NGMN Evolution towards LTE-A Systems

Prof. Dr.-Ing. Bernhard Walke

Communication Networks Research Group
RWTH Aachen University, Germany

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The Problem of Cellular – in General: Cell Capacity vs. Distance is Inverse to the Needs

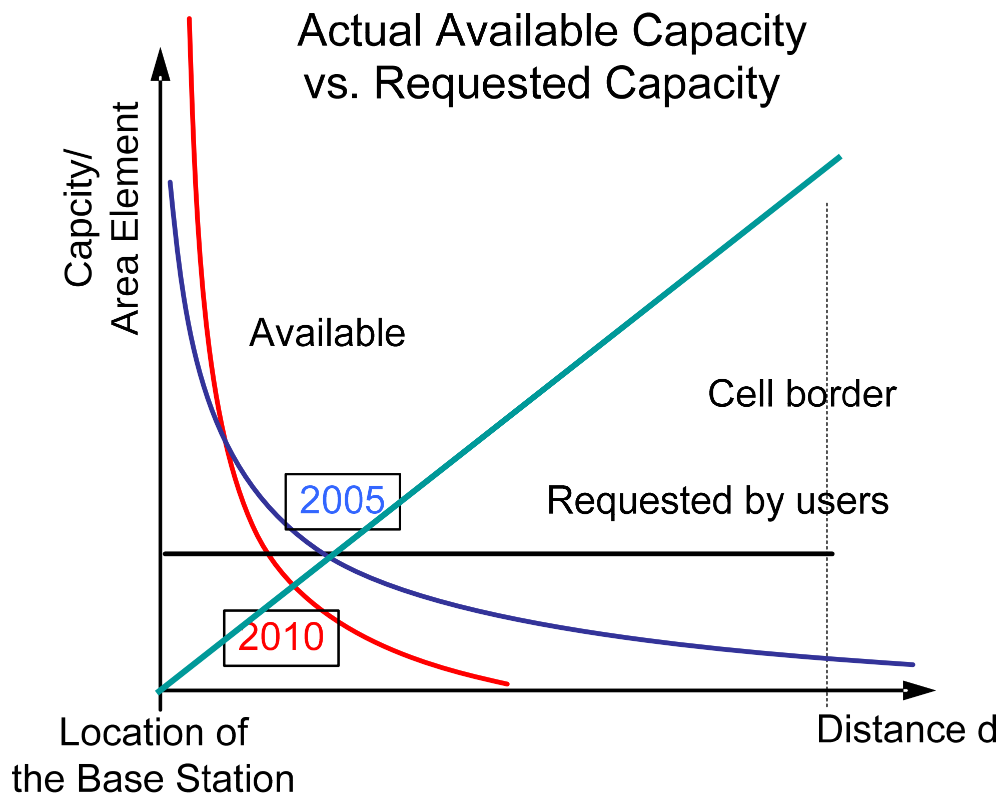
Range of broadband Base Station is limited by
- Attenuation and shadowing
- Transmit power (EIRP limits)

