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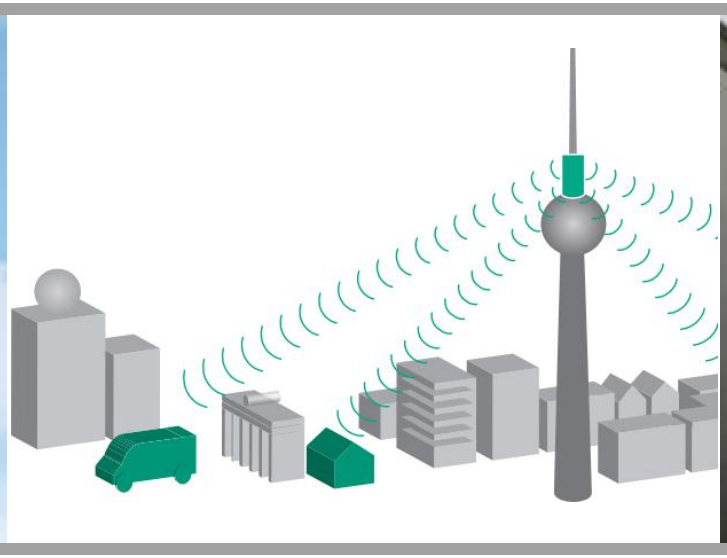
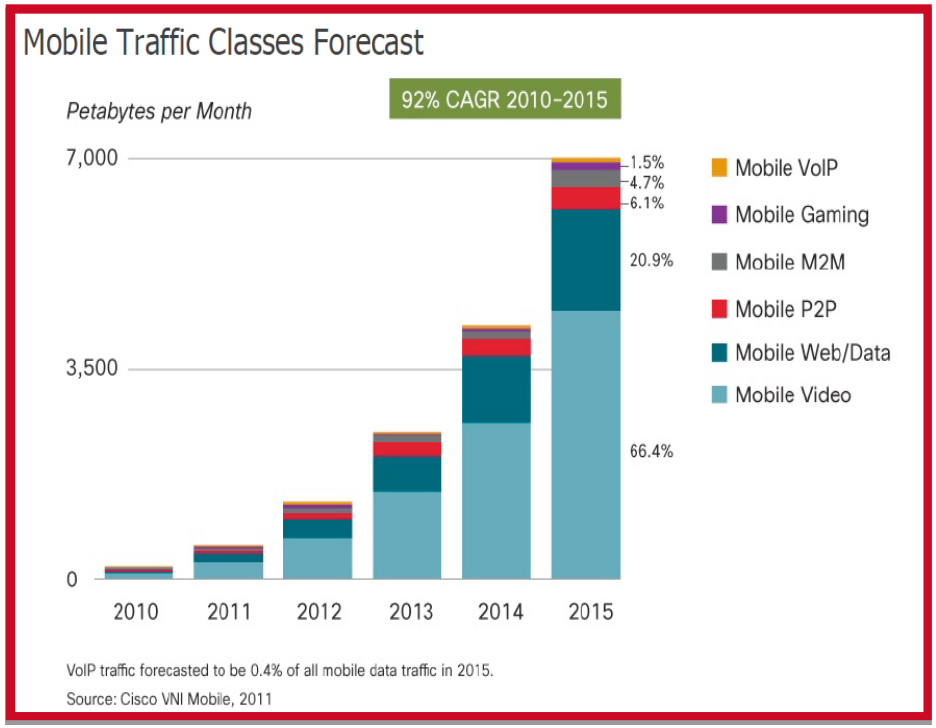
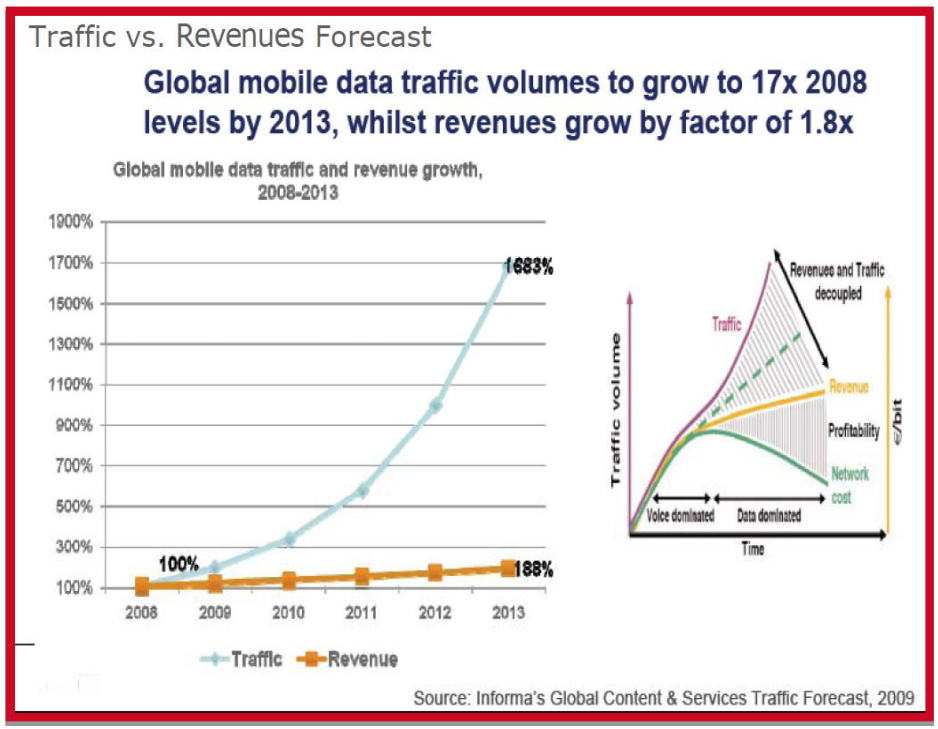
Spectrum Efficiency for Mobile Broadband SOTA, Trends and Outlook

Dr.-Ing. Thomas Haustein



Challenges in Mobile Communication





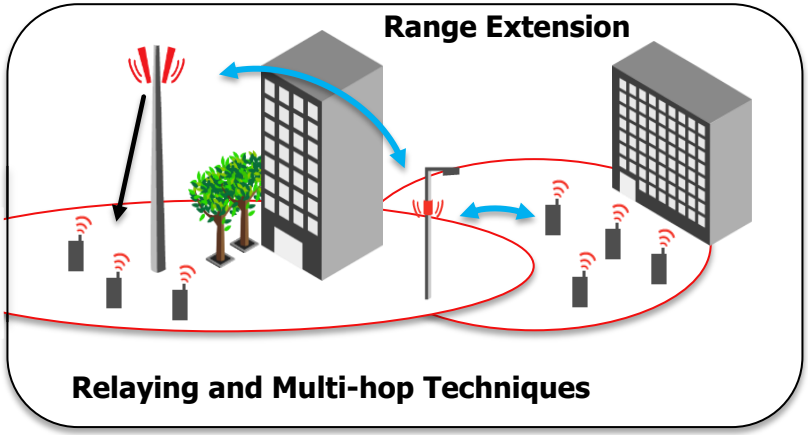
Almost 2X / year growth in data traffic projected for years to come

