Evolution in Mobile Radio Networks

Multiple Antenna Systems & Flexible Networks

InfoWare 2013, July 24, 2013

The thirst for mobile data will continue to grow exponentially

3D, high- and ultra-high definition screens

Video integrated everywhere

Digital universe continues to grow exponentially

Everything from and on the cloud

Billions of connected objects

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Content

- Multiple antennas
- Network architecture
- Liquid Net for mass events

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Multiple Antennas

- Antenna configurations
- Antenna vs. antenna port
- Multiple receiving antennas
- MIMO & multiuser MIMO
- Beam forming
- Hybrid beam forming

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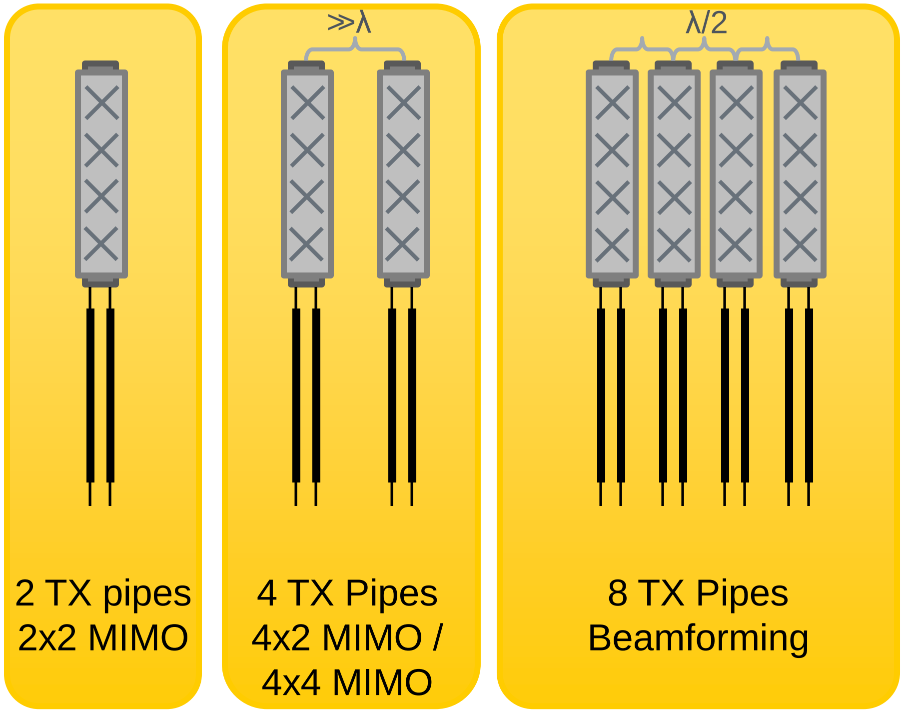
Antenna Configurations

Base station antennas

- Omni-directional
- Directional (≈λ/2)
  - vertical : tilt, adaptive
  - horizontal : sector, beam forming
- Diversity
  - Orthogonal polarization
  - Spacing segments (≫λ)

Terminal antennas

- Single omni-directional antenna
- Two cross-polarized antennas



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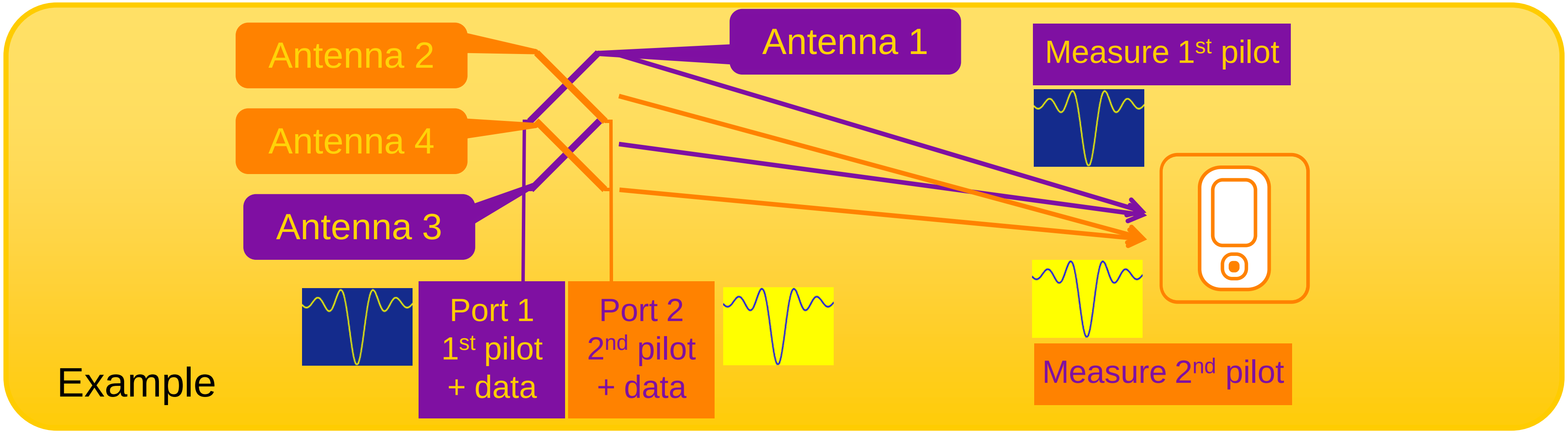
Antenna vs. Antenna Port



Antenna port
- Each port bears its own pilot
- Data are mapped to port according pre-coding rules

TX pipe
- Several antenna segments can be connected by a common TX pipe

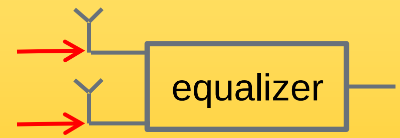
Antenna
- HF signal of TX pipes is transmitted on air

Terminal ‚sees' logical antenna ports, not physical antennas

Multiple Receiving Antennas
CIR & SINR as Measure for Radio Quality

Carrier to Interference Ratio : Measured at RX antenna

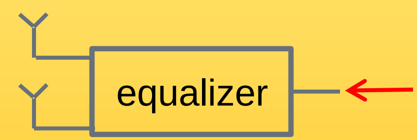
$$\mathrm{CIR} = \frac{\text{carrier power at RX antenna}}{\text{interference power at RX antenna}}$$



- No mutual dependency of RX antennas
- Impact from TX diversity

Signal to Noise and Interference Ratio : Measured at equalizer output

$$\mathrm{SINR} = \frac{\text{signal power at equalizer output}}{\text{interference + noise power at equalizer output}}$$



