WIRELESS WORLD
RESEARCH FORUM®

# *5G :*
# *on the count of three…*
# *… paradigm shifts*

**Angeliki Alexiou**
University of Piraeus

Chair of WGD
on Radio Communication Technologies,
WWRF

aalexiou@ieee.org

# WWRF Colleagues who contributed to this presentation:

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- Panagiotis Demestichas, University of Piraeus
- Andreas Georgakopoulos, University of Piraeus
- Antonis Gotsis , University of Piraeus
- Clara Li, Intel Corporation
- Werner Mohr, NSN
- Nigel Jefferies, Huawei
- Yao Jing, Huawei
- Shalini Periyalwar
- Vino Vinodrai

# Outline

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- WWRF
- Wireless beyond 2020: Requirements and Challenges
- 3 paradigm shifts to realize 5G
  - Technology Trends
  - System Concept evolution
- 5G enabling radio technologies
- The way ahead

# WWRF's role and mode of operation

WIRELESS WORLD RESEARCH FORUM®

- Develop future vision of the wireless world
- Inform and educate on trends and developments
- Enable and facilitate the translation of the vision into reality
- Bring a wide range of parties together to identify and overcome significant roadblocks to the vision

- Global
- Open to all
- Not
  - standards body
  - research funding body
  - A typical research conference
- Based on membership
- All can attend meetings and make contributions

# WWRF – members and Working Groups

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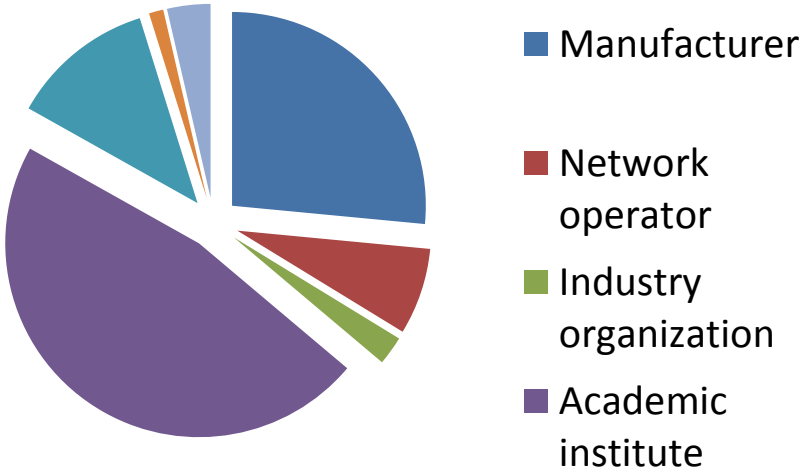


- WGA - User Needs & Requirements in a Wireless World
- WGB - Services, devices and service architectures
- WGC - Communication architectures and technologies
- WGD - Radio Communication Technologies

# Radio Communications in 2020s become pervasive

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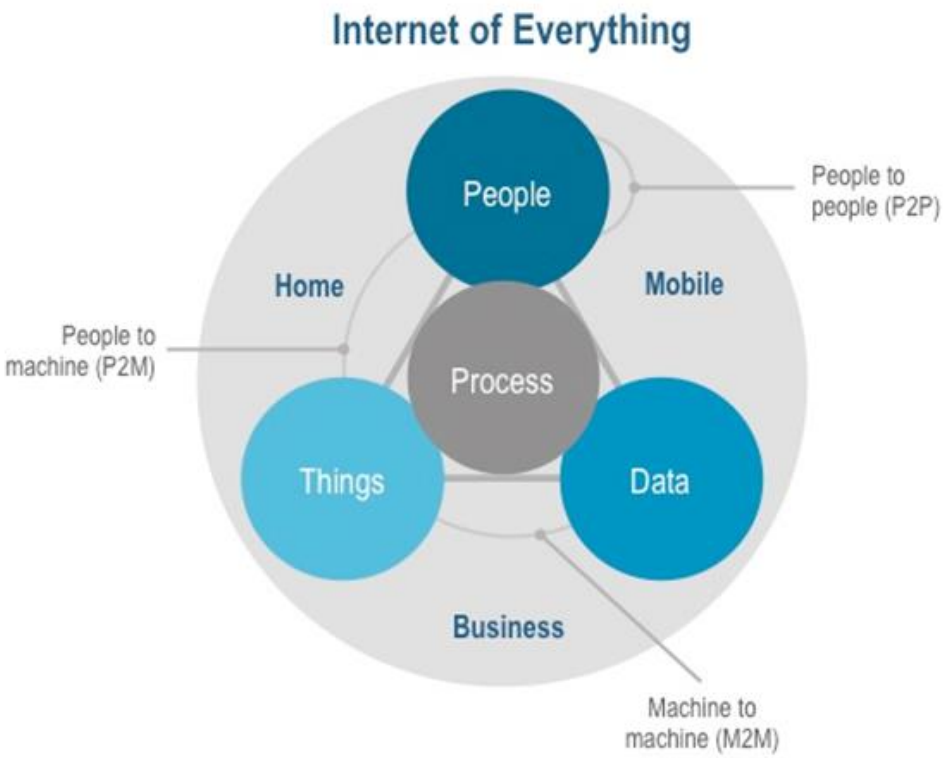


*[Internet of Everything (credit: Cisco)]*

**Pervasive Communication Systems** consist of a very large number of *things/devices* -often of small size and/or embedded in the environment- *with computing/communication capabilities*, which are able to

- *interact with each other* and with mobile users,
- *dynamically form telecommunication networks,*
- *probe the environment* in order to *adapt and optimize* the user QoS, and
- *process and transmit/receive large volumes of data,* often under ultra reliable/low-latency requirements.

# Early indications and …
# …high expectations

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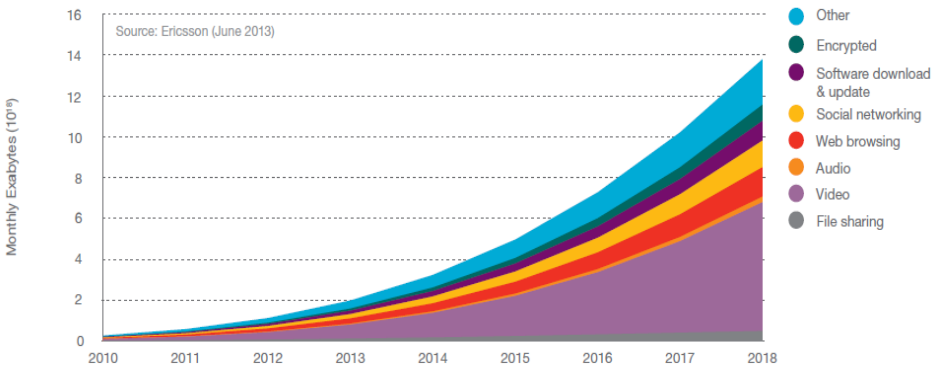
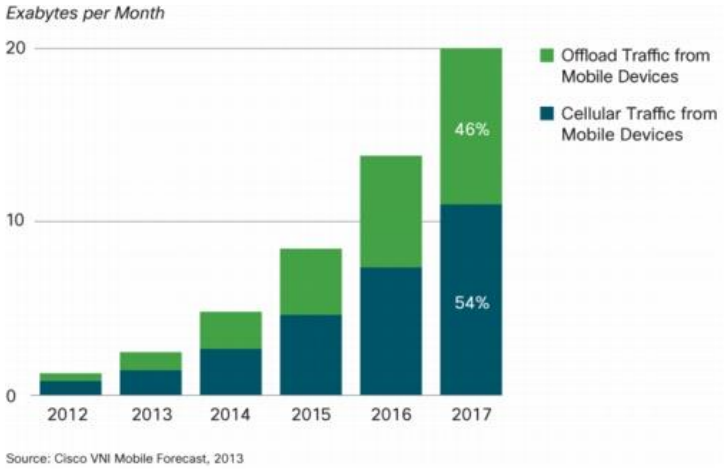
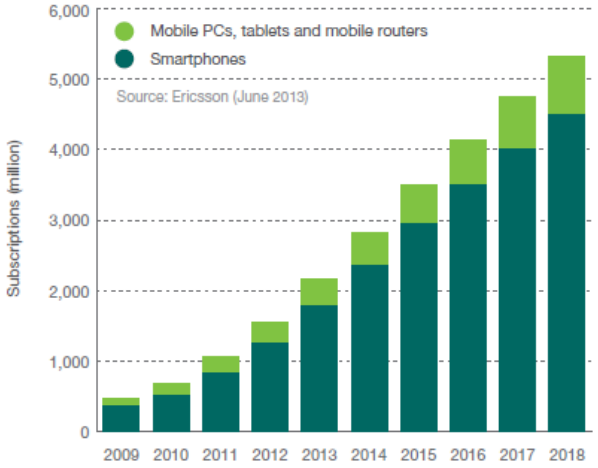
## Mobile Data Traffic by Application Type