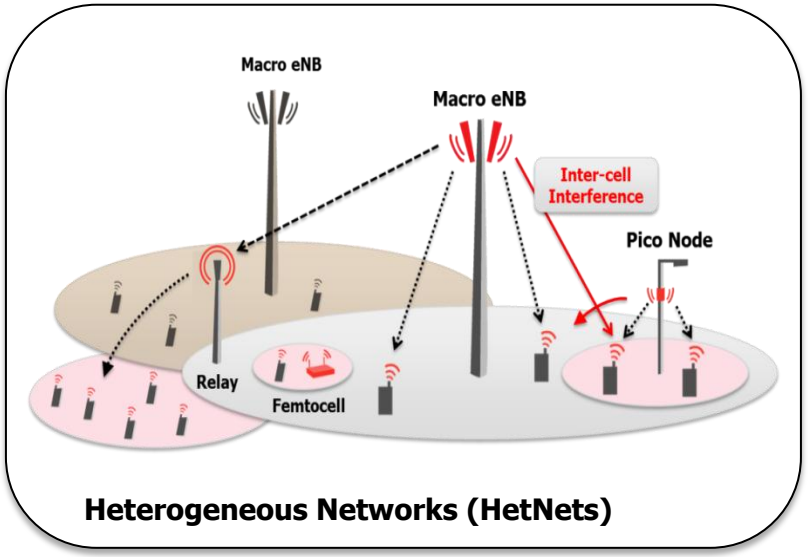
Huge fraction is **mobile video**

40% of mobile data at home
35% of mobile data at work
25% of mobile data is mobile

Wireless Access and Backhaul

- LTE / LTE-Advanced & beyond
- Relaying and multi-hop technologies
- Fiber and wireless backhauling techniques
- Distributed antenna systems (DAS) and remote radio heads
- HetNets, small cells and SON
- Carrier aggregation and multi-band techniques
- Higher order MIMO processing {4,8,12}-TRx
- Cooperative antenna systems: CoMP/Network MIMO
- Sensing for cognitive radios systems
- Radio resource management (RRM) & cross-layer design for video over wireless
- C-RAN technologies