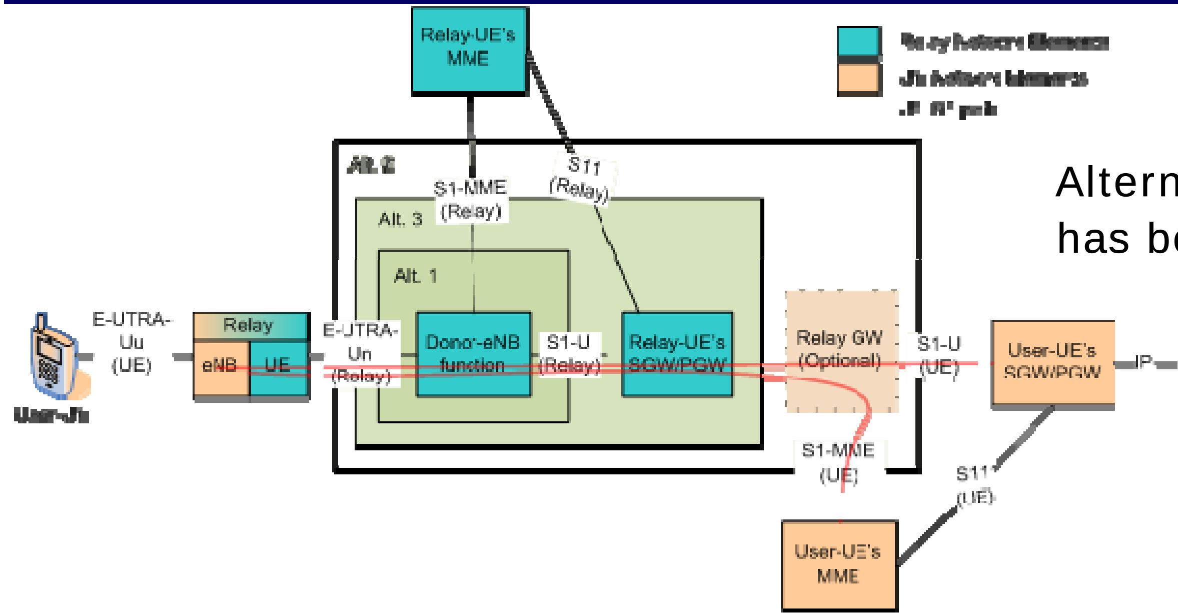
➔ The higher the carrier frequency, the higher the # of BS needed to cover a service area (-> high CAPEX / OPEX)

➔ High cost/bit transmitted

➔ Capacity per service area element is inverse to capacity requested by users

➔ Technology trend worsens situation, cp. 2005 vs. 2010

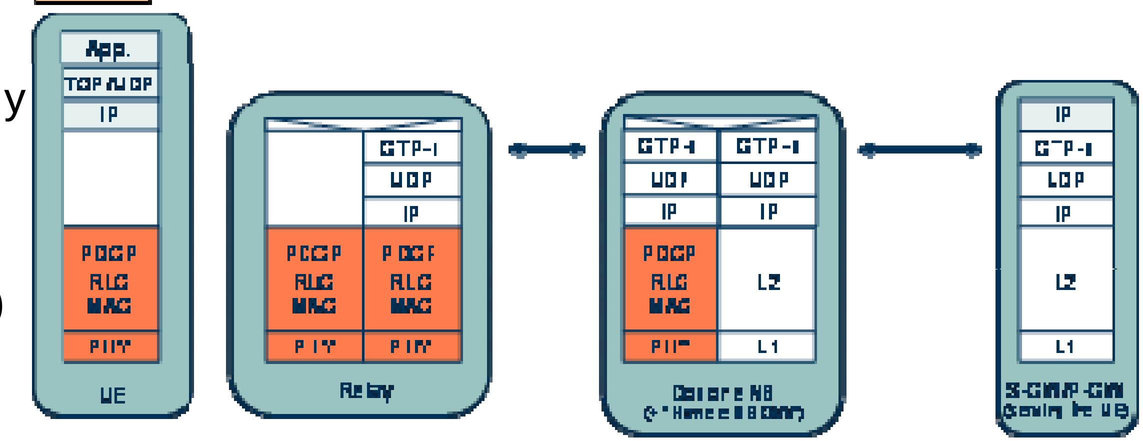




Alternative 2 of Architecture Family A has been chosen by 3GPP.

Relays in 3GPP are in layer 3. Both, eNB and UE functionality is contained in RN.

eNBs may operate in tandem as relays („eNB backhauling")