## Offload vs Cellular Traffic

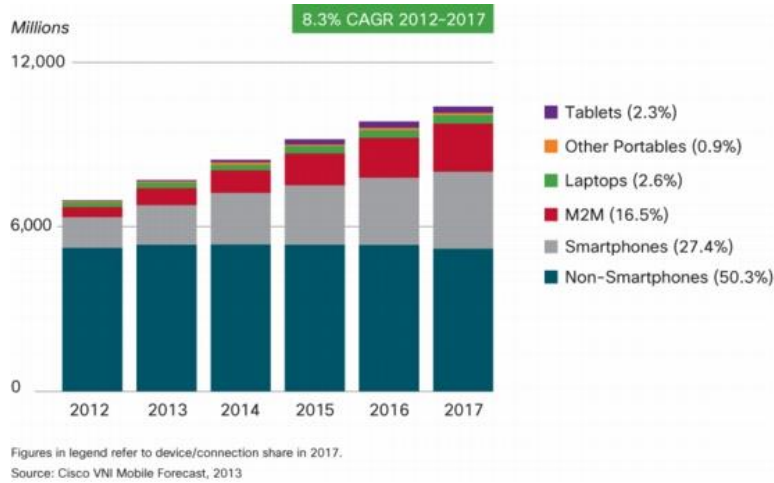



## Mobile Subscriptions




Source: Ericsson, "Mobility Report", June 2013

## Mobile Devices Growth



# Capacity scaling with user demands

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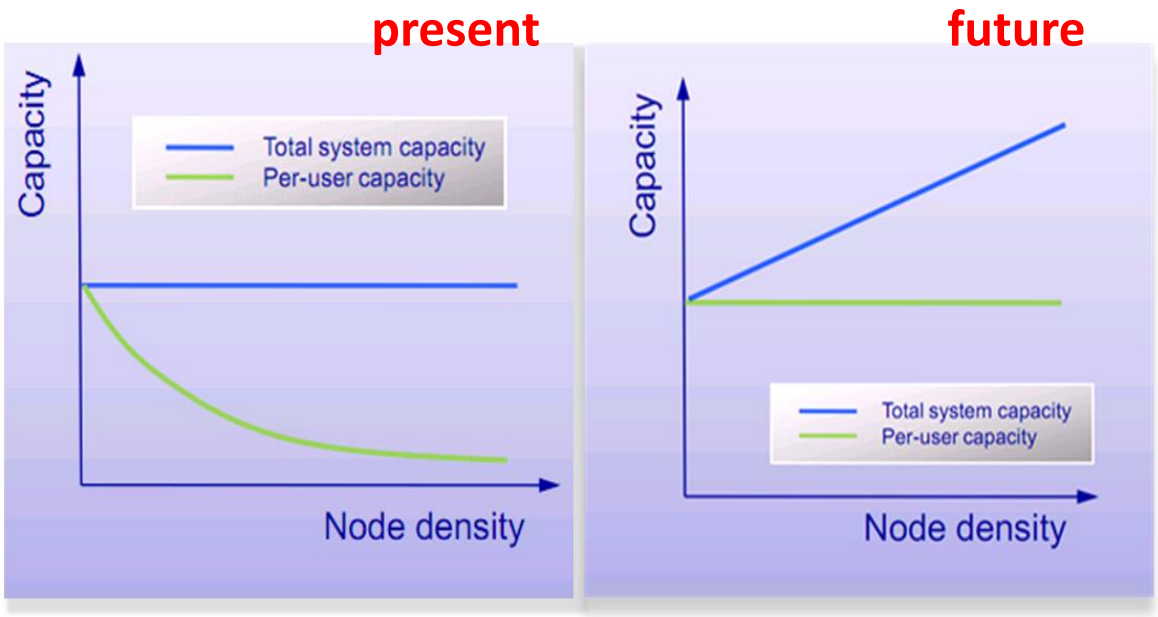
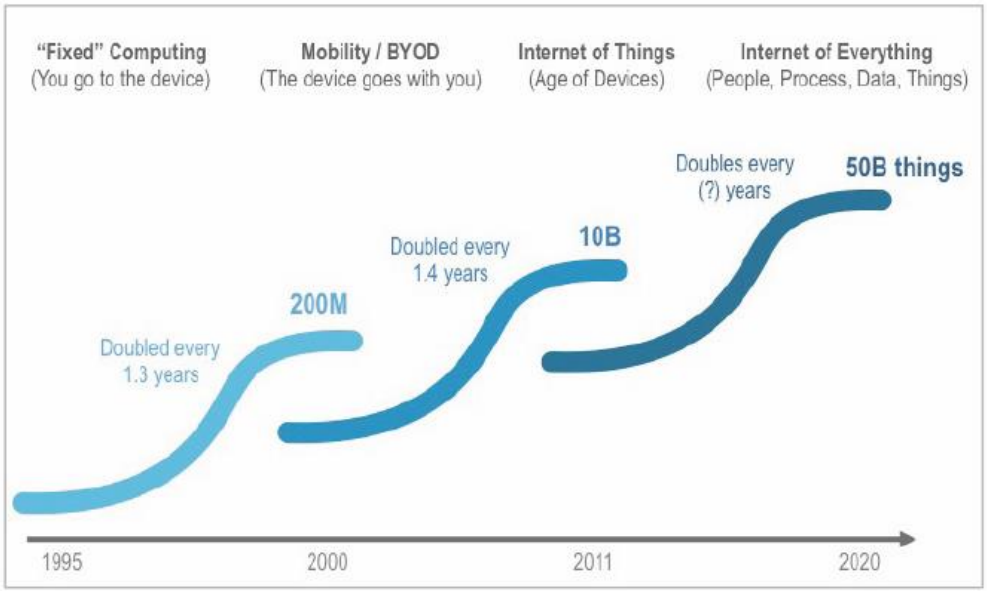


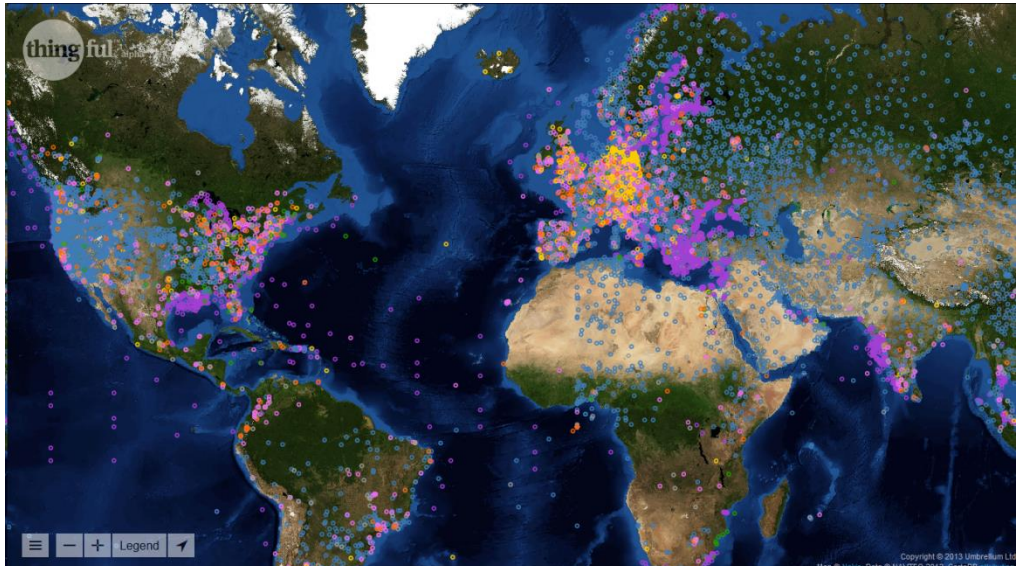

# Wireless connectivity beyond 2020




Source: Cisco IBSG, 2012

"Thingbook"


"Thingful"



# .. or is it all about control?

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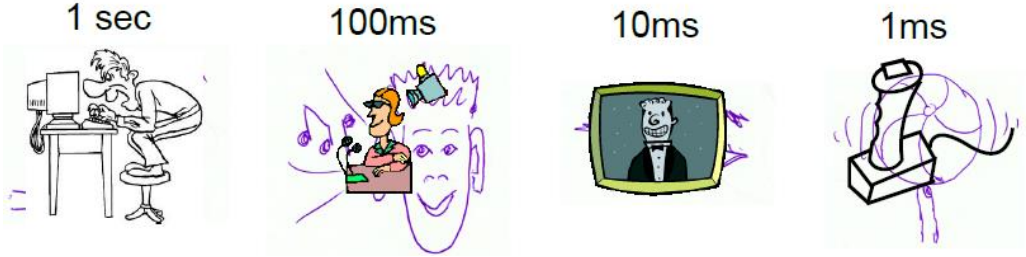
*"The Tactile Internet": Communications at the speed of human senses*




[G. Fettweis, "A 5G Wireless Communications Vision", Microwave Journal, Dec. 2012]

*5G Ultra-Reliable/Low Latency: Communications to substitute human senses/intelligence*