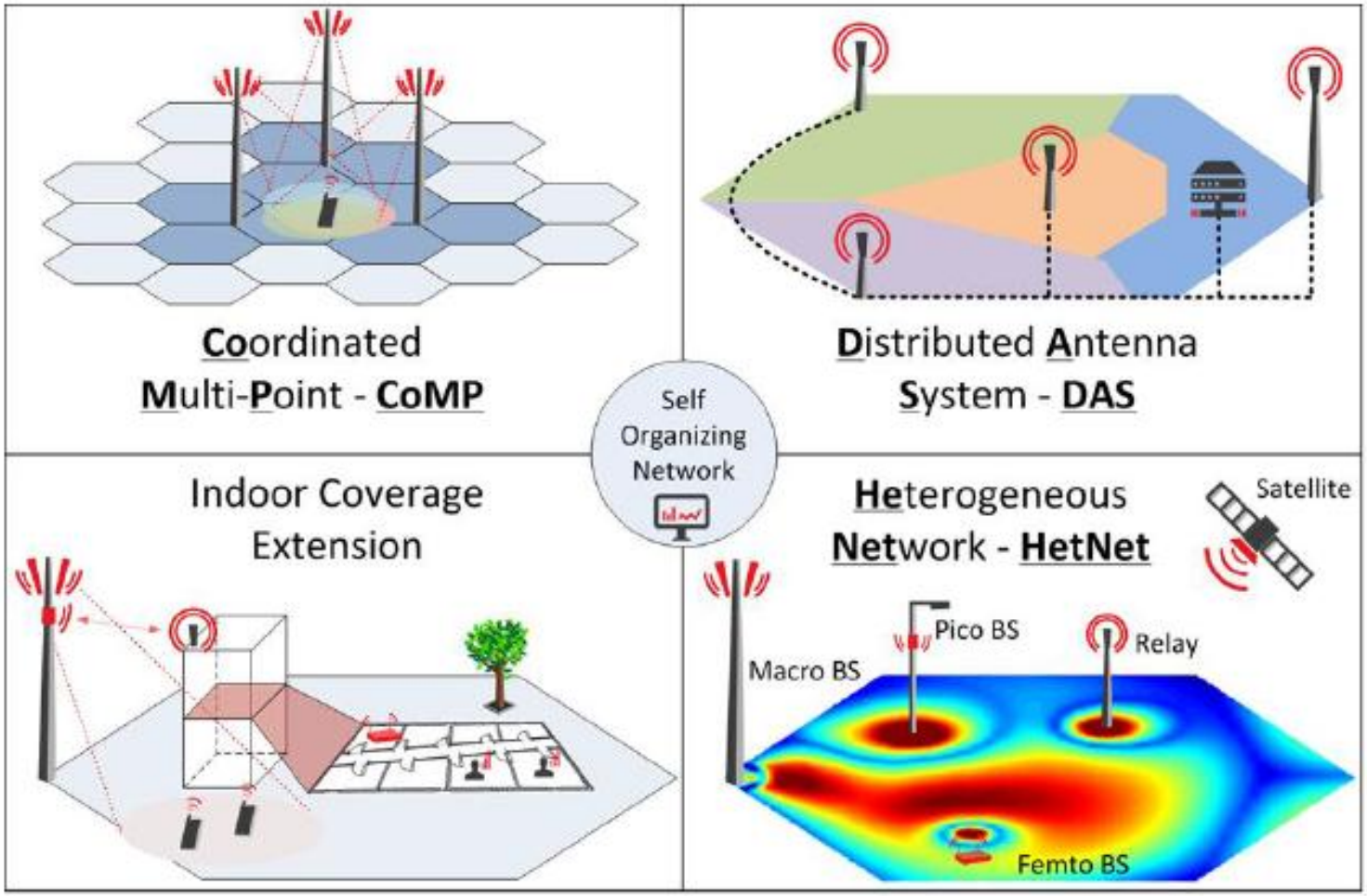


Space – the Degree of Freedom #1

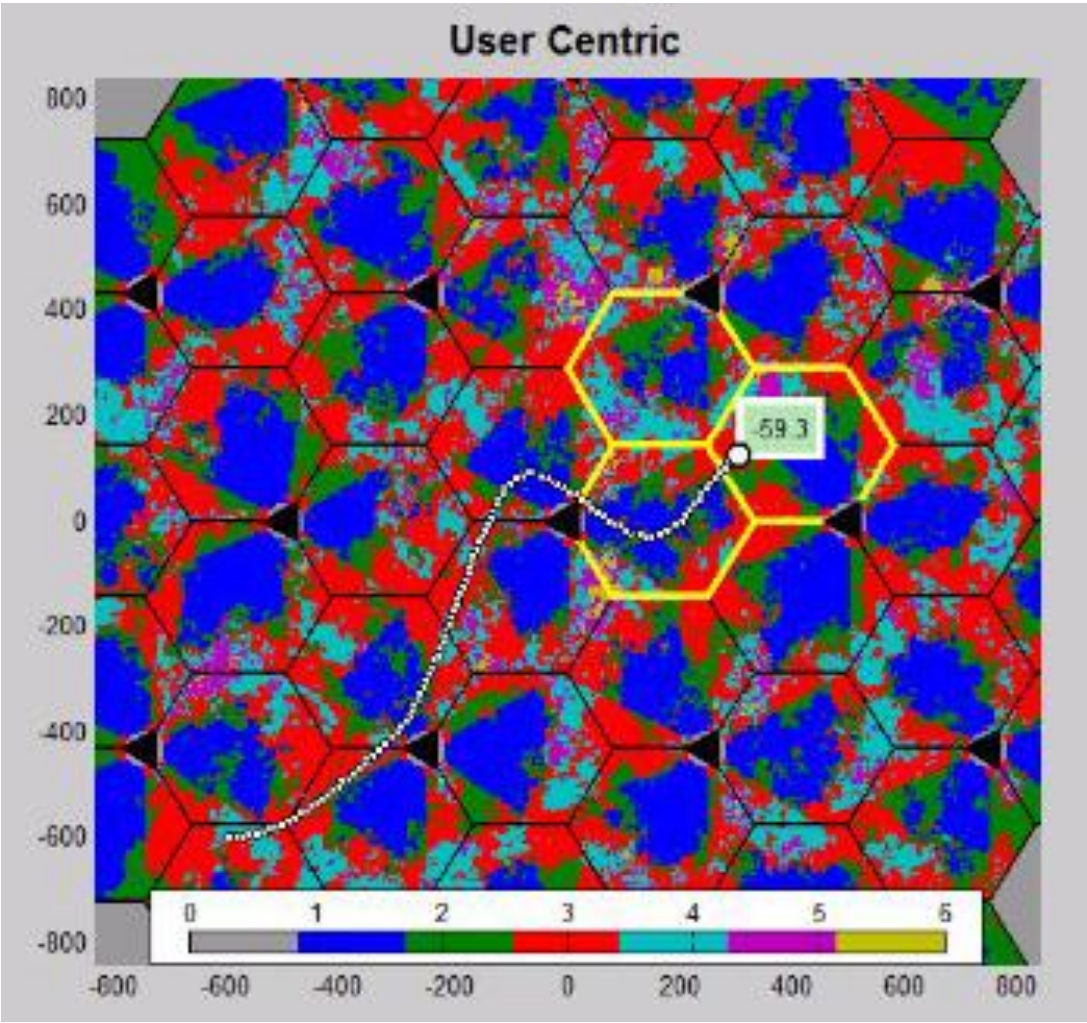
- Multi-Antenna Systems MIMO
- Spatial Multiplexing
- Beamforming
- Massive MIMO
- Multi-user MIMO
- CoMP/ Network MIMO

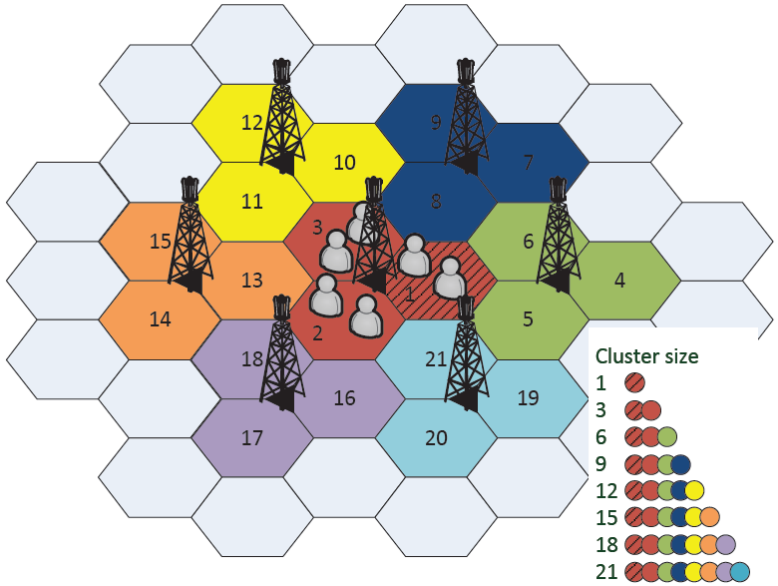
- Spatial Reuse
- Cellular layout
- Cell densification / HetNets
- Intercell Interference

Spatial MUX and Reuse



Adaptive Cluster Size Selection for CoMP

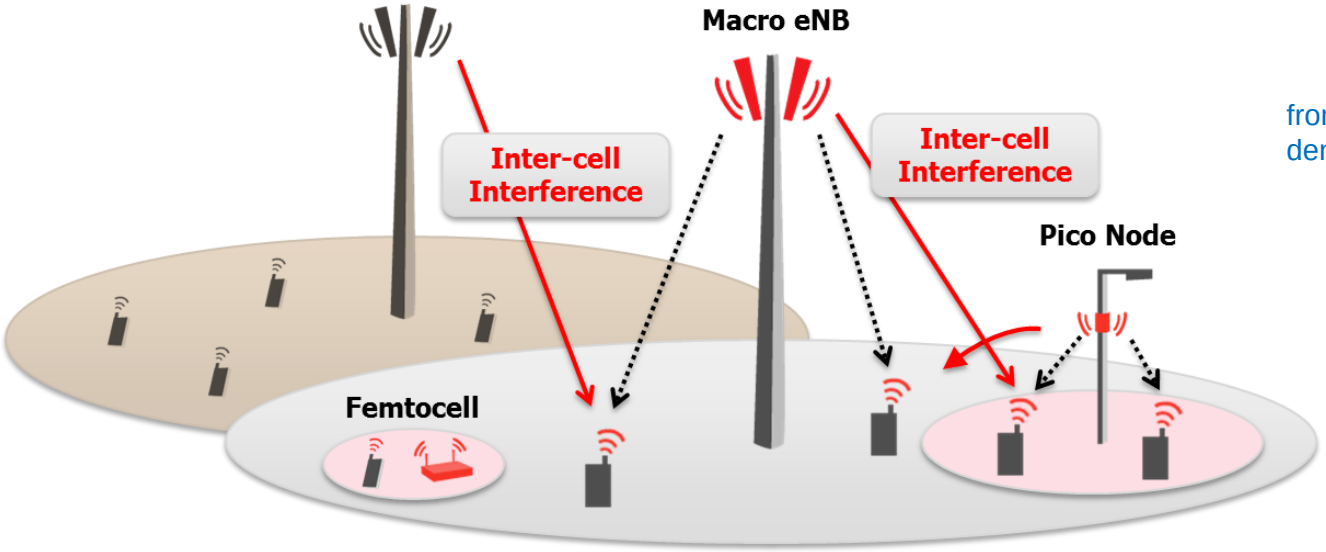


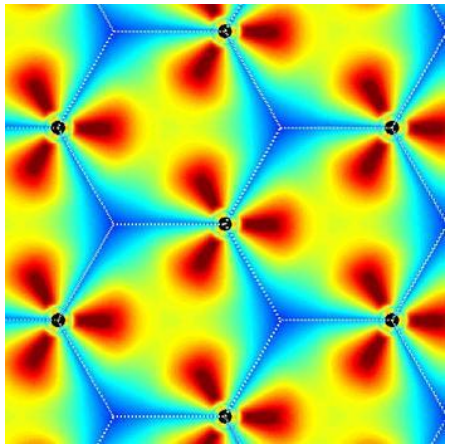


- ISD 500 m
- Downtilt 1/3 ISD
- corellated shadow fading
- selection window 15 dB