- RX combining gain
- Impact from TX diversity

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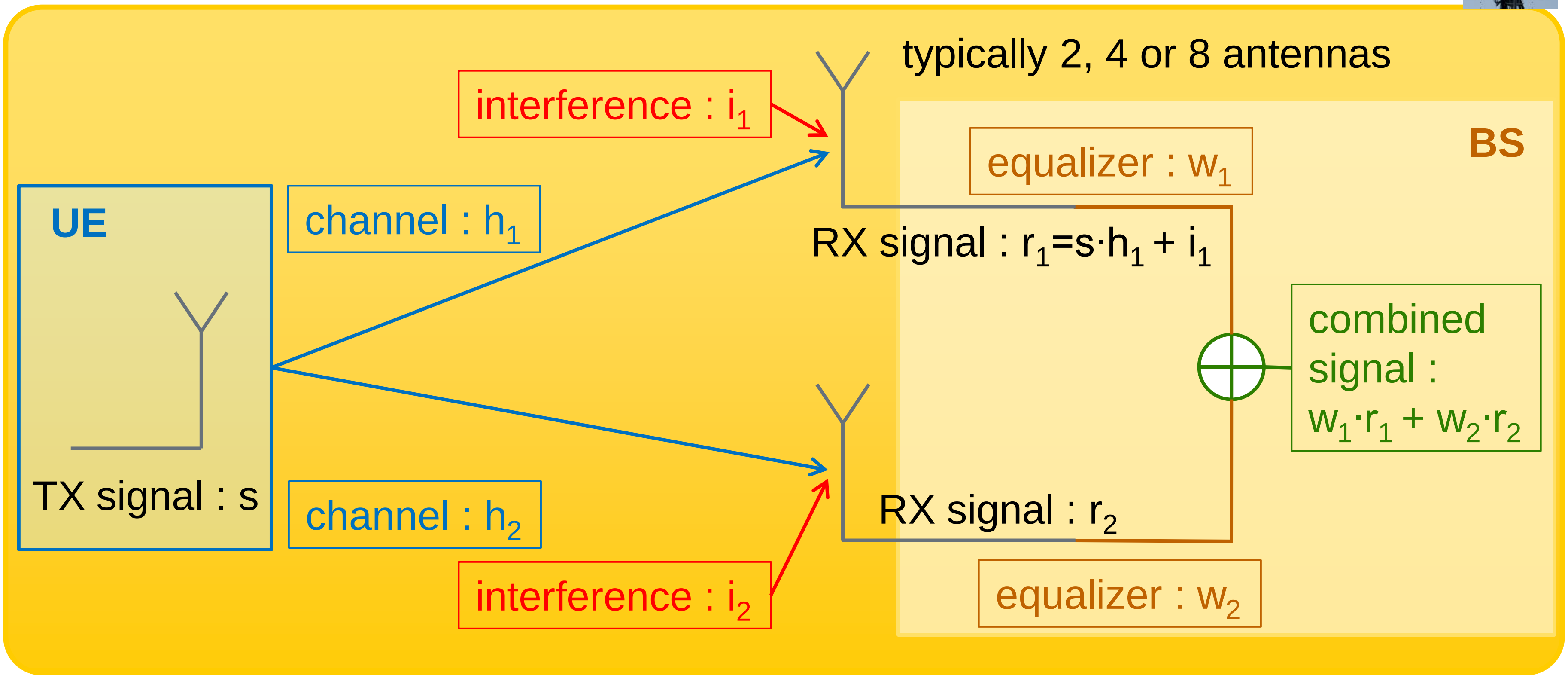
Multiple Receiving Antennas



Power of received signal (coherent) : $P_S = |w_1 \cdot r_1 + w_2 \cdot r_2|^2 \approx |s + s|^2 = 4|s|^2$

Power of noise & interference (incoherent) : $P_I = |w_1 \cdot i_1 + w_2 \cdot i_2|^2 \approx |i_1|^2 + |i_2|^2 \approx 2\,|i_1|^2$

Multiple Receiving Antennas
Equalizing at Single Receiving Antenna

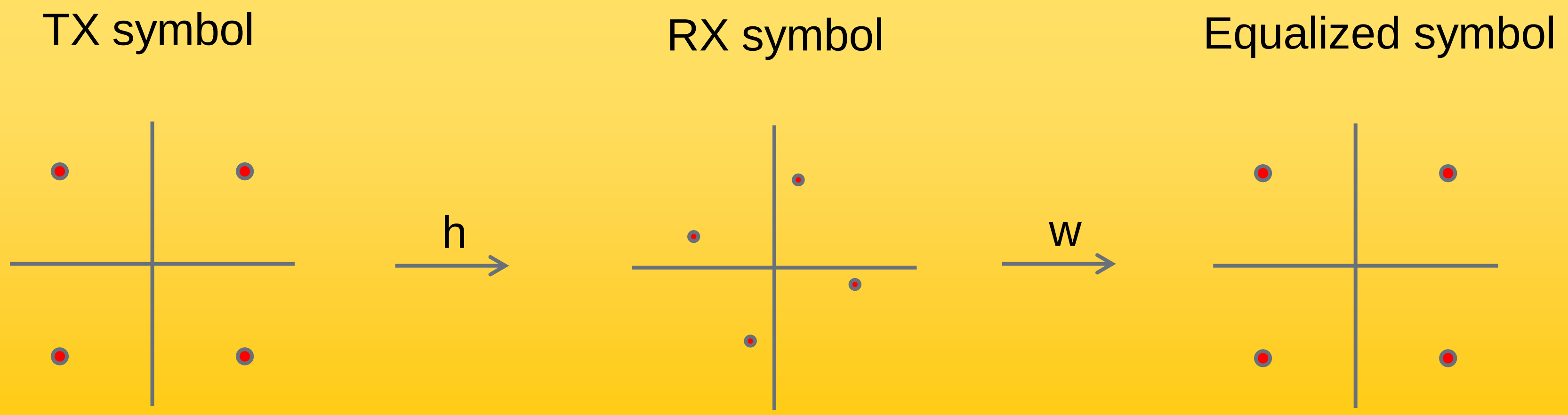
OFDM : Operation per PRB

- Narrow band signal
- Operation in frequency domain

→ Weight is complex scalar

Restoring TX symbol

- Phase alignment: w ~ h*
- Unbiasing: |w|=1/|h|



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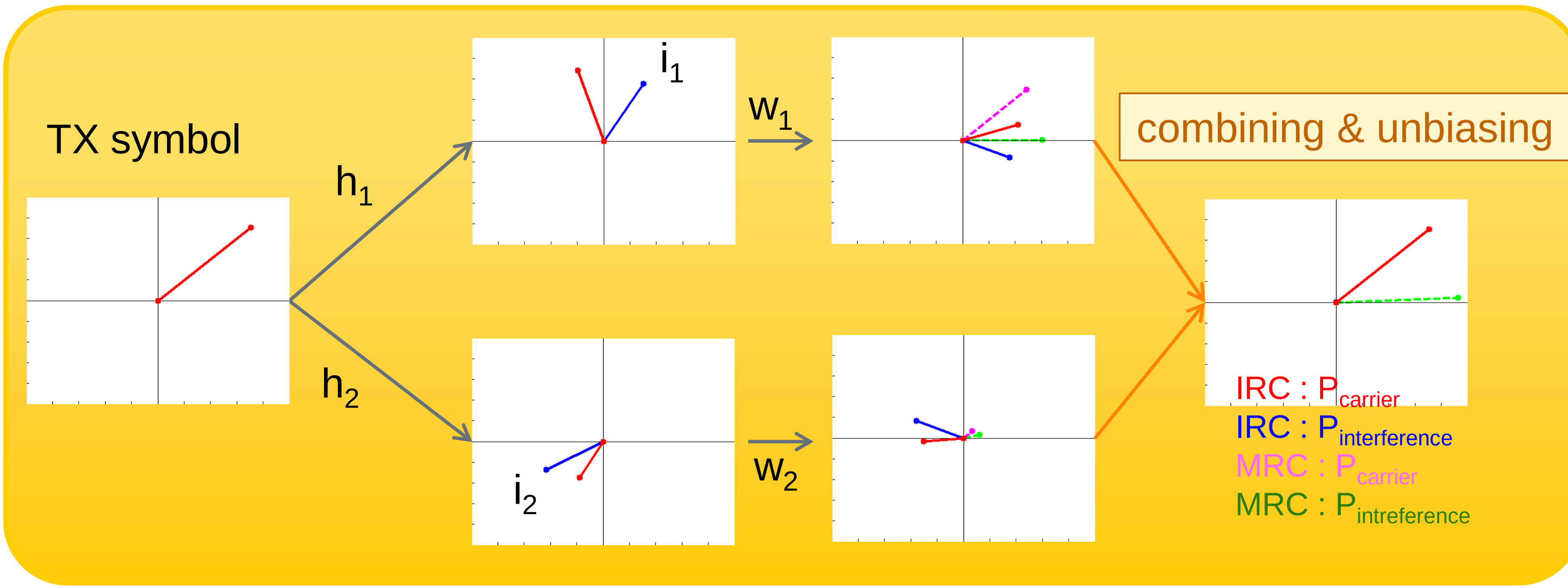
Multiple Receiving Antennas
Combined Equalizing