# 5G wish list

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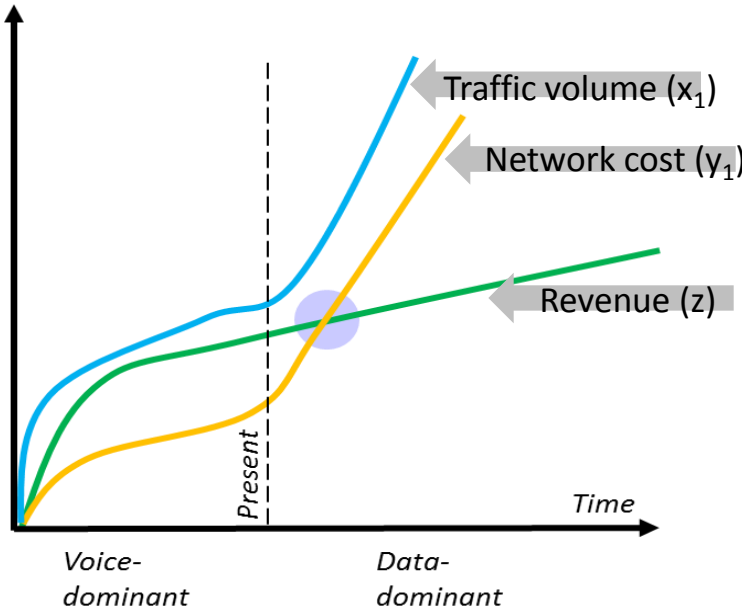


- Ultra-High Capacity: 1000x
- Ultra Low Latency: few milliseconds
- Ultra Reliable: traffic safety, health,..
- Energy efficiency
- Flexible/fast deployment and service creation: D2D, local cashing,..
- New spectrum and spectrum management approaches
- Virtualization : 'Everything as a Service' (EaaS)
- Sustainable NEW business models and profitability

# Paradigm Shift #1
# Ultra Dense Networks (UDN)

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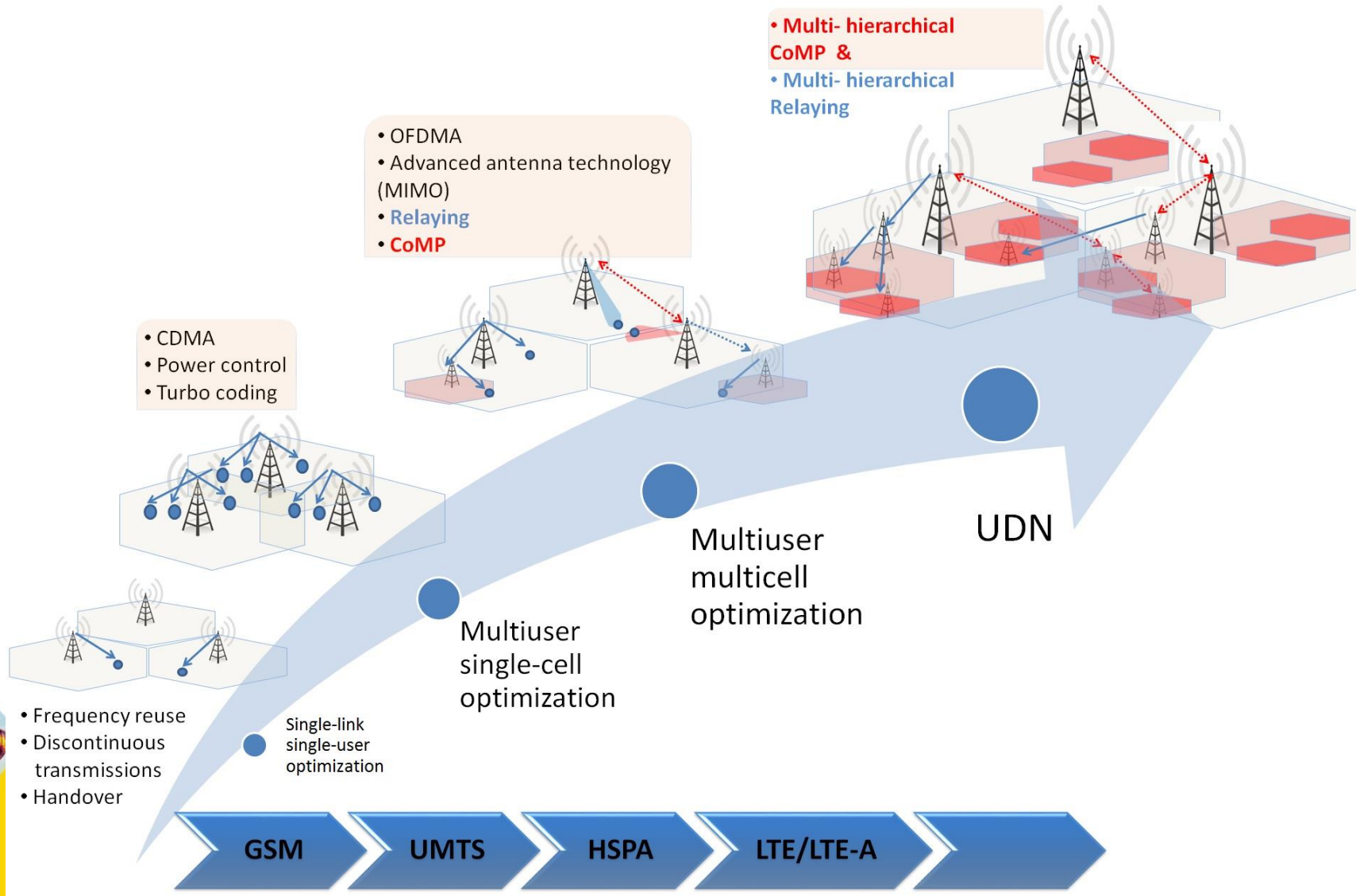

# UDN Landscape

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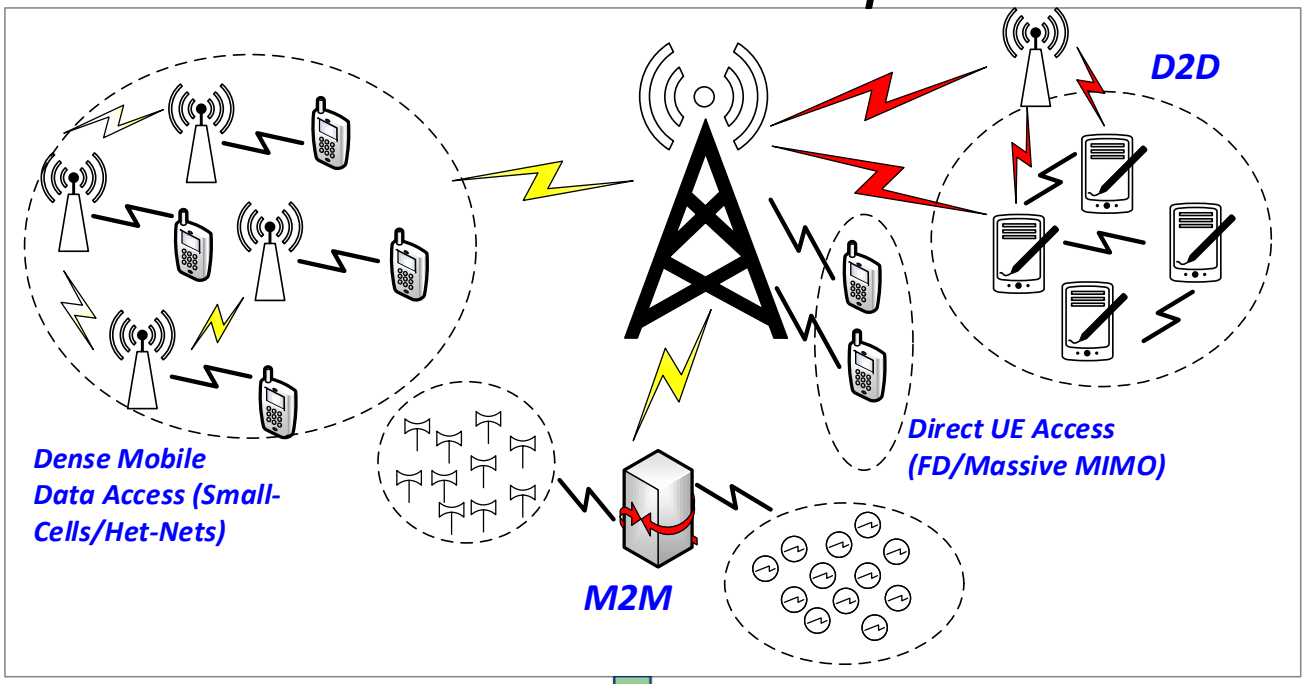
## The UDN Landscape