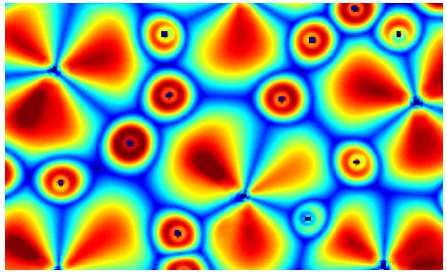
Heterogeneous Networks - HetNets

- Coverage and capacity enhancements by cell densification
- Deployment of small cells: Macro – Pico – Femto – Relay – DAS
- Challenges:
  - Interference (Coordination, Cooperation)
  - Backhaul (Wireless Backhaul)
  - Scalability (complexity, cost issues)
  - Energy efficiency (distributed or virtual cells using AAS, directivity vs. spectrum)



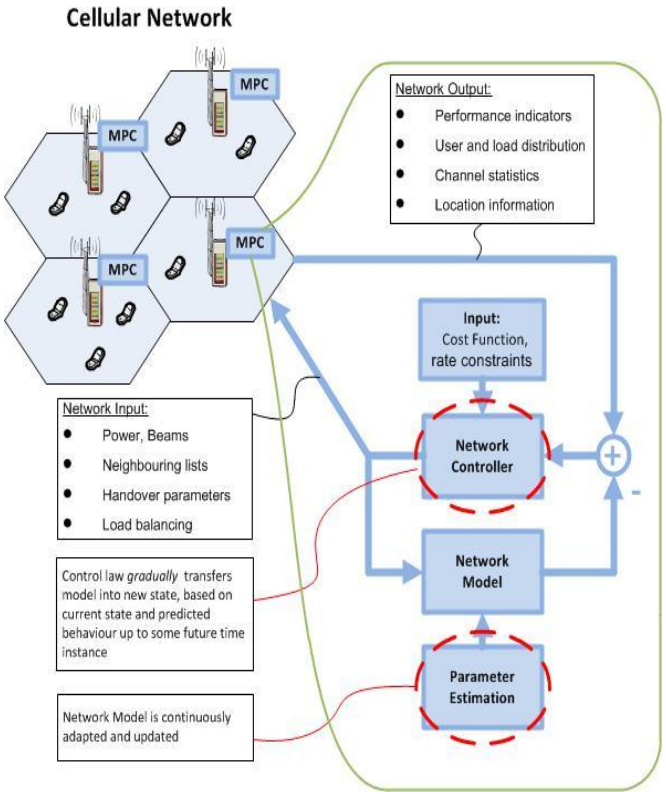


from macro cells to dense deployments



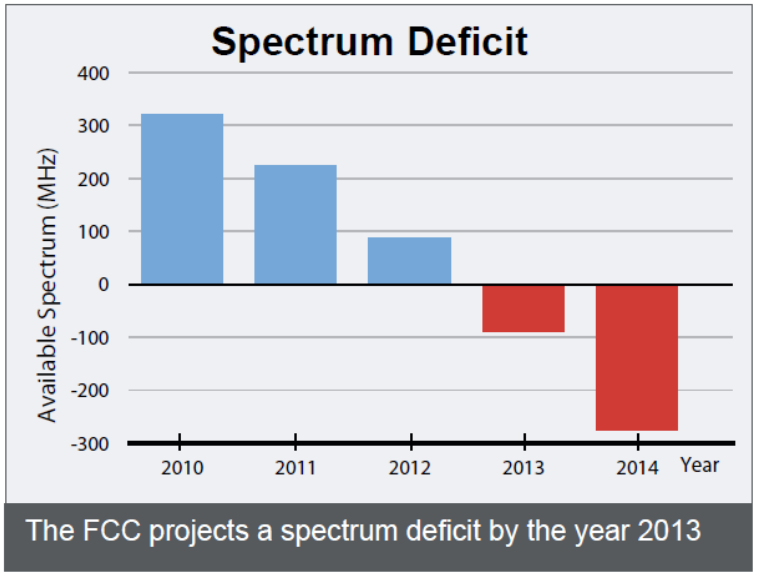
Self-Organization

- **Self-organizing (cellular) networks**
  - Different use cases: handover, load balancing, capacity, coverage, energy efficiency etc.
  - Interaction between different use cases/joint optimization
- **Methods**
  - Stochastic optimization
  - Machine learning and inference
  - Multi-objective optimization
- **Challenges in Heterogeneous Networks**
  - Large amount of measurements
  - Delayed & limited feedback
  - Unavailability of suitable (statistical) network models



Spectrum Deficit Expected

U.S. Study claims: Wireless Point of Disconnect!



The FCC projects a spectrum deficit by the year 2013

U.S. networks: 1800% increase in mobile data expected over the next 4 years

[SanDiego2011] Point of View: Wireless Point of Disconnect, GIIC, Oct. 2011

Approaches for solutions:

- Cognitive Radio Systems:
  flexible spectrum access and sharing of broadcast and cellular bands
- microwave and THz-spectrum:
  Utilize additional spectrum

Spectrum – the Degree of Freedom #2

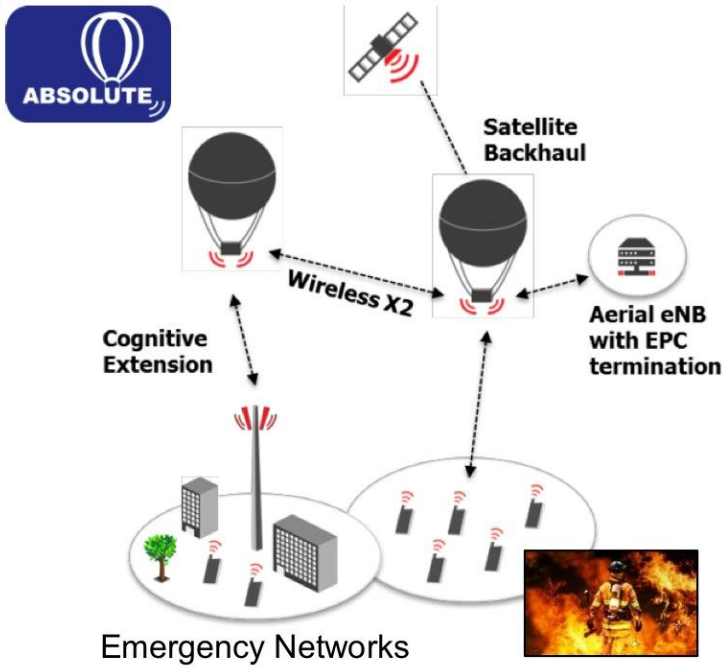
- **Spectrum Efficiency**
- **Frequency Reuse / Frequency Planning / ICIC**

- **Multiband Carrier Aggregation**
- **New frequency bands / upto 300GHz**
  - Coverage strongly depends on carrier frequencies

- **Flexible Spectrum Usage**
- **Opportunistic Spectrum Access**
- **Dynamic Spectrum Management**
- **Spectrum Sharing**
- **Secondary Usage**
- **Cognitive Radio Systems**