Maximum Ratio Combining
- Equalizing ‚per antenna' : $h_i^*/(i_i \cdot i_i^*)$
- Adding of equalized signals

Interference Rejection Combining
- Combined equalizing
- Constraint : maximize SINR



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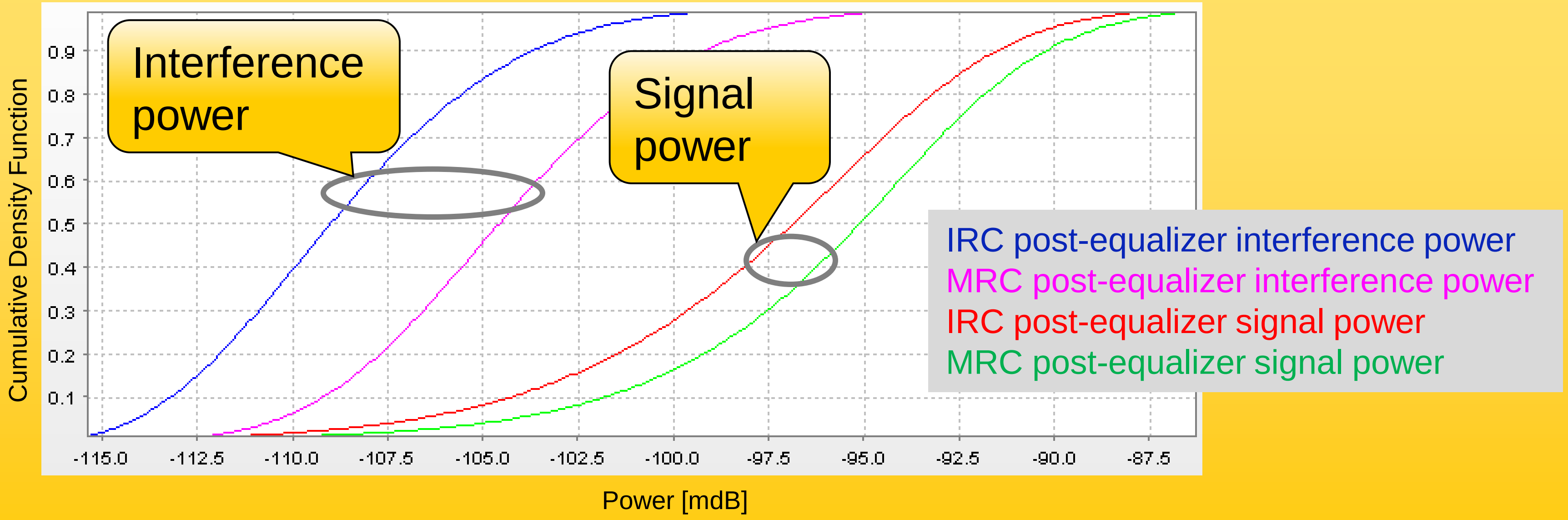
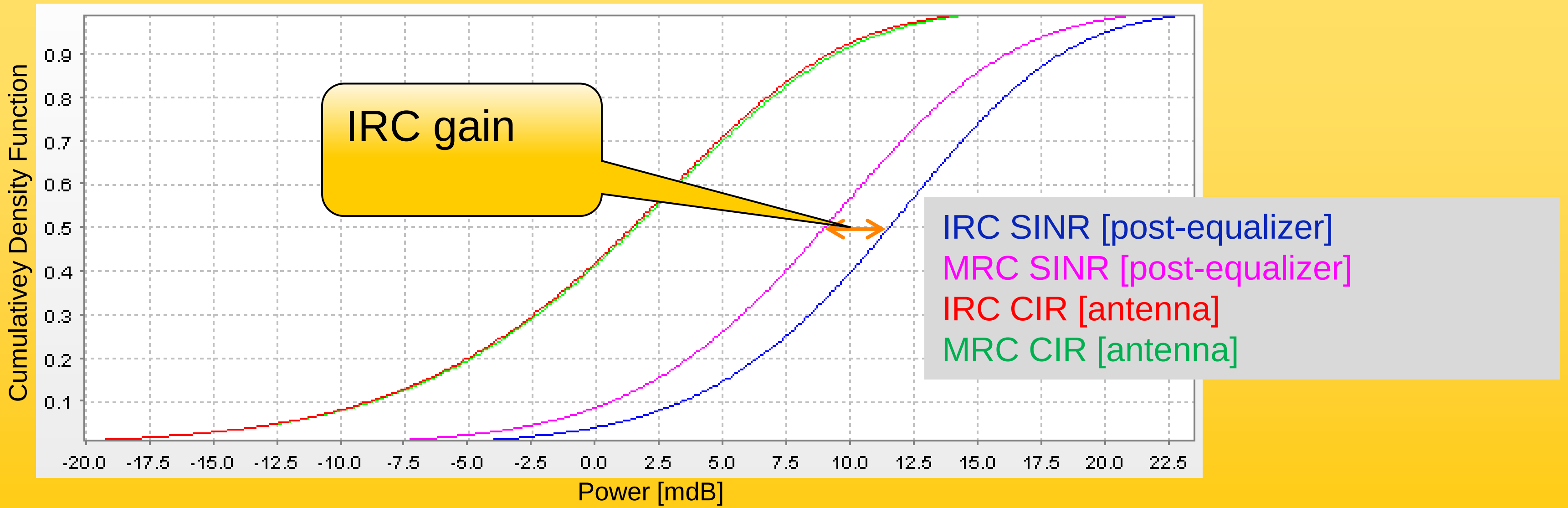
Multiple Receiving Antennas
IRC LTE FDD 4RX – Post Equalizer Powers



- MRC shows higher carrier power than IRC
- MRC shows **much** higher interference power than IRC

  Wolfgang Aichmann / 2013-07-24

Multiple Receiving Antennas
IRC LTE FDD 4RX – CIR and SINR



- CIR of MRC and IRC aligned
  (measured at antenna, i.e., before equalizer)
- SINR much better for IRC compared to MRC
  (measured at equalizer output)