Macro-BS

Small-Cell Node

Gateway

Backhaul Link

Coordination Link

Access Link

Mobile-Broadband enabled UE

M2M device

D2D-enabled device

**A UNIVERSAL INFRASTRUCTURE DIMENSIONING & RESOURCES MANAGEMENT FRAMEWORK FOR UDNs**

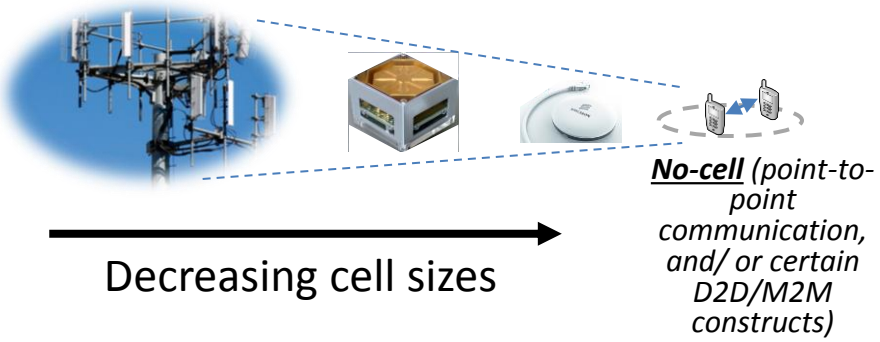
*Massive Infrastructure Densification*

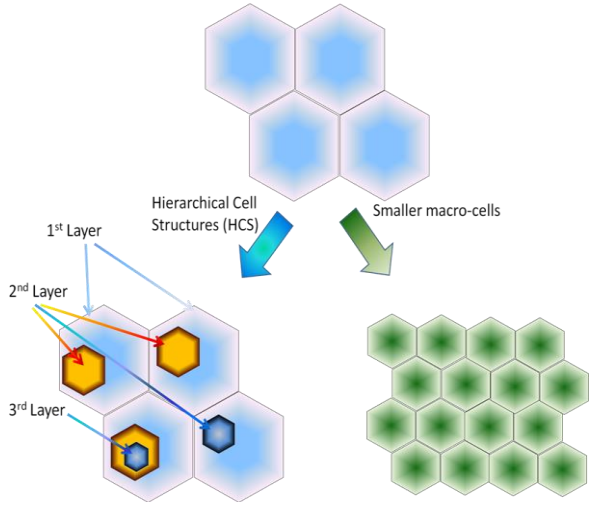
*Multiple Carriers (1800,2100, 3.5GHz, ~60 GHz,…)*

*Massive Served Nodes (UEs, Devices, Gateways) Population*

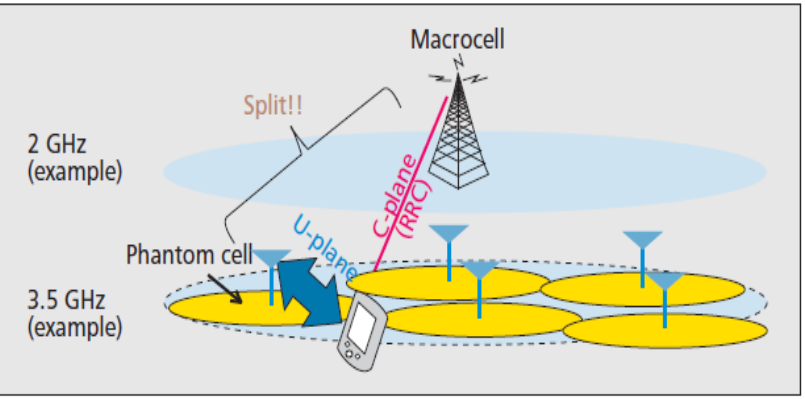
*Large Number of Hierarchies, Communication Possibilities and Target Applications (HetNets, M2M clusters, D2D groups)*

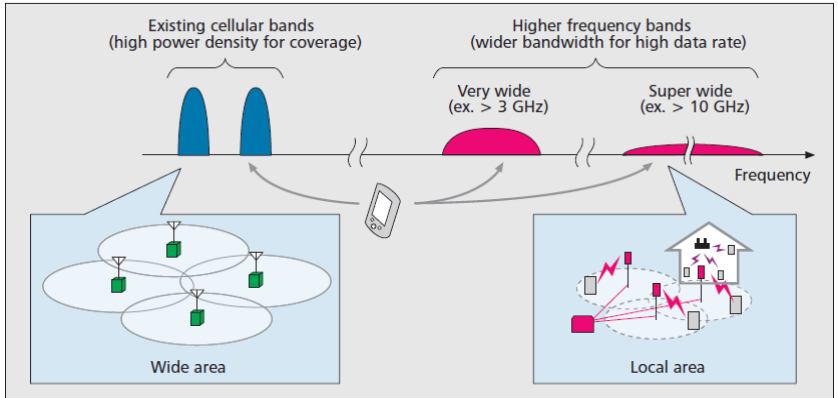
# UDN system concept: *User-centric or the disappearing cell*




- Multiple Hierarchical Layers
- Operator/User deployed
- Scheduled/Random access
- Licensed/Unlicensed bands
- Microwave / mm Wave



# UDN system concept:
## *M2M over wireless infrastructure*

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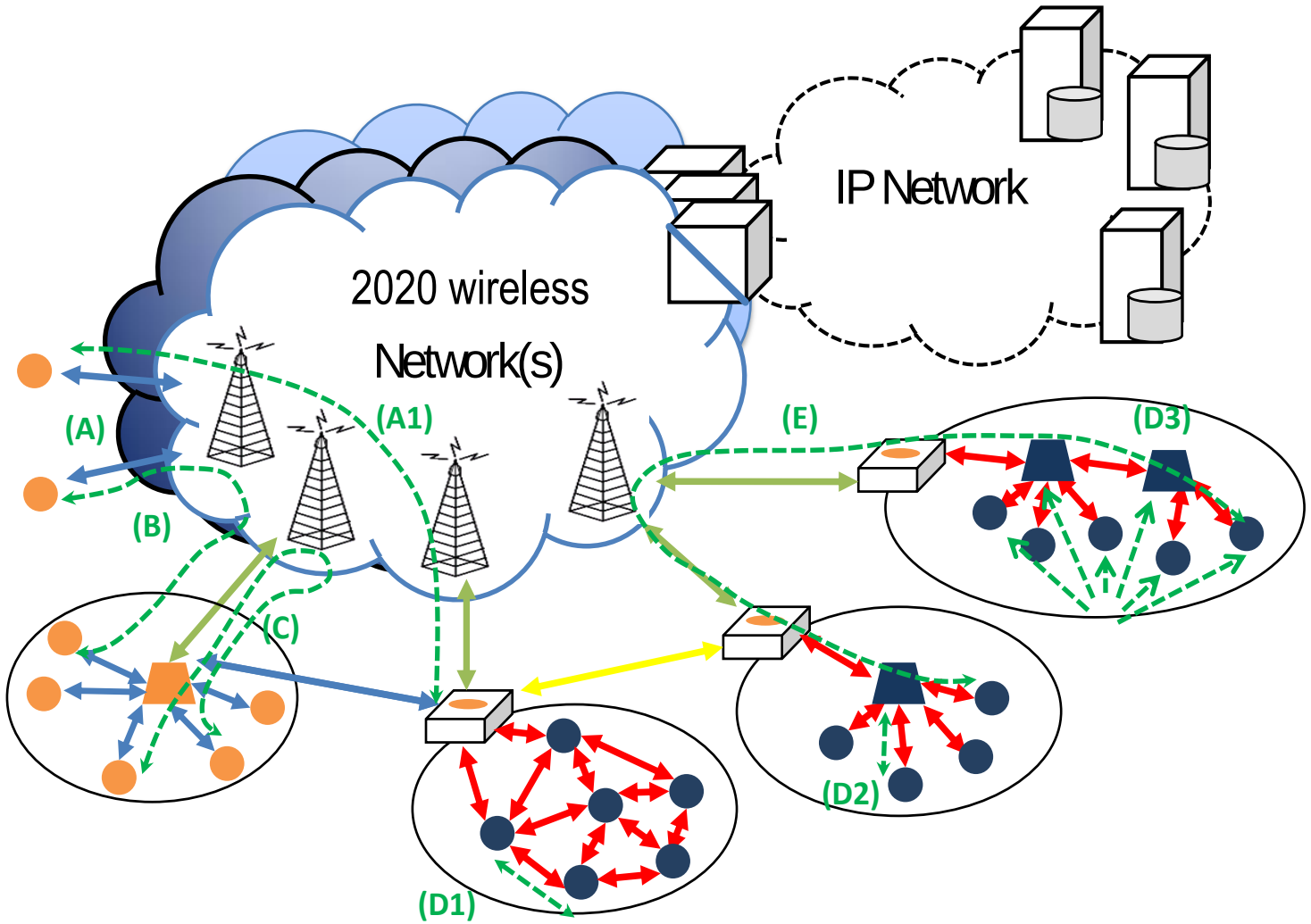


Capillary parts of the network collect data and aggregate info through the gateways towards the wireless infrastructure

[source: ICT-EXALTED fp7 project, 2011]