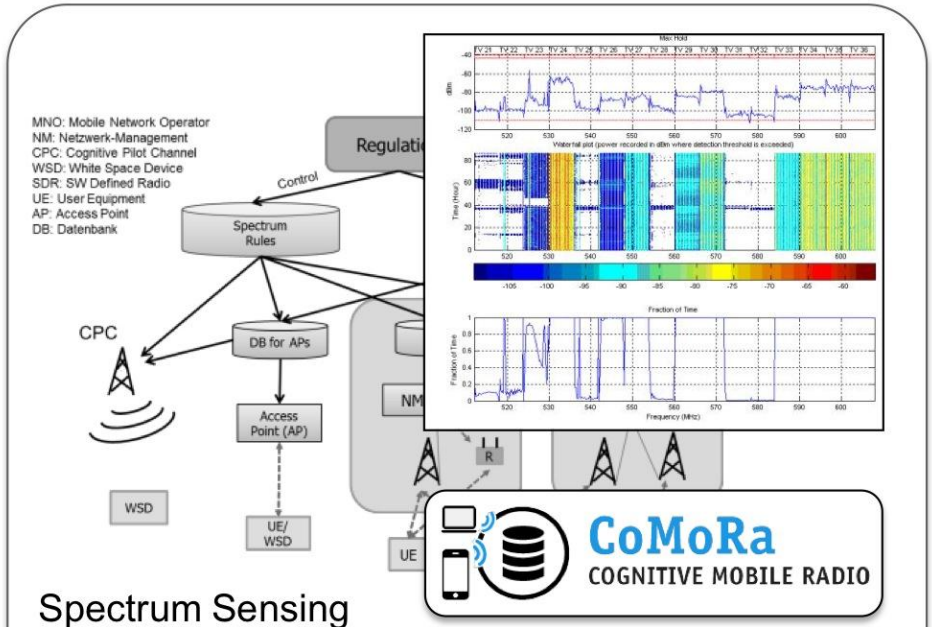
Cognitive Radio Projects

Resilient Flexible LTE-A Networks



http://www.absolute-project.eu

Cognitive Radio Applications



Spectrum Sensing
Flexible Spectrum Usage

http://www.comora.de

Sharing Physical Resources in Frequency

Thinking beyond one band per service or one band per MNO

Concept: *Flexible frequency sharing between cells with shared coverage footprint for small cell deployments within one's MNO spectrum domain between several MNOs with cell footprint overlap*

- Micro-Economic spectrum trading driven by geo-location aware small scale traffic forecasts

Advantages:

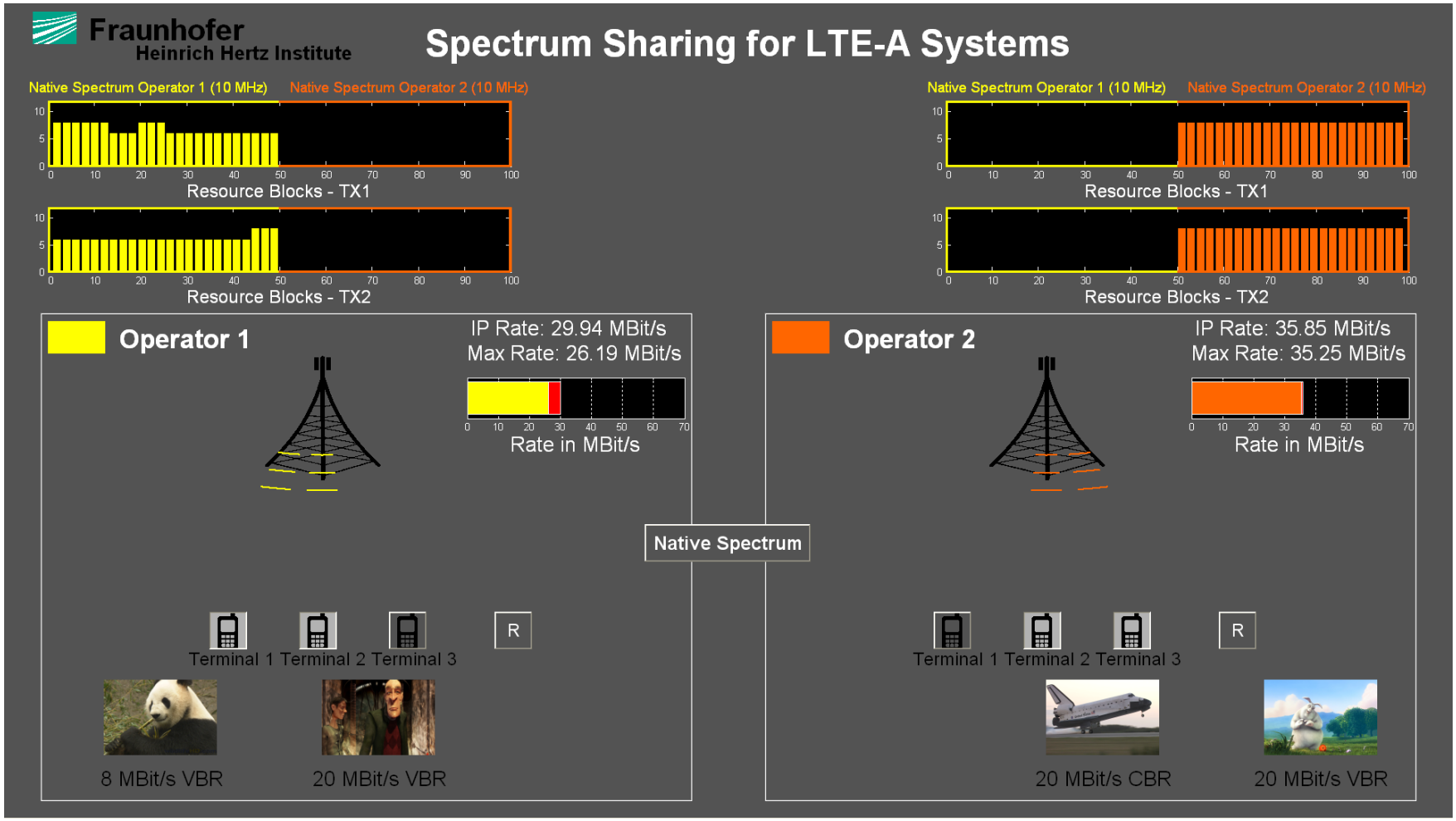
- w/ site sharing: local immediate capacity shifts on demand
- w/o site sharing: easy shift of exclusive spectrum between cells
- based on CA mechanisms
- subscribers remain in native network (national roaming vs. spectrum sharing)
- additional cell deployments can be postponed
- follows concepts of DSM and SON based load balancing

Options:

obtain/ offer spectrum options based on load predictions specific in time and geo-location (introduce a convertible metric between eg MNOs or MNOs and Broadcasters)

