the possibility to balance the trade-off between random and scheduled access in regions of dense traffic (closer to a sink node) where contention-based access becomes inefficient

Enabling Radio Technology #2
Combining wide and local areas, scheduled and random access

Exploiting the vast amounts of ‘free’ broadband access offered by settled and nomadic WiFis would require advanced URM and interference management in the unlicensed bands.
Enabling Radio Technology #3

*Jointly optimizing the Physical and Virtual Substrates*
Enabling Radio Technology #3

Jointly optimizing the Physical and Virtual Substrates

- MD-MIMO
  - Fundamental Limits
  - Spatial Modeling
  - Advanced Transceivers
  - Overhead Signaling Reduction

- CLOUD & VIRTUALIZATION
  - Cloud Computing
  - Virtualization
  - Joint Radio & Computing Optimization
  - Computing Resources Management

- LARGE & COMPLEX SYSTEMS OPTIMIZATION
  - Convex/SDP/SOCP
  - Sparse Matrices
  - Large-Scale Matrices
  - Integer/Combinatorial
Enabling Radio Technology #3

Jointly optimizing the Physical and Virtual Substrates

Universal Radio Resources Management

- Heterogeneous Terminals
  - Mobile/Portable UEs
  - M2M devices
- Connectivity Links of infrastructure elements to the Cloud

Cooperation Area

Coordination Area
Promising radio communication research directions and critical technology innovations

**Distributed Input Distributed Output (DIDO)- the new PHY:**
- Network MIMO and partitioning based on ‘effective throughput’ criteria

**Advance resource management:**
- Universal Radio Resources management and large systems optimization
- Scheduled versus random or scheduled+random access?

**Balancing centralized and distributed control:**
- Centralized deployment concepts with Cloud-based architectures
- Virtualization and efficient mapping of physical to virtual resources

**Efficient design and use of signaling:**
- Hierarchical feedback schemes
- Optimal exchange of contextual information among different layers
- ‘Over the air’ and backhaul bandwidth requirements
Conclusions and the way ahead

- Ultra dense user-centric deployments: new cell-less system concept
- DIDO: the new PHY
- Scheduled+random: the new Multiple Access scheme
- Universal Resources Management: the new MAC
- Cloud empowered centralization: new virtualized RAN
- Large & complex systems optimization: new radio engineering approach
Next Generation Radio
Workshops organized by WWRF

• “Wireless World 2020” Workshop, Quebec City, Canada, 4 September 2012
  Part of IEEE VTC Fall 2012

• “Wireless World 2020” Workshop, Berlin, Germany, 24 October 2012
  Part of WWRF 29th meeting

• “Wireless World 2020” Workshop, Pune, India, 11 March 2013
  Part of the GISFI meeting
Upcoming Next Generation Radio Workshops organized by WWRF

- “Research Challenges for Communications in 2020” Workshop,
  Lisbon, Portugal, 3 July 2013
  *Part of Future Network & Mobile Summit 2013*

- “Future Ultra Dense Wireless Networks: Air Interface and Radio Resources Management Challenges” Special Session,
  London, UK, 8-11 September 2013
  *Part of IEEE PIMRC 2013*