# Paradigm Shift #2
# Universal Resources Management (URM)

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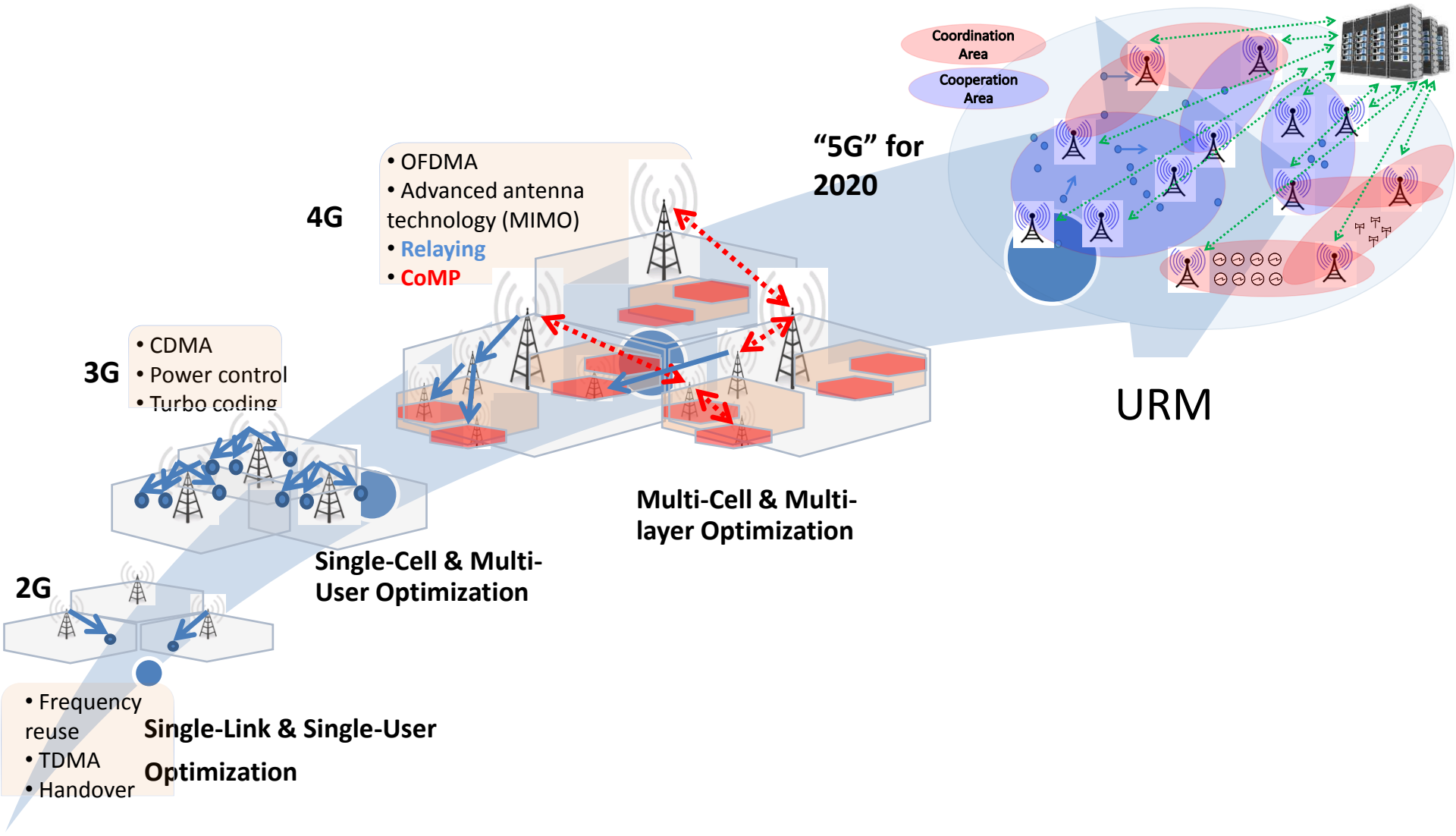

# URM System concept:
## *Cell-less architecture*

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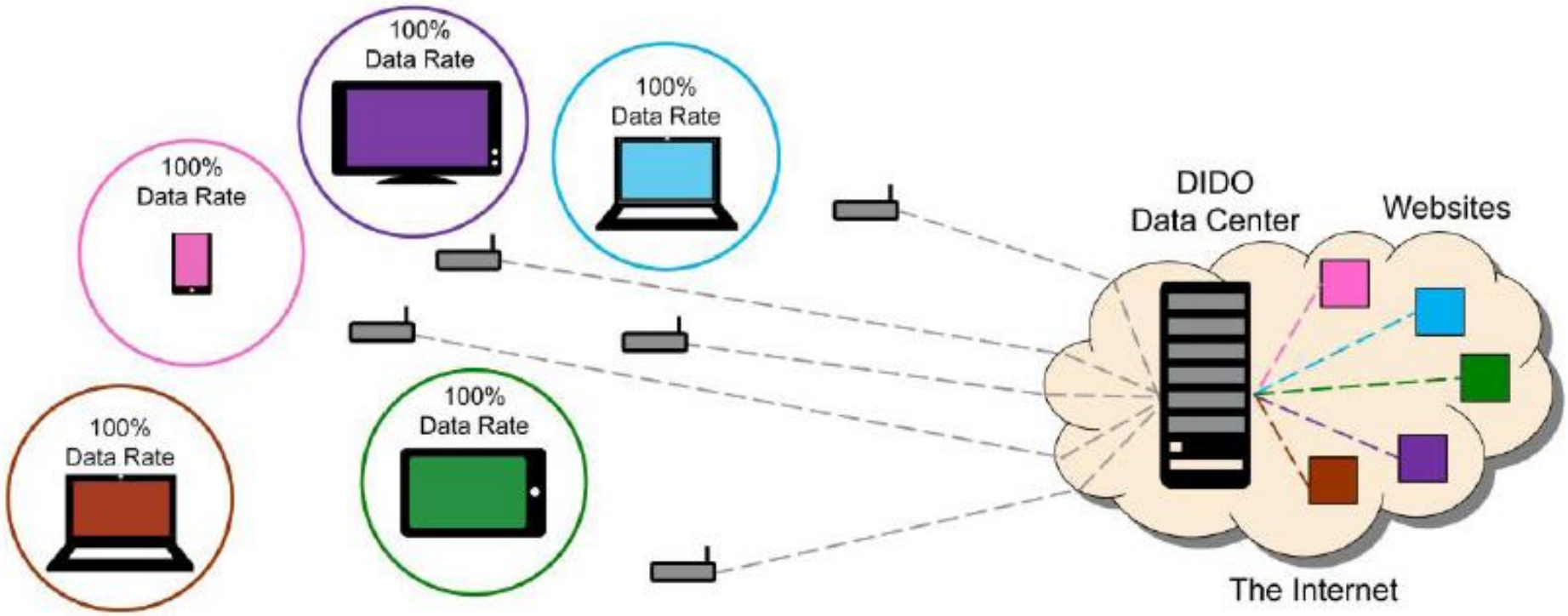


Distributed-Input-Distributed-Output (DIDO) wireless technology allows each user to use the full data rate of shared spectrum simultaneously with all other users, by eliminating interference.

"Distributed-Input-Distributed-Output (DIDO) Wireless Technology A New Approach to Multiuser Wireless", a white paper, Steve Perlman, Antonio Forenza, Rearden Companies, 2011