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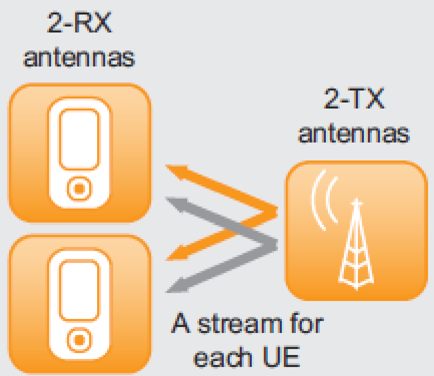
MIMO & Multiuser MIMO

Singleuser MIMO (e.g. DL)
- Diversity by spatial antenna separation or polarization
- Maximum number of data streams limited by number of TX and RX antennas
- Multiple streams differ in RX signal strength which limits the maximum achievable data rate
- Closed loop : Antenna phase factor information is signalled by UE

Multiuser MIMO (e.g. UL)
- Transmission of single streams to different UEs
- UE selection such as to assign the strongest stream to each of them
- High data rates possible on both streams



2x2 Multiuser MIMO

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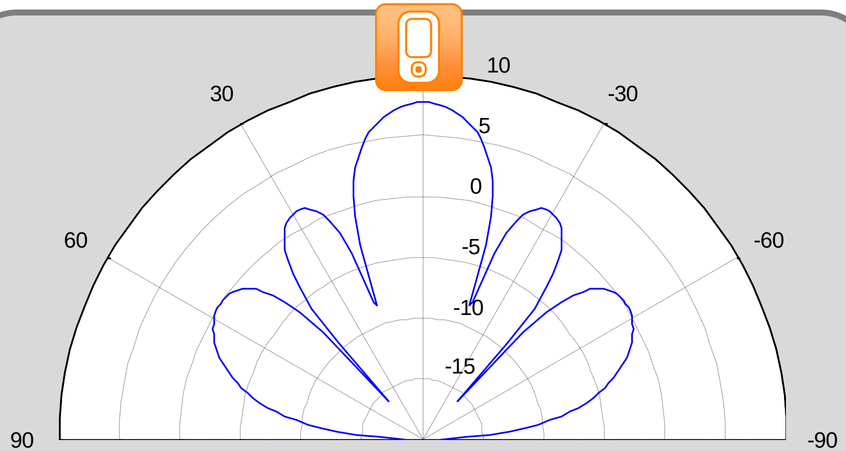
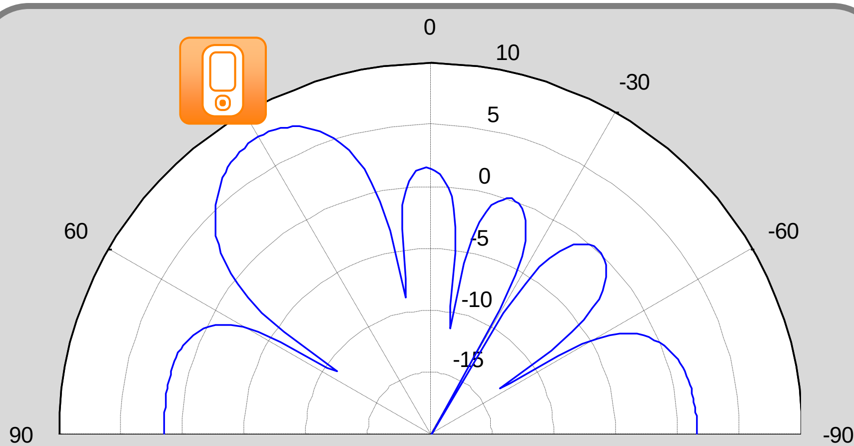
Beam Forming

Multiple TX antennas

- RX signal strength depends on phase differences of incoming signals
- Optimization of phase difference for single terminal already on TX side
  - Requires good channel knowledge for each TX to RX antenna path
  - Applied only for TDD systems (same physical channel for UL and DL)
- Multiple terminals can be served in parallel with different beams



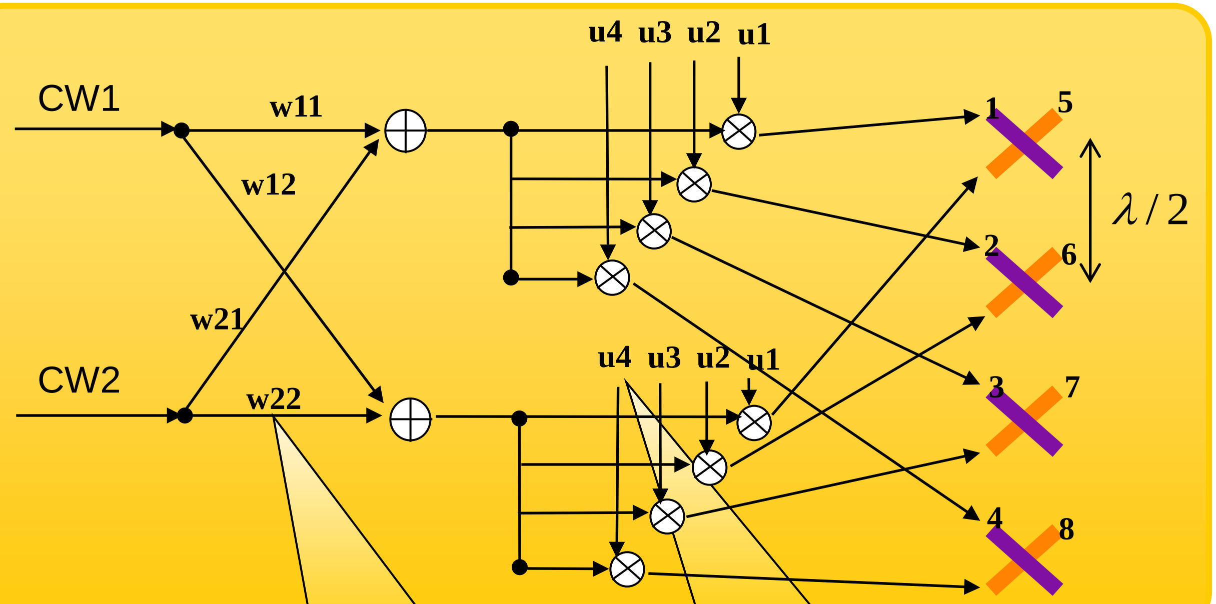
Beam direction 0º



Beam direction 30º

Uniform linear array, 6 elements, 0.5λ spacing, antenna pattern in dB

Hybrid Beam Forming



Example
- 4 X-Pol segments, i.e., 8 antennas at all
- Polarization → MIMO
- Spatial diversity → beam forming
- Effective weights: (short term weights) x (long term weights)

→ MIMO & BF : hybrid

Short term weights **w** for mapping code words to data layers.

Long term weights **u** for beam forming.