User plane protocol stack – Alt 2 -

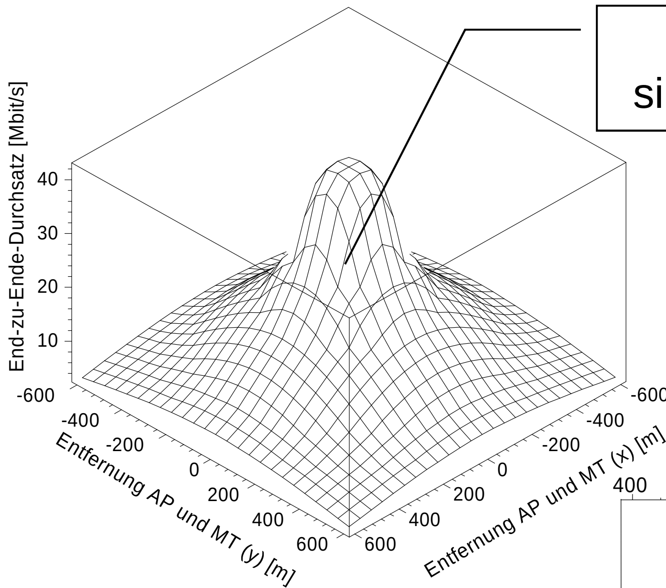
3GPP TR 36.806 V2.0.0 (2010-02) benutzt das 2003 von ComNets vorgeschlagene Konzept

B. Walke, R. Pabst, D. Schultz: ***A Mobile Broadband System based on Fixed Wireless Routers***. In *Proc. of ICCT 2003 International Conference on Communication Technology*, 04/2003, Beijing, China

Abstract—A new radio access network architecture for a mobile broadband system is introduced that uses Fixed Wireless Routers (FWR) to provide radio coverage to otherwise shadowed areas. ….

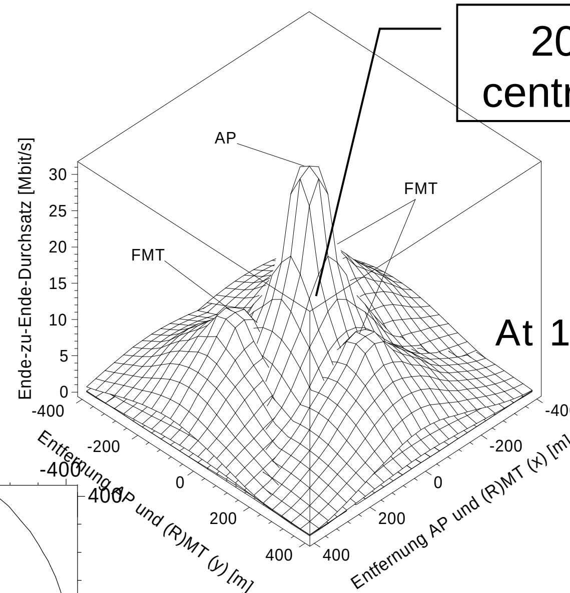
The so-called Wireless Media System (WMS) provides broadband access to terminals with medium velocity of movement and is embedded into a cellular radio network to support a high velocity of terminals with medium transmission rate. The low power used at the base stations leads to a pico-cellular concept relying essentially on multihop communication across FWRs. The new concept to achieve broadband radio coverage in dense populated areas is described and first analysis results of some crucial elements are presented.