# Paradigm Shift #3
# Network Functions Virtualization (NFV)

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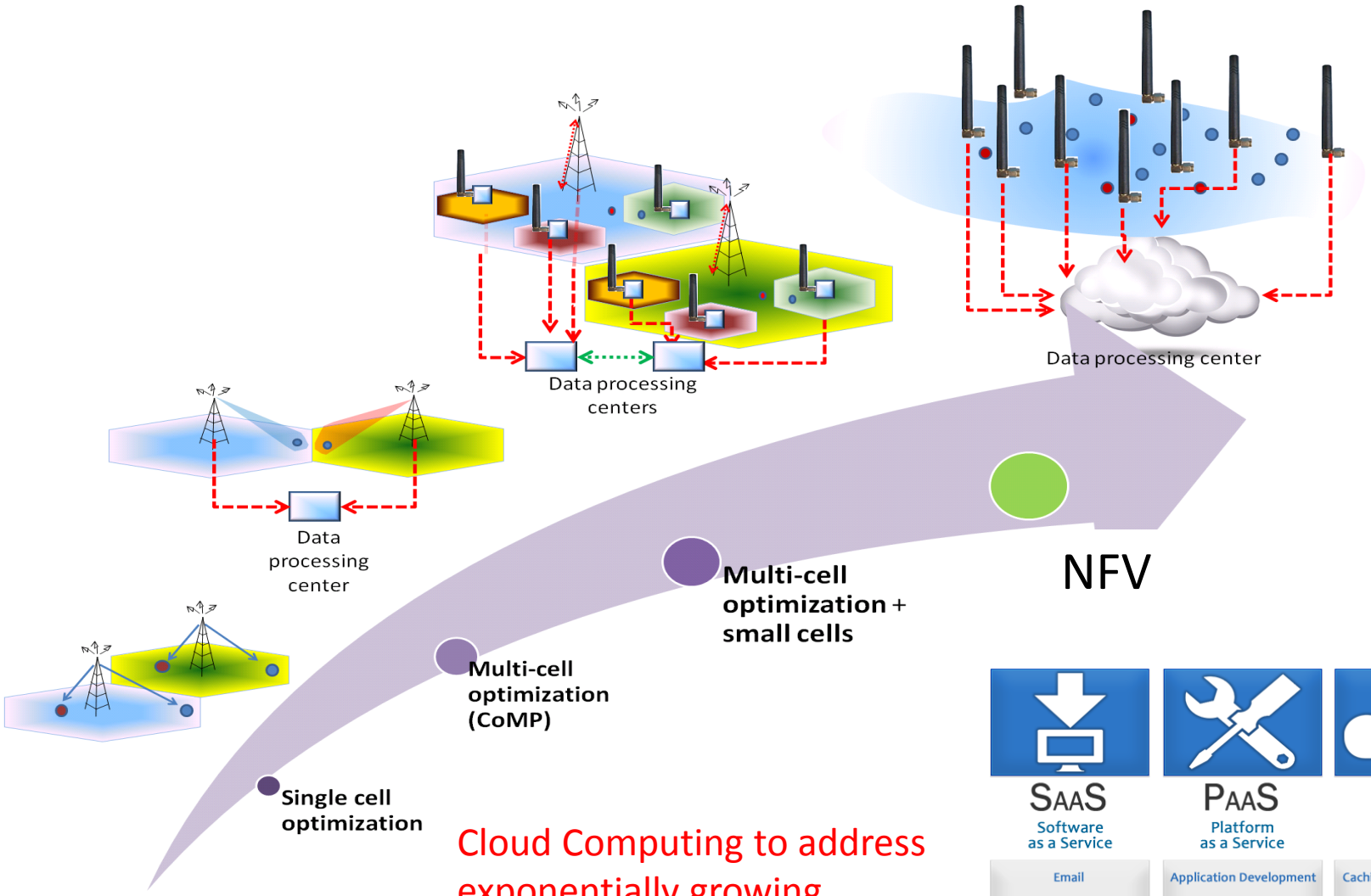
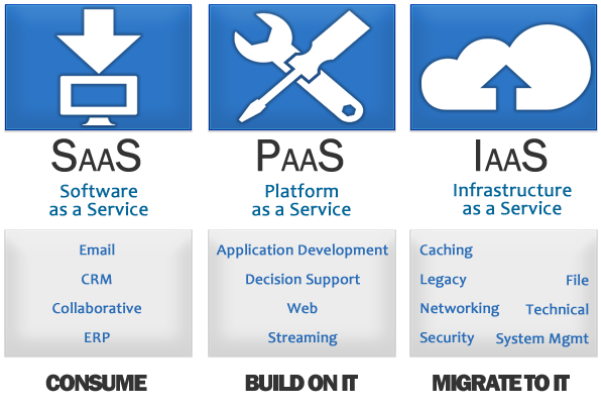



Cloud Computing to address exponentially growing demand for real-time, reliable data processing in the IoT



# NFV System concept: *Virtualization of resources and networking*

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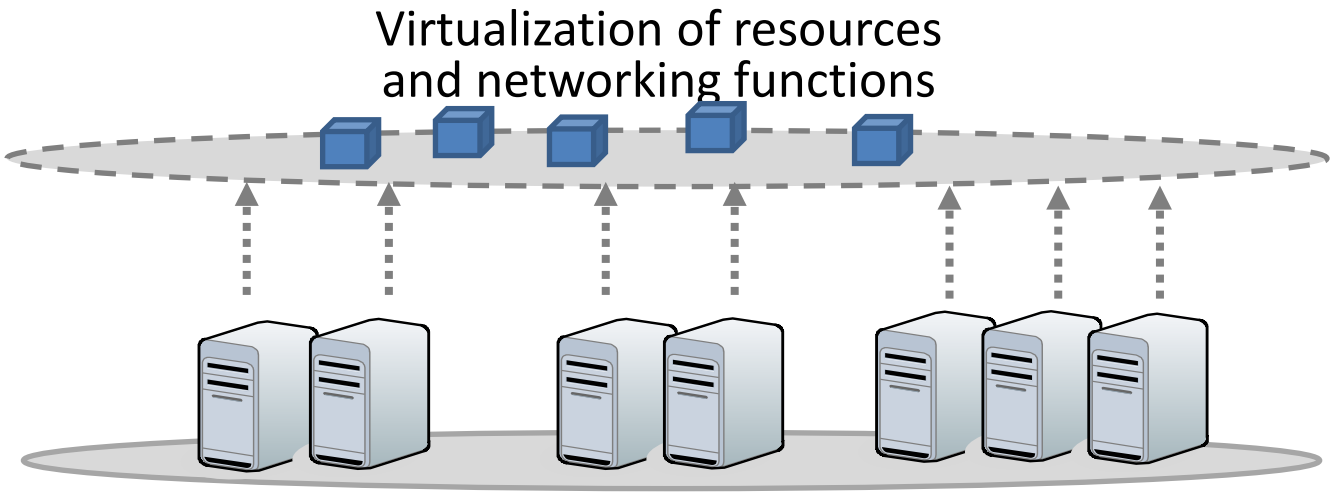


SDN

- Structure/ layer the intelligence
- SDN Controller layer
  - Southbound interface
  - Northbound interface
  - Intelligence within

NFV

- Functions which can be virtualized
- Functions which should have standardized interfaces
- Intelligence for optimal configurations
- Cloud-RAN (as an instantiation of NFV)

# NFV System concept: *Cloud RAN*

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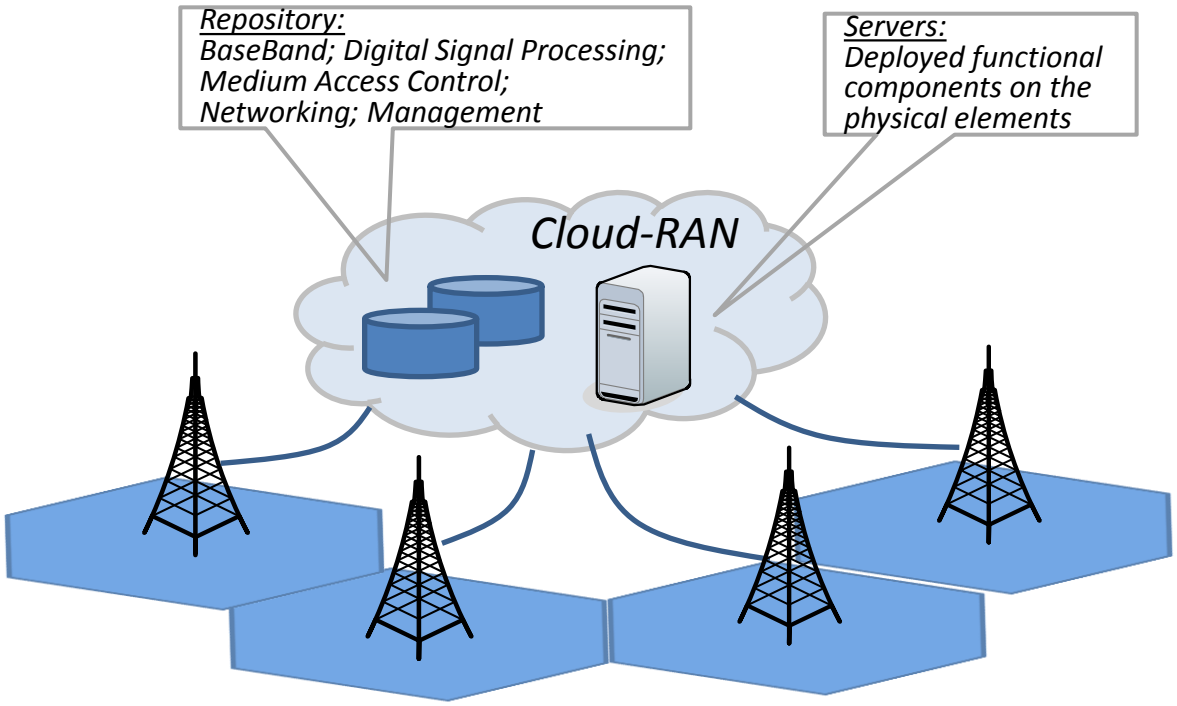


- Versatile placement of small-sized/light transmission units
- Software components in repositories
- Dynamic software deployment and activation
- Aiming at reducing capital/operational expenditures of operators
- Introducing smart management of available resources i.e. software components and physical elements
- Interaction with fixed technologies/optics