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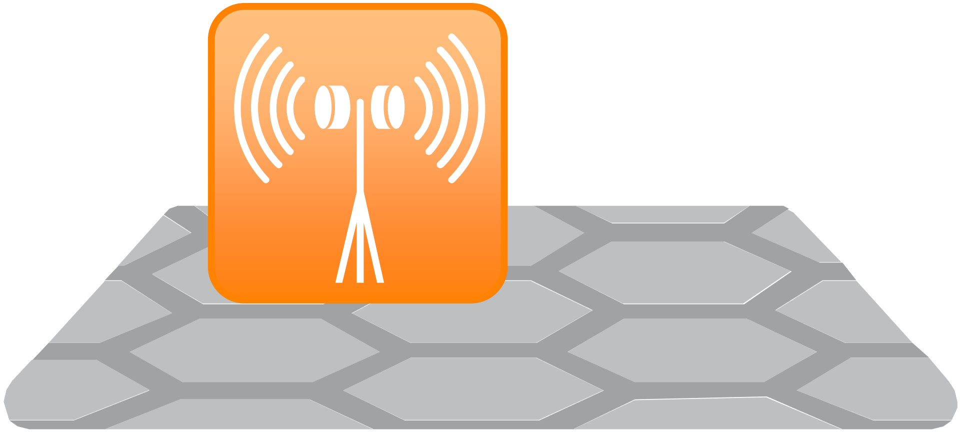
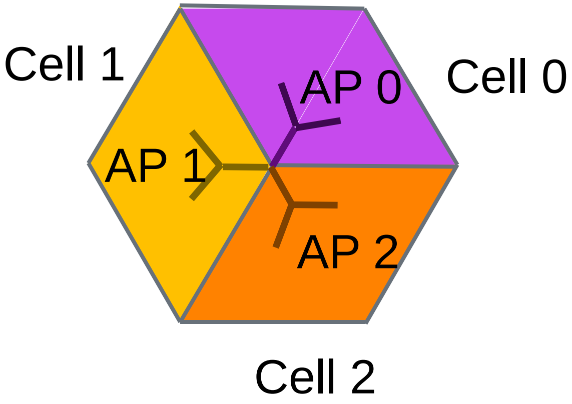
Network Architecture

- Co-ordinated Multipoint (CoMP)
- Distributed Antennas
- Supercell
- Heterogeneous Networks (HetNet)
- Carrier Aggregation

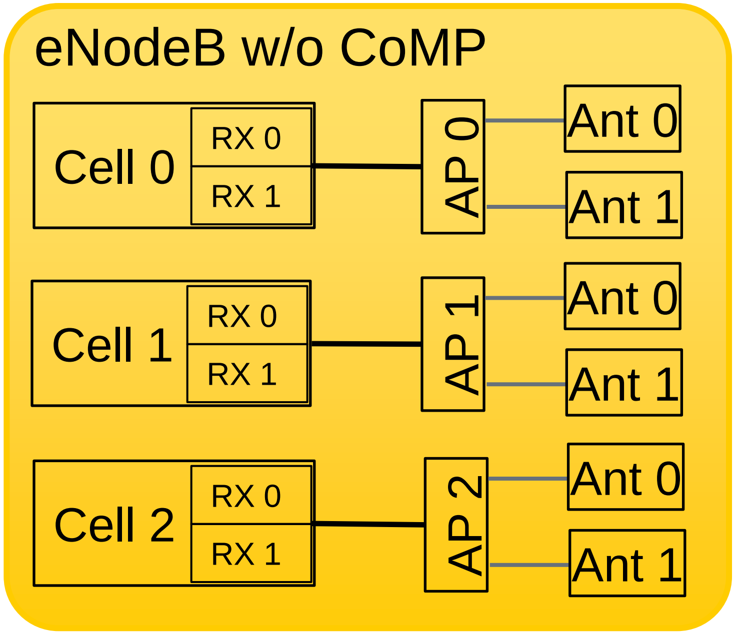


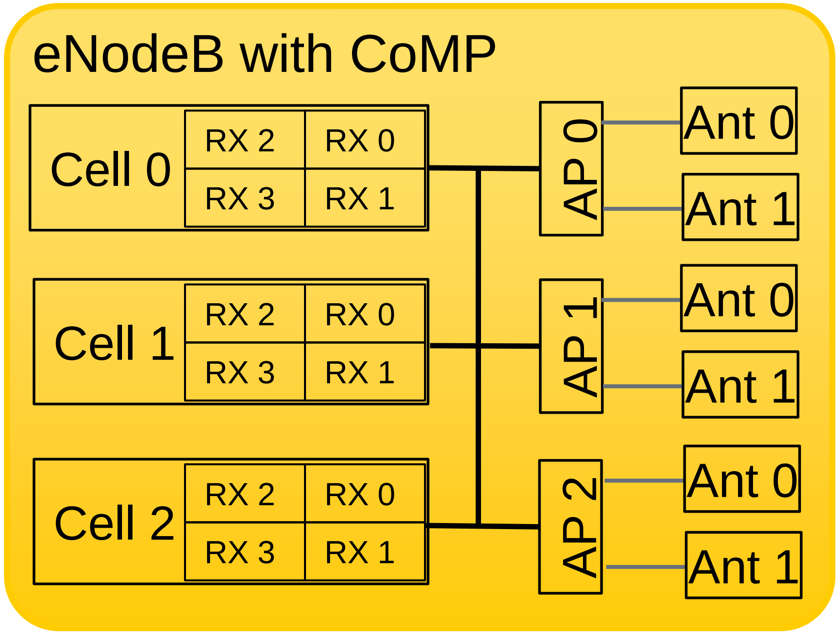
Co-ordinated Multipoint (CoMP)
Step 1: Co-Sited



Logical separation of antenna point from cell
- More cell antennas w/o new antenna locations
- Low technical effort, at least in uplink (MRC / IRC)

Requirement:
- Remote radio head (RRH)
- Fast data connection to all Antenna Points (AP)