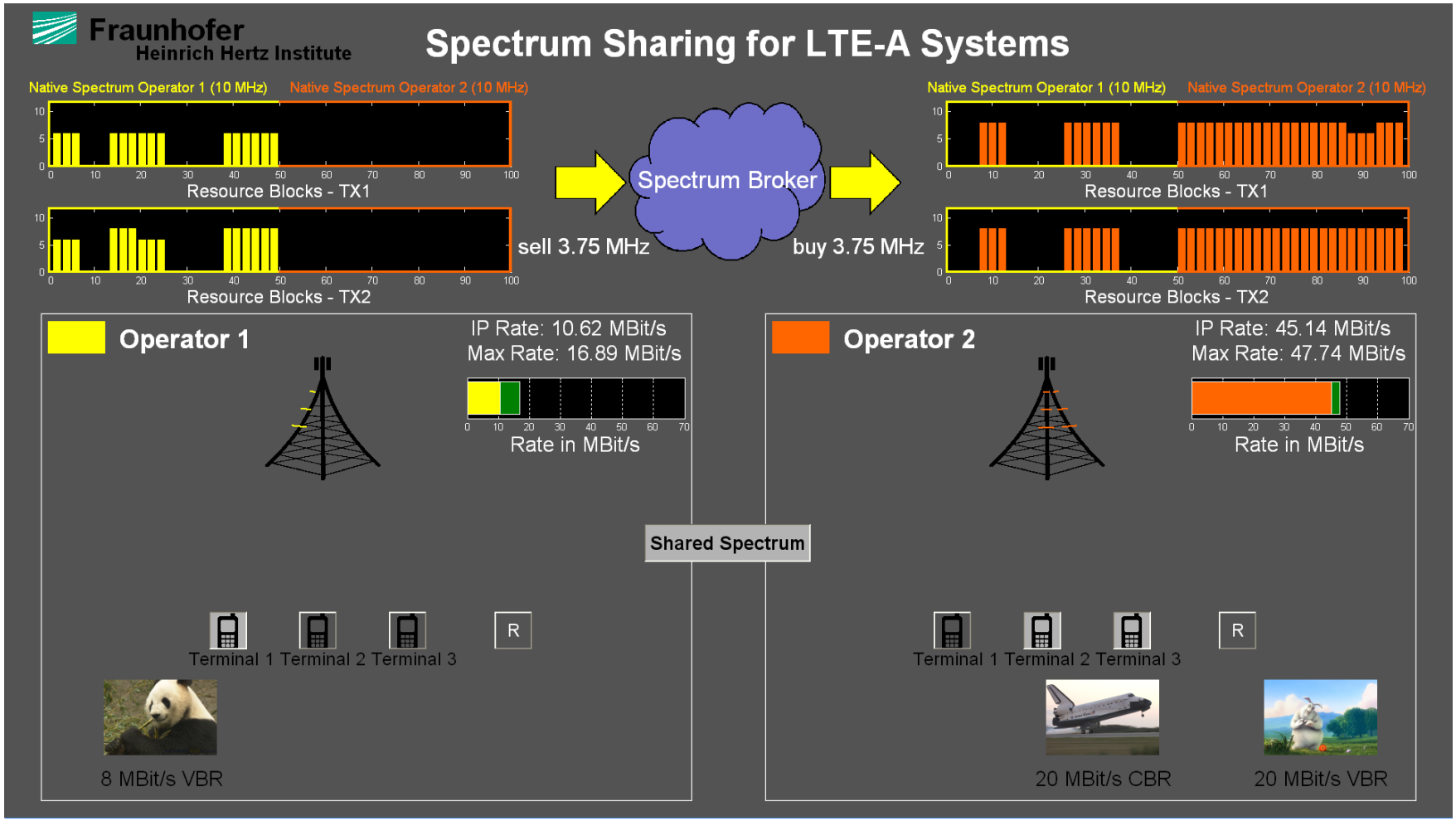
Spectrum – Exclusive Bands per MNO

Thinking beyond one band per service or one band per MNO



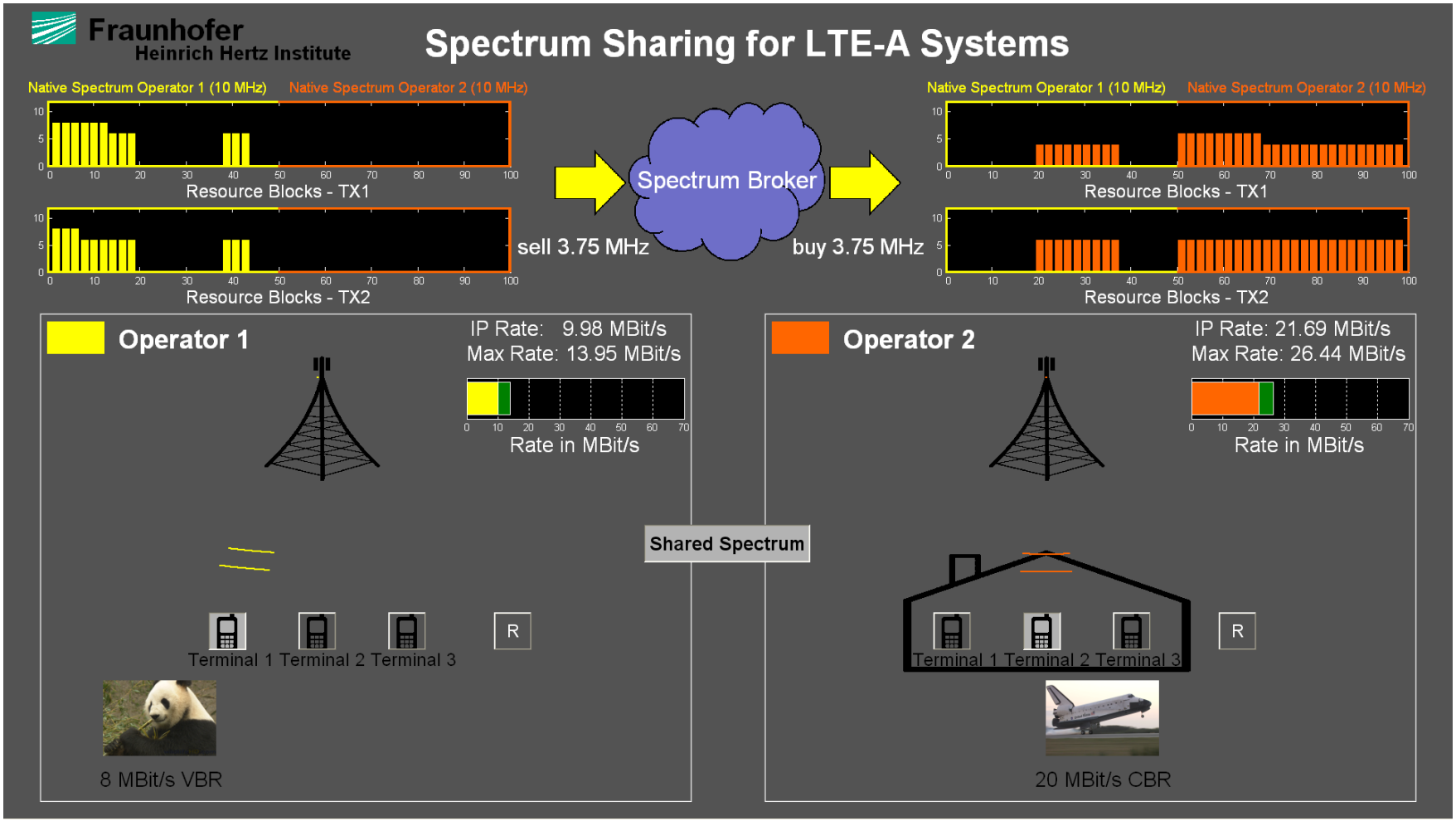
Spectrum – shift spectrum to other cells temporarily

Manage Peak Load Imbalances between cells of shared footprint



Spectrum – shift spectrum to other cells temporarily

Manage Spectrum Demand Imbalances between cells of shared footprint



Embedding secondary services in your own active bands

Scenario: narrow band / low rate services to be operated on LTE footprint; low complexity devices used

Concept: smart coexistence between LTE and systems with lower bandwidth and complexity (meters/sensors w/o LTE capability) →gray space comm