# 5G Enabling Radio Technology

## *'Super' MIMO*

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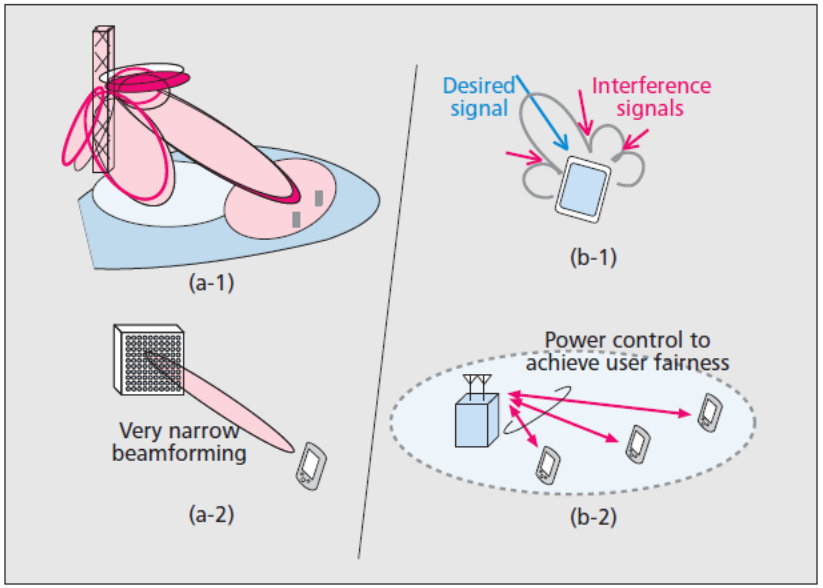


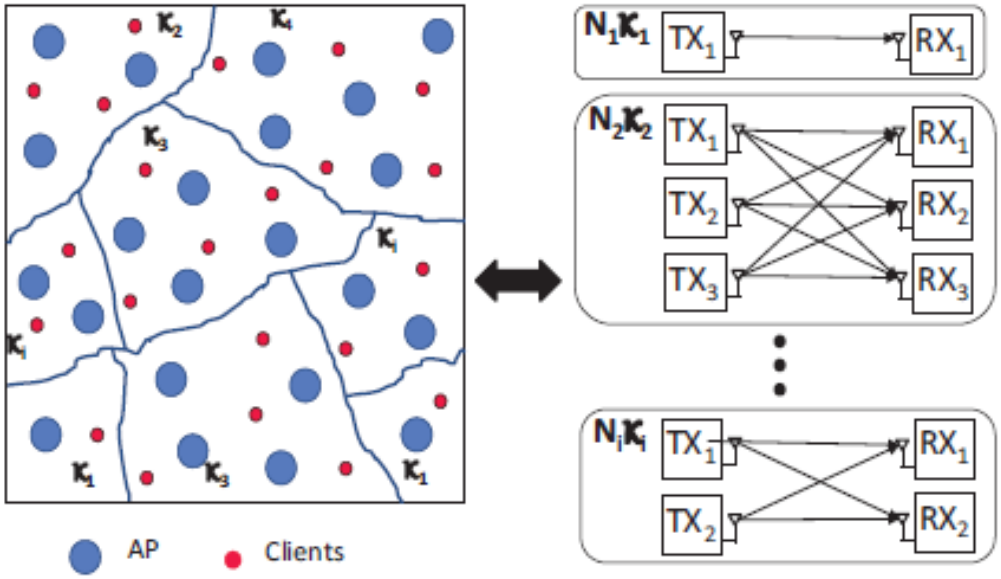


- 3D MIMO
- massive MIMO
- advanced RX
- non-orthogonal multiple access

Network MIMO with efficient partitioning

# 5G Enabling Radio Technology
## *Combining scheduled and random access*

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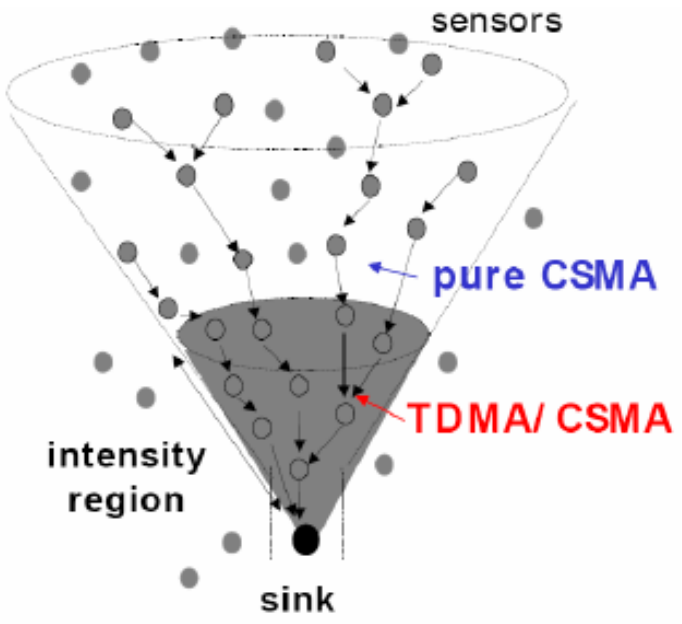


- Scheduled access is optimized for cellular
- Wireless sensor networks use random access based on contention (CSMA)
- New hybrid approaches (e.g. Funneling MAC) can offer the possibility to balance the trade-off between random and scheduled access in regions of dense traffic (closer to a sink node) where contention-based access becomes inefficient

# 5G Enabling Radio Technology

## *Jointly optimize DoF from Cooperation and Coordination with URM*

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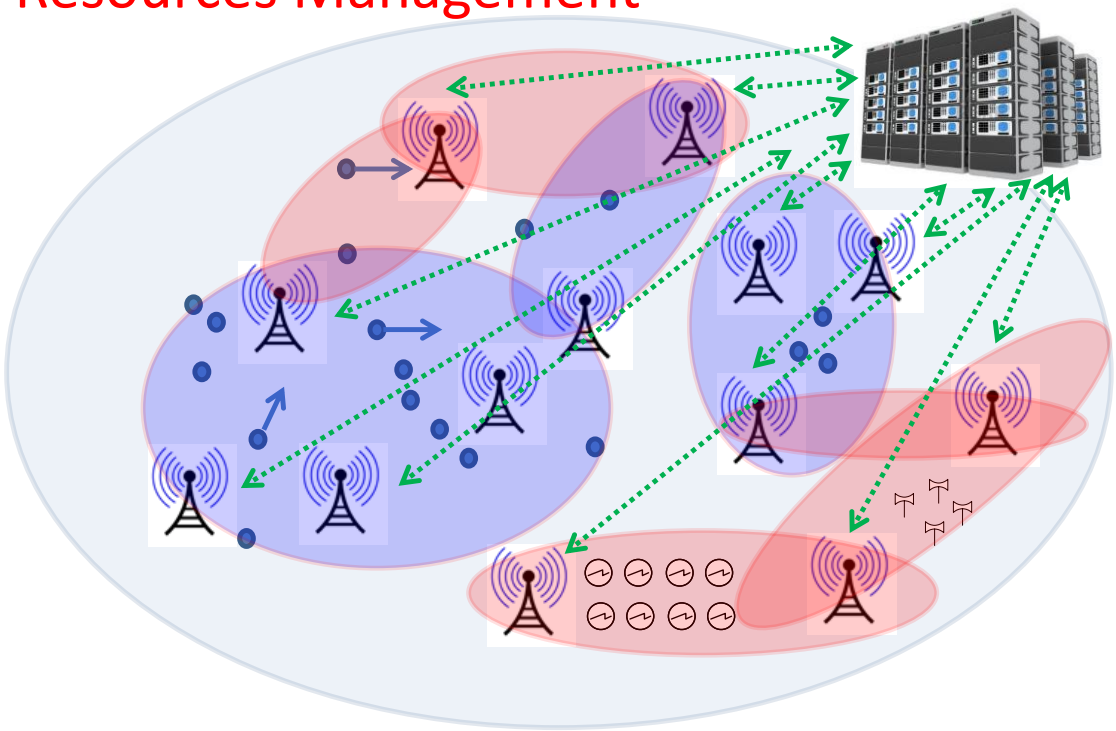
## Universal Radio Resources Management



Heterogeneous Terminals
- Mobile/Portable UEs
- M2M devices

Connectivity Links of infrastructure elements to the Cloud

**Cooperation Area**

**Coordination Area**

# Initial research results: 1000x Capacity Gain Break Down

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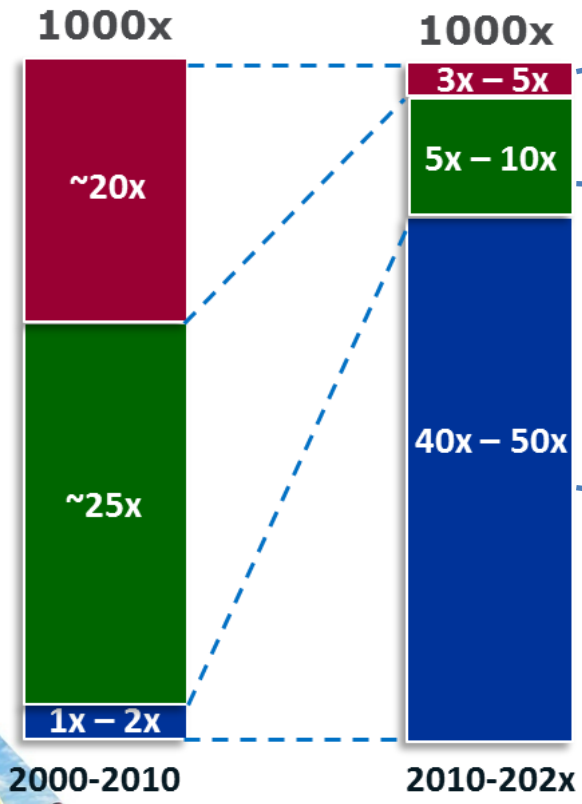