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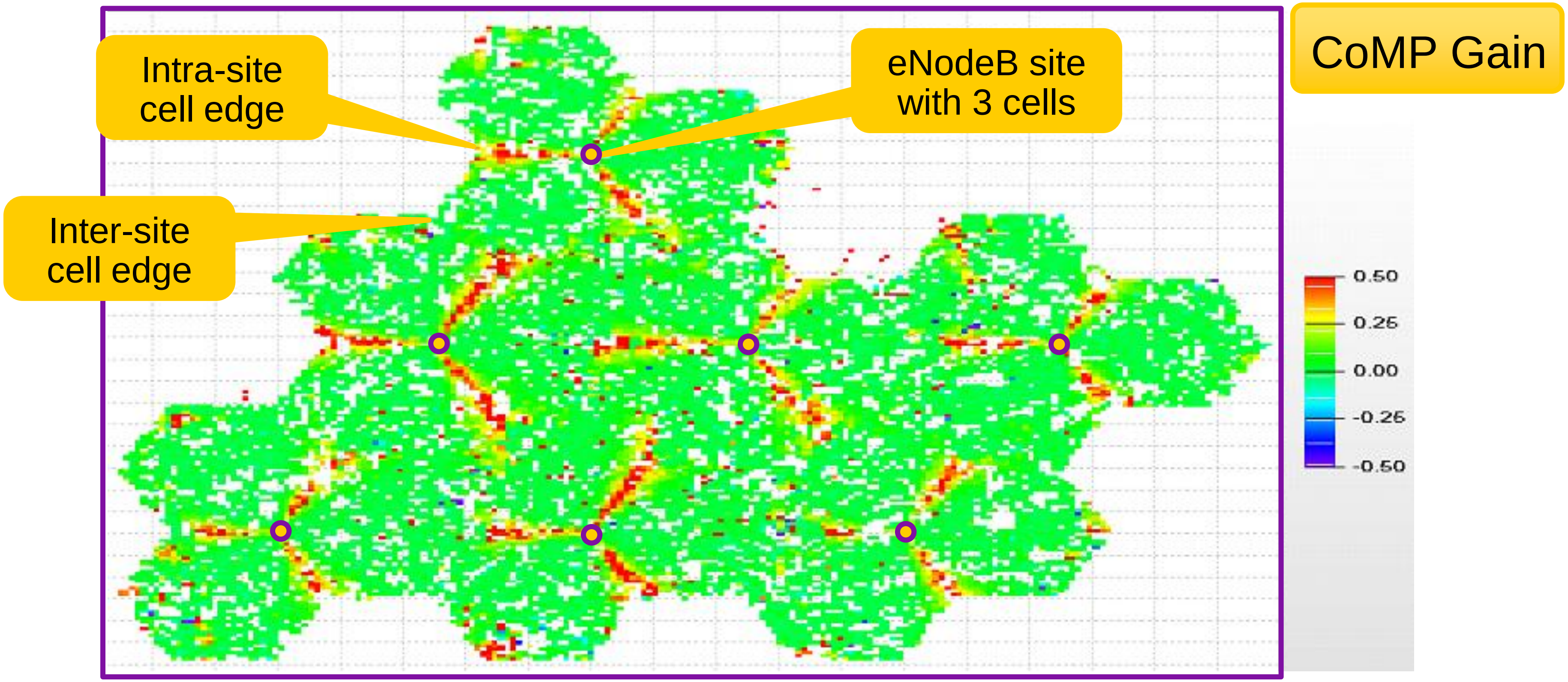
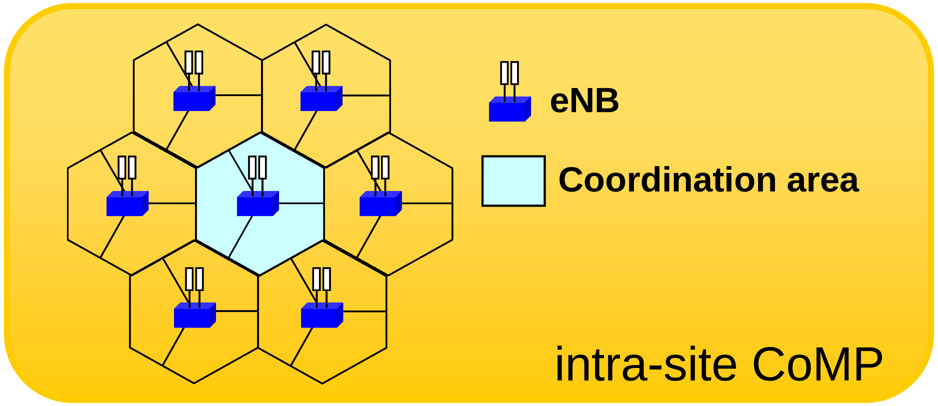
CoMP
Simulation Results for UL Inter-Site CoMP

- Each cell has 2 own antennas
- Each cell has access to antenna points of the 2 co-located cells
- At maximum 4 antennas are used for combining (MRC)

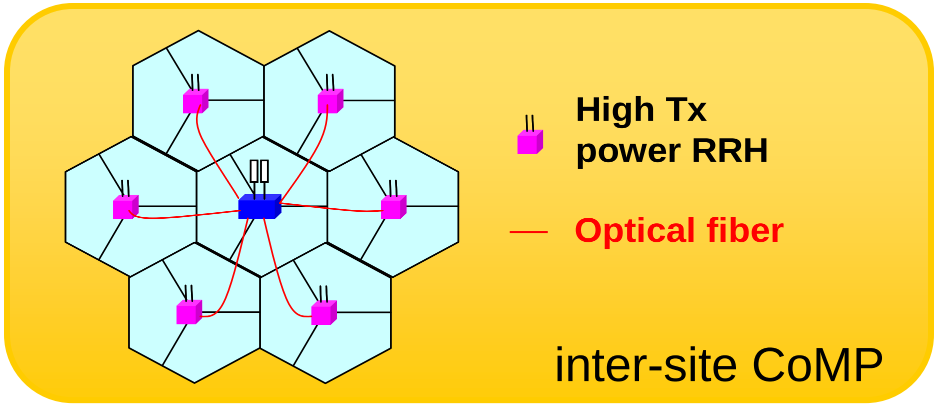


Co-ordinated Multipoint (CoMP) Step 2: Inter-Site CoMP



Intra-site CoMP

- eNodeB located at antenna points
- Sharing antenna points of cells hosted in same eNodeB
- Interface within eNodeB



Inter-site CoMP

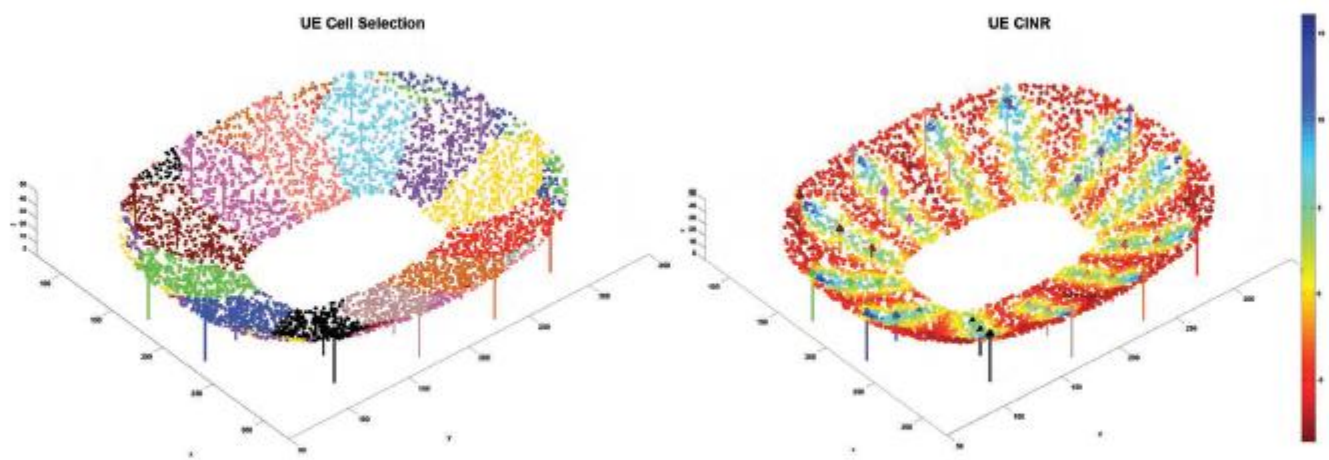
- Many remote antenna points
- All accessible in each cell
- Fast data connection to all Antenna Points (AP)
- Interface within eNodeB

source: 3GPP TR 36.819 V11.1.0 (2011-12)

Distributed Antenna Systems (DAS)