Primary system view:

embedding of secondary services air-interfaces in own spectrum

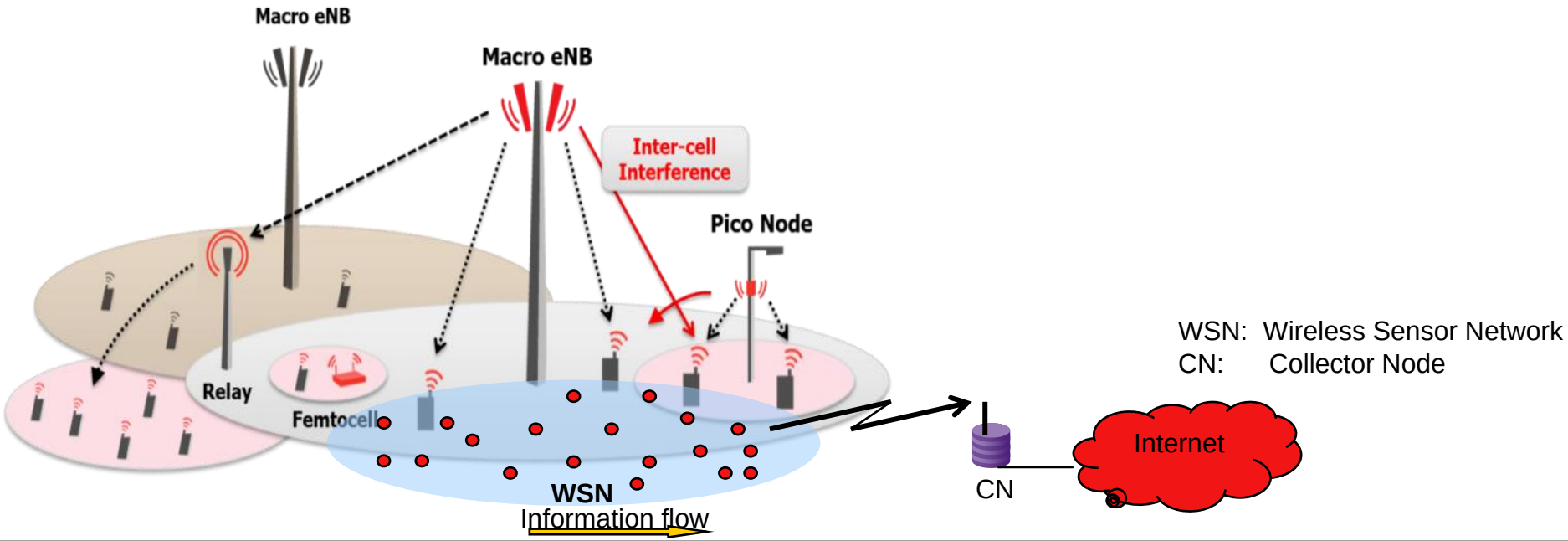
- based just on permit to operate, volume driven or event driven
- coordination with secondary's aggregation points or control channels
- can cope with interference anyway, improved resilience by e.g. CoMP

Secondary system view:

- can be operated with low complexity coordination capabilities (simple, cost and energy efficient)
- Basic knowledge about LTE bands and structure is sufficient

Wireless Sensor Networks
Data Transmission and Data Processing

- **Wireless Sensor Networks** (MTC, AAL, IoT)
  - Energy optimized data transmission and processing (maximum network lifetime)
  - Optimized and robust routing
  - Energy efficient MIMO techniques
  - Scalable range and flexible deployment (indoors, outdoors)



Thank you for your attention!

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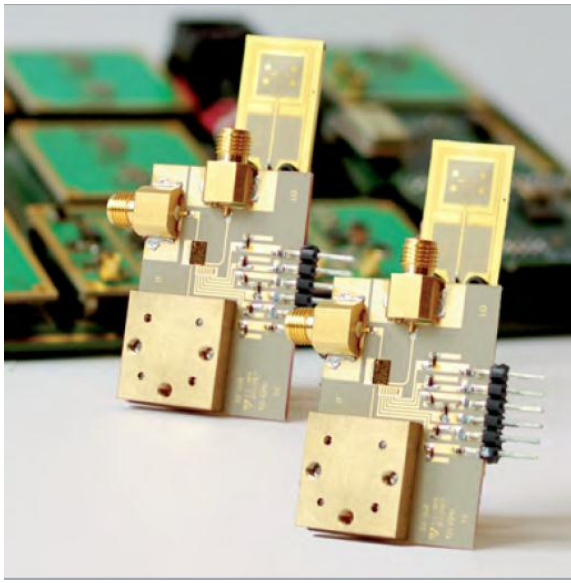
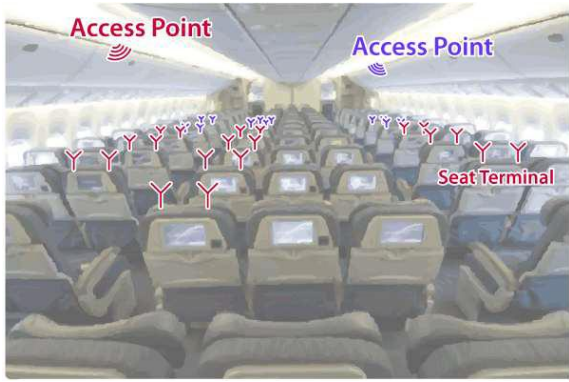
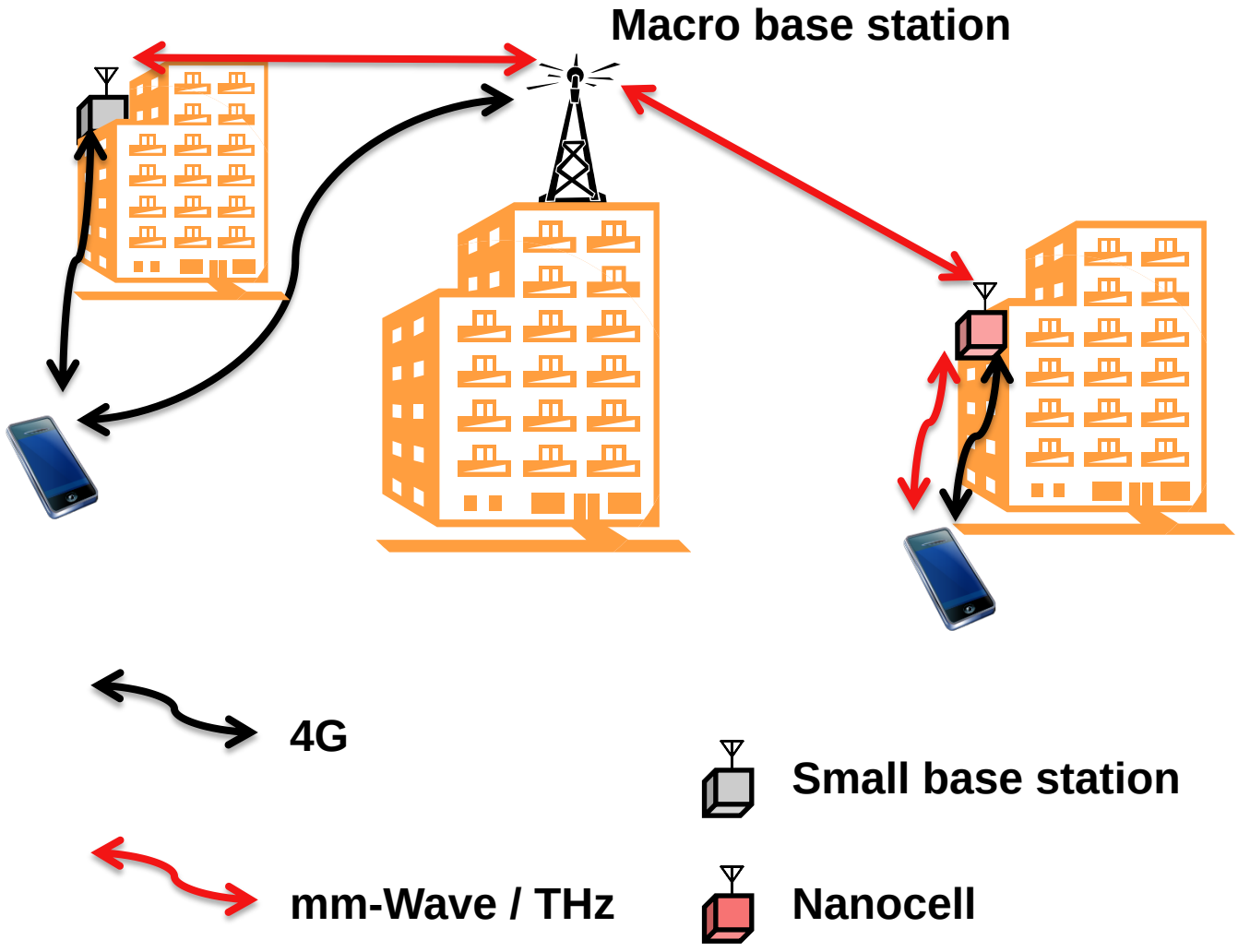
Millimeter-wave and Terahertz Solutions for Access and Backhaul