Air interface

- Coordinated Multi-Point Tx/Rx
- 3D/FD-MIMO
- New modulation and/or coding schemes

Spectrum

- More licensed and unlicensed spectrum, i.e., 3.5 GHz, mmWave bands, WLAN@5GHz
- LSA
- Unlicensed spectrum sharing: in 5GHz band, 200MHz spectrum is expected

Heterogeneous nets
Multi-Comm devices
IT for telecom

- Cell densification
- Device-to-device
- Interference management
- WLAN offloading
- Integrated Multi-RAT operation
- ICT coupling
- Measured in bit/s/Hz/$m^2$

To meet the projected 1000x traffic increase by 2020 as compared to today's traffic
Capacity increase baseline is current deployed technology, i.e., LTE Rel-10

[Source: Intel, Mobile and Communications Group]

# Initial research results: Capacity Scaling and URM in UDN

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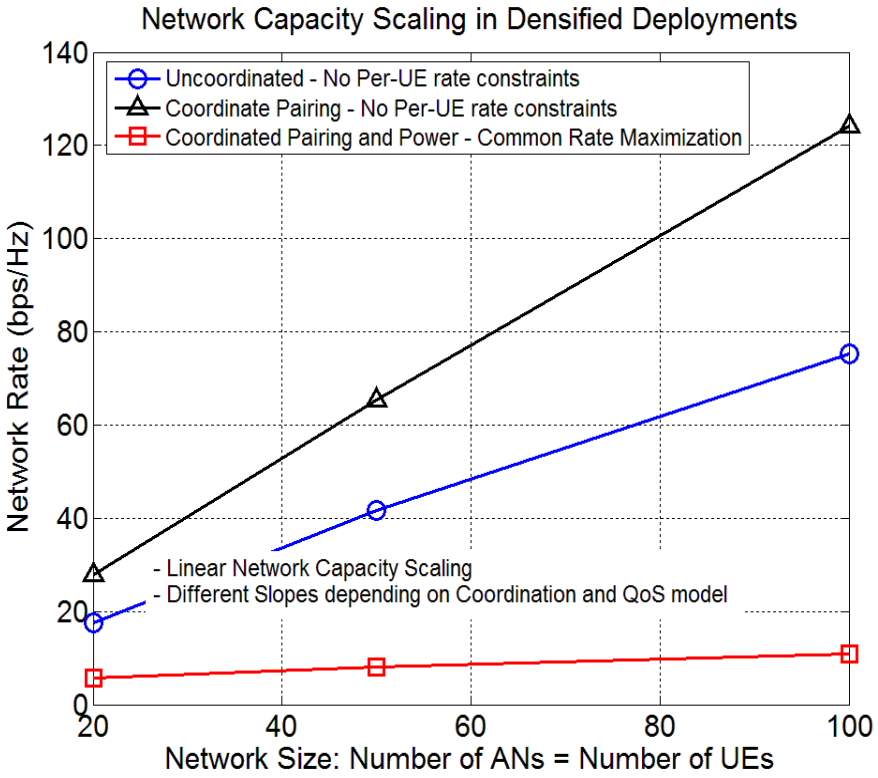


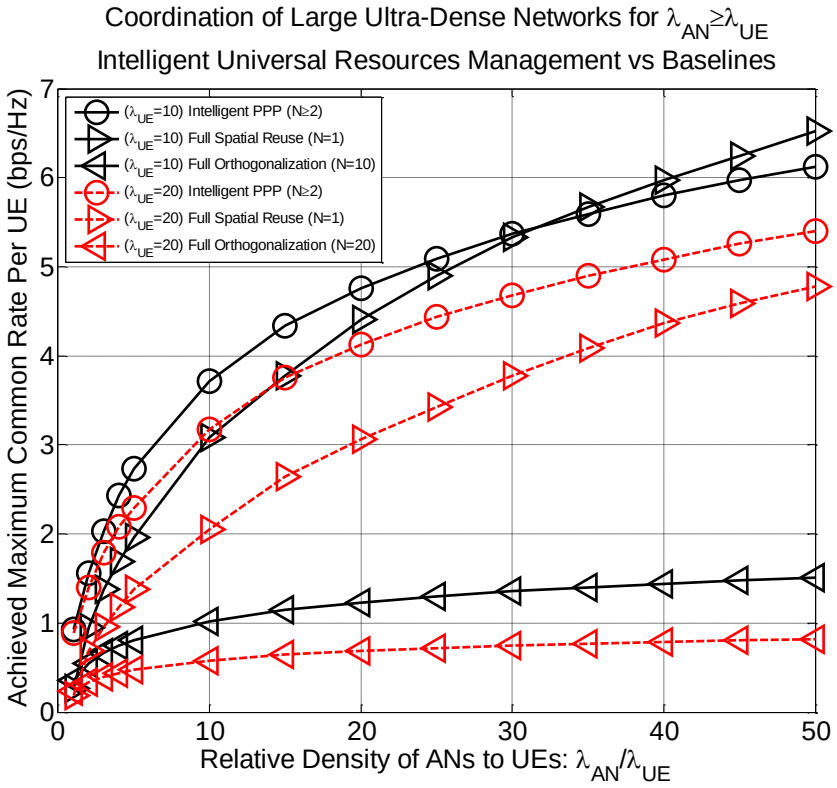




[A. G. Gotsis, and **A. Alexiou**, "Global Network Coordination in Densified Wireless Access Networks through Integer Linear Programming", *IEEE PIMRC 2013*, London, UK, September 2013.]

# 5G technology challenges..

## *..may require a little revolutionary radio-communications thinking*

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**Distributed Input Distributed Output:**

- Network MIMO and partitioning based on ‘effective throughput’ criteria and efficient signaling design

**Advance resource management:**

- Universal Resources management and large and complex systems optimization

**Balancing centralized and distributed control:**

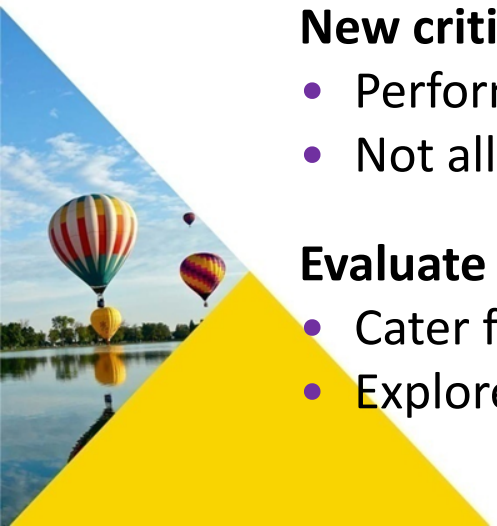
- Virtualization and efficient mapping of physical to virtual resources

**New critical scenarios and large dynamic range of requirements:**

- Performance trade-offs assessment
- Not all requirements can be satisfied at the same time!

**Evaluate realistic spectrum needs:**

- Cater for flexible spectrum use (e.g. ‘Spectrum Access’ networks)
- Explore high frequency (10x GHz) opportunity



# 5G on the count of three…
# …paradigm shifts

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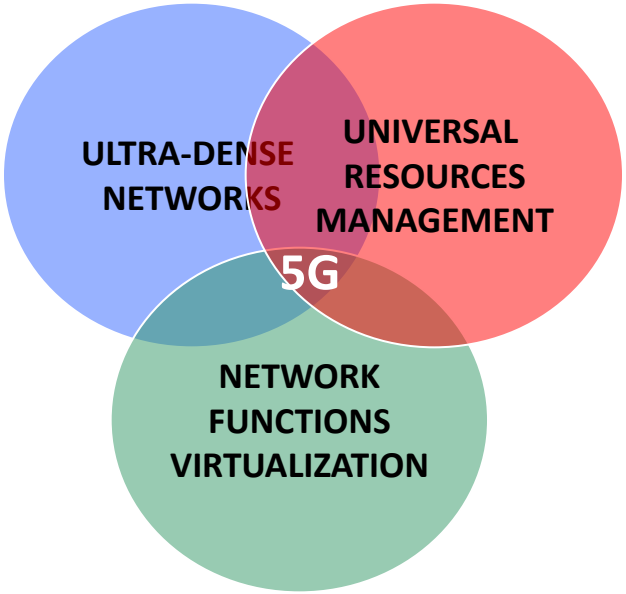


- UDN: the new cell-less system concept
- DIDO: the new 'Network' PHY
- URM: the new MAC
- Scheduled+random : the new Multiple Access scheme
- Cloud empowered centralization: the new virtualized RAN or 'EaaS'
- Large & complex systems optimization: the new radio engineering
- 'Spectrum Access' networks: the new DSA

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