- Hosting multiple wireless operators and technologies
- DAS infrastructure provided by venue
- Operators attach their RF Head antenna ports to the DAS node

Example: Stadium with 12 cells each with six antennas

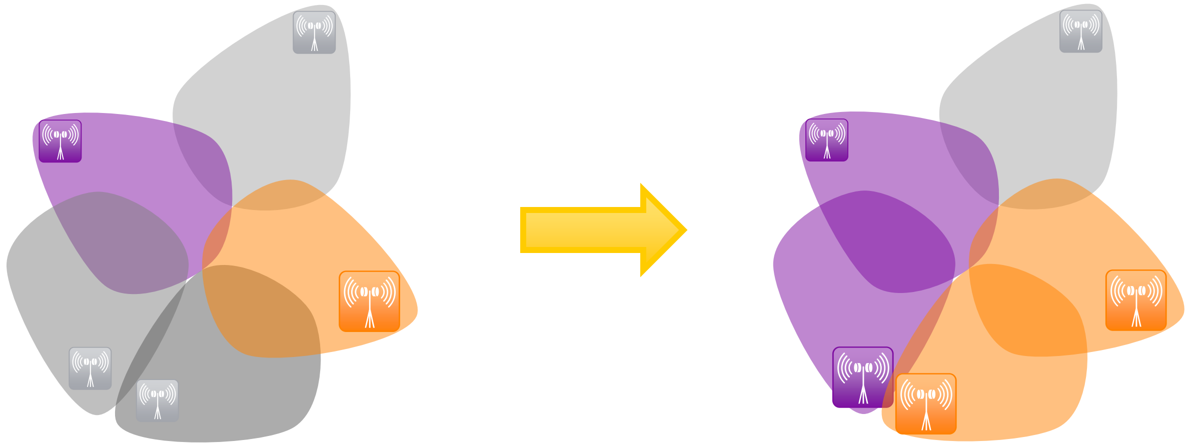


High Carrier to Interference Ratio (CIR) indicates antenna locations

source: High Capacity Mobile Broadband for Mass Events, White Paper, Nokia Siemens Networks, 2013

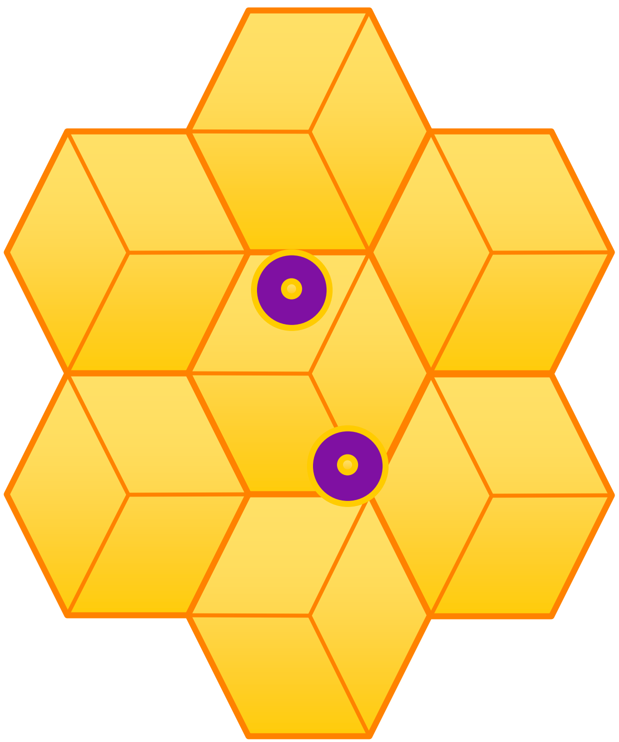
Supercell

- Installation of additional cells
  - Coverage holes
  - Insertion of additional cells
  - Increase capacity
  - Decrease cell size
- Cell fragmentation
  - High number of hand-overs
  - High inter-cell interference
- Combining different cells to one logical supercell



Heterogeneous Networks (HetNet)

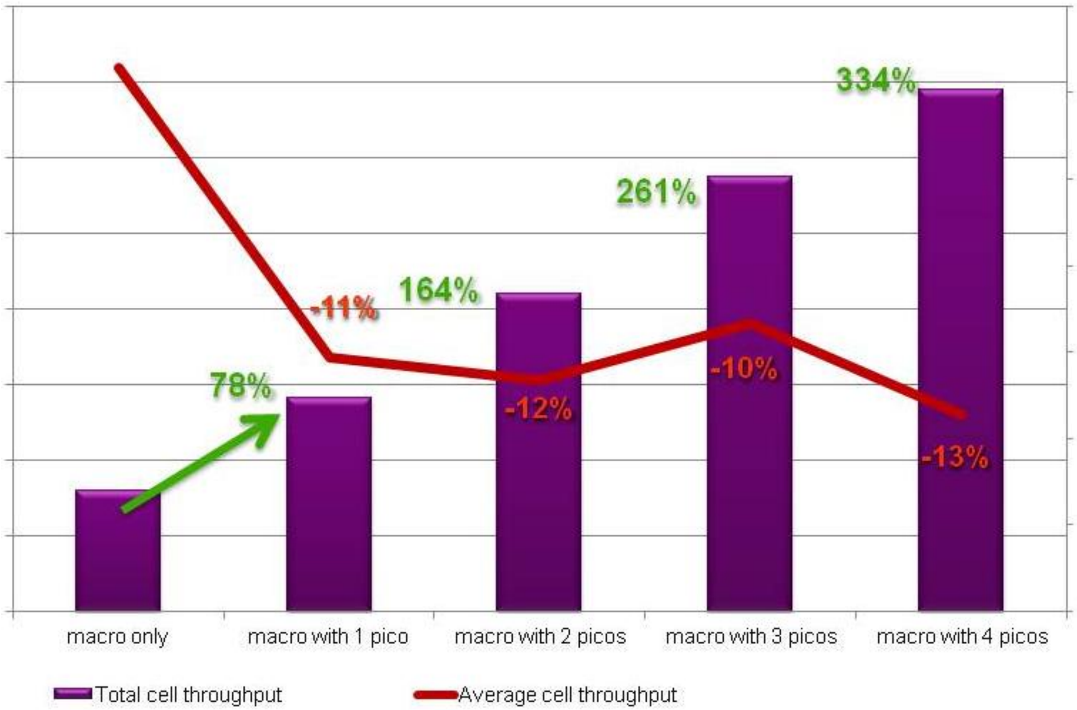
- Challenge: Traffic hot spot within an existing network
- Solution: Placing small cells inside the network
- Applicable: Office buildings, railway stations, parking aerea, shopping centre



- High interference because of overlapping cells within the same frequency band
- Interference management
  - Interference Rejection Combining (IRC)
  - Enhanced Inter-Cell Interference Co-ordination (eICIC)
  - …

Heterogenious Networks Simulation Results

- Average cell throughput decreases (no simple scaling with # of cells)
- Total cell throughput increases (more cells)