- Inflight / incabin communication
- Wireless backhaul for cellular networks
- Short range communication (WiGig)
- High capacity small cells (Microwave-WiFi, mm-wave cell overlays)



mm-Wave in Mobile Communication



- Macro BTS for coverage
- Small cells for capacity enhancement

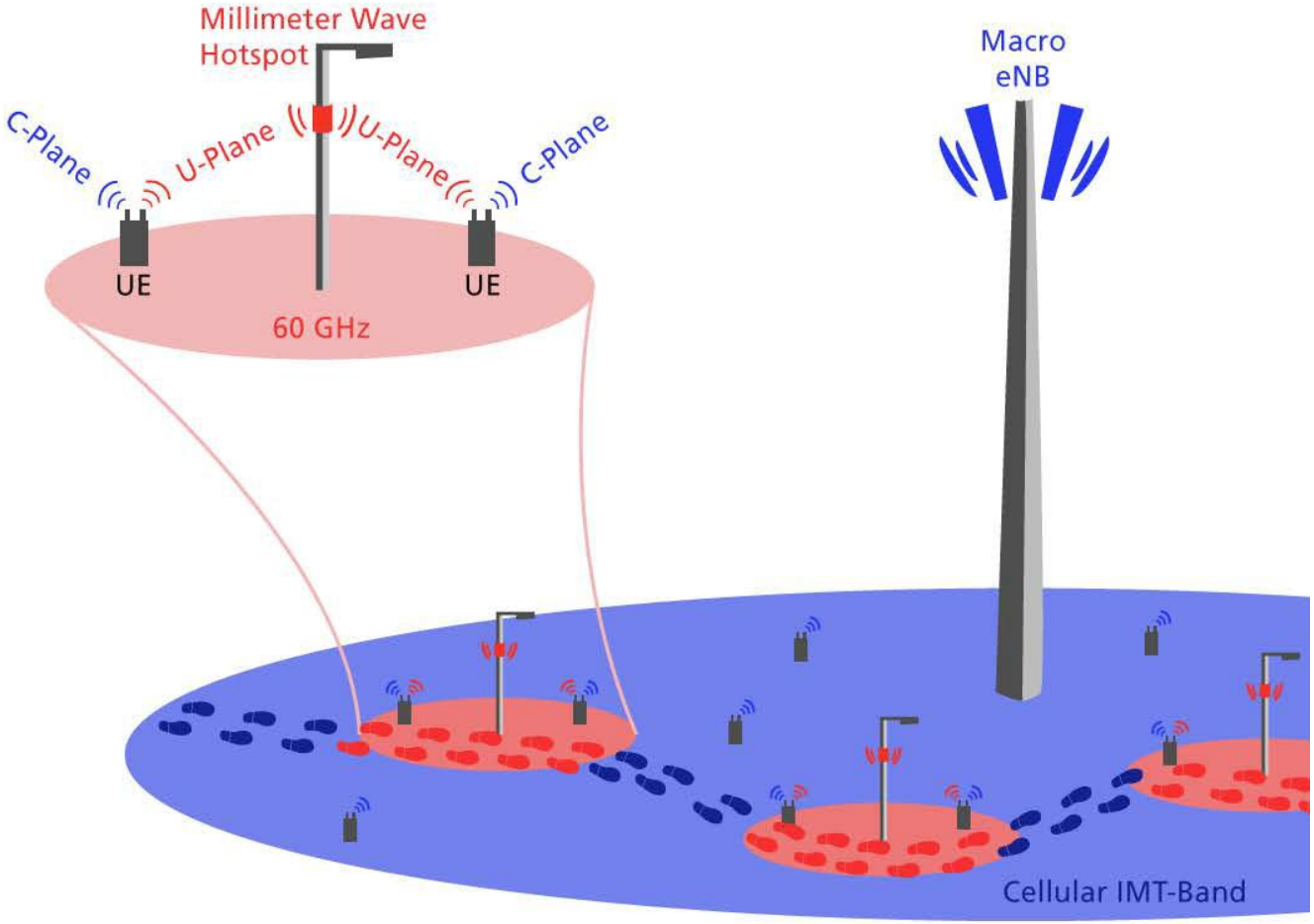
➔mm-wave backhaul (point-to-point)

- Nanocells for Gbit/s offload

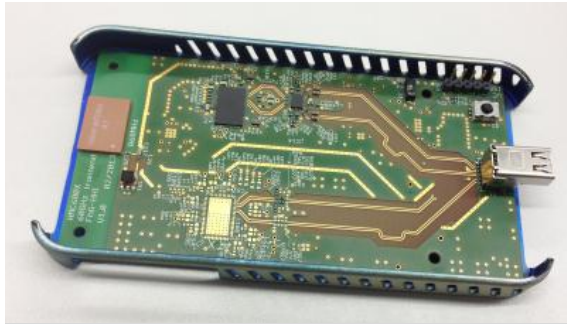
➔mm-wave or THz access (mobile)

➔mm-wave backhaul

Millimeter Wave Cellular Overlay Showcase MWC 2013 Barcelona



Booth at MWC 2013



RF frontend with 60 GHz and 800 MHz

mm-Wave Challenges and Approaches

mm-Wave Backhaul

- Reliable and efficient communication for realistic environments (low antenna heights)
- Interference Management for license-free bands
- Installation

➔ Advanced Modem and PHY-Design

➔ Cognitive spectrum management

➔ Beamforming, Self Organization

Nanocell Overlay

- User Mobility and Beam Tracking
- Handover between cellular network and overlay

➔ Hybrid data link layer and control plane