Single-Hop and 2-hop Cell Throughput



346m
single hop cell

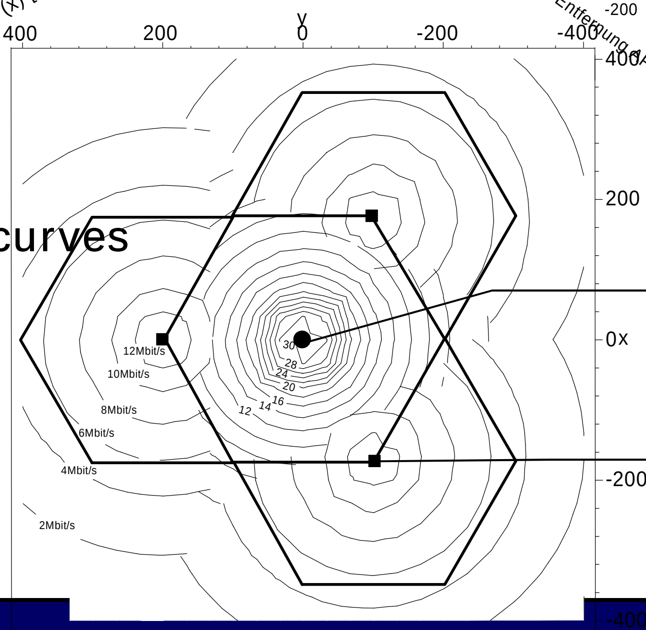
Area
=



200m
central cell

At 11,8 dbi

Iso-throughput curves

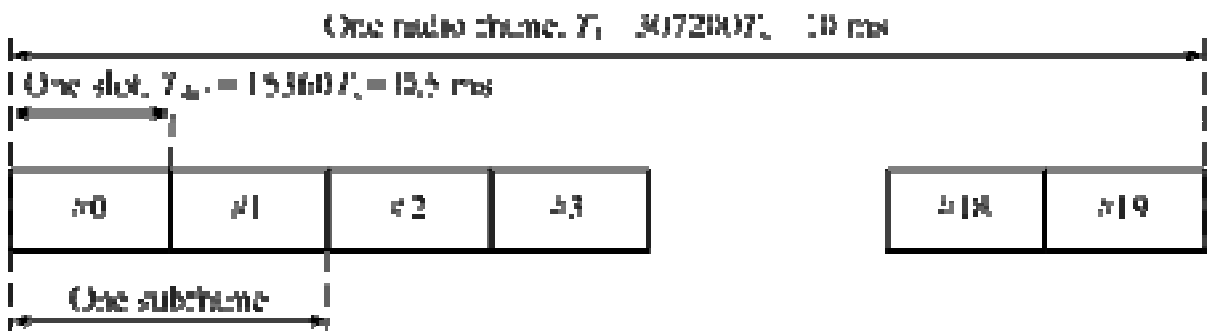


200m

200m

3GPP Basic Parameters

20 MHz bandwidth, 1 200 sub carriers, 100 RB in frequency domain.
Resource Block (RB): set of resource elements (RE) on 12 (subcarriers) *14 (OFDM) modulation symbols.
Time wise: one sub frame = 1/10th of a frame duration.
Frequency wise: 1/100th of the bandwidth.
64 QAM modulation (6 bit/symbol): 14 symbols/sub frame = 140 symbols/10 ms frame or 1000 sub frames/s.
Frame structure type 1: applicable to FDD. A radio frame is Tf=307200*Ts =10ms long and consists of 20 slots of length Tslot =1536*Ts =0,5 ms, numbered from 0 to 19.
Sub frame: 2 consecutive slots; subframe i consists of slots 2i and 2i+1.
For FDD, 10 sub frames for DL and 10 sub frames for UL transmissions in each 10 ms interval. UL and DL transmissions are separated in the frequency domain. Figure 4.1-1: Frame structure type 1.



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Innovation Areas to Reduce the Problem[1]

The following innovations are, preliminary, qualified as backward compatible to LTE, candidates for future standardisation in the LTE-A process, or topics for future research studies.

Resource Allocation: efficient, flexible scheduling & spectrum allocation.

OFDMA systems require optimum dynamic resource allocation algorithms that allows extending the opportunistic scheduling concept (i.e. the resource allocation scheme which exploits the multi-user diversity to enhance total system throughput) to all dimensions. Generally, there are five innovative concepts considered in WINNER+:

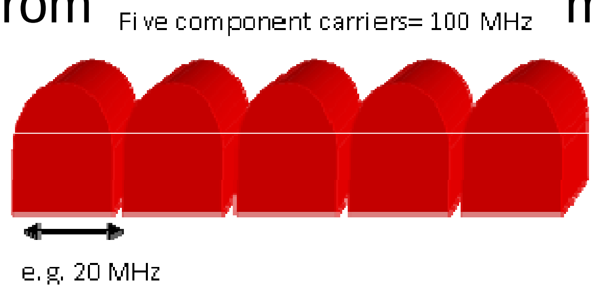
- QoS scheduling,
- coordinated MIMO scheduling,
- spectrum allocation techniques,
- traffic identification and load balancing,
- MBMS provisioning.

[1] **Final Innovation Report (