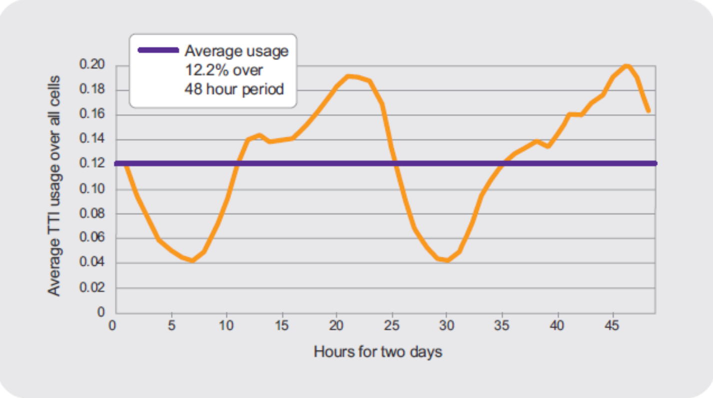
Downlink

Carrier Aggregation

Smart phones cause bursty traffic:

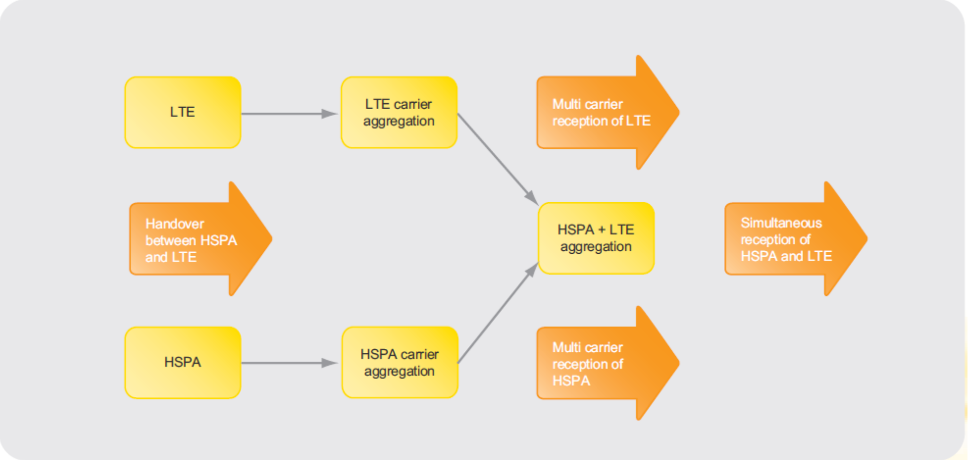
- Big variation of required radio resources
  - Over time
  - Between cells
  - Between frequency layers

At any time significant unused resources while other parts are in overload.



Aggregation of multiple carriers

- Diversity gain from scheduling on best carrier(s)
- Pooling & load balancing
  - Increased througput
  - Decreased delay



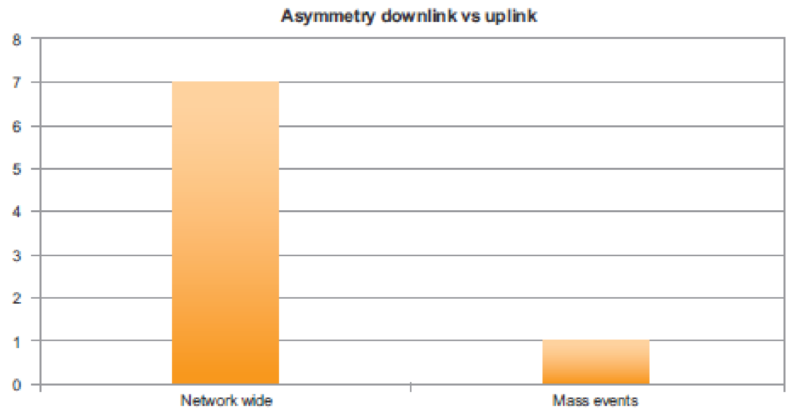
source: Efficient resource Utilization Improves the Customer Experience, White Paper, Nokia Siemens Networks, 2013

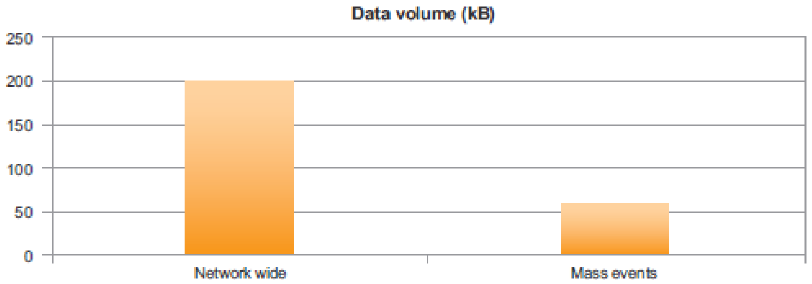
Liquid Net for Mass Events

- Traffic Profiles at Mass Events
- Liquid Net Measures

Traffic Profiles at Mass Events

Typical challenges at mass events:
- Large number of people using smart phones to share pictures
- This creates traffic profiles that differ from typical ones:
  - Higher uplink traffic
  - More frequent packet transmission



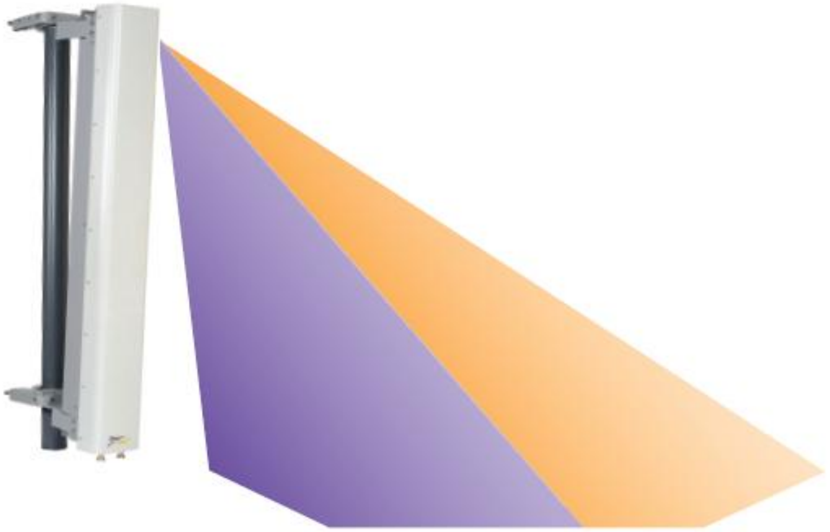


Examples:
- Huge sports event in UK: >25GB of data per hour
- Korean fireworks festival: >150GB of data per hour
- 6-day Hajj pilgrimage: >100TB

source: High Capacity Mobile Broadband for Mass Events, White Paper, Nokia Siemens Networks, 2013

Liquid Net Measures

- Appropriate parameterization
  - Cell parameters
  - Control channels
  - Signalling
- Increasing number of cells
  - Overlapping of cells increases interference
  - Careful cell planning recommended
  - Usage of active antennas for flexible beam steering, e.g., vertical sectorization
- Distributed Antenna Systems
- Smart Wi-Fi Capacity



source: High Capacity Mobile Broadband for Mass Events, White Paper, Nokia Siemens Networks, 2013

Conclusion

- High smart phone penetration
- Completely new user bahviour
  - High data traffic with small packages
  - High upload traffic at mass events
- There is not a single technical solution.
- A bundle of technical possibilities available

Intelligent & flexible application of all these solutions makes the radio network running.

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for a world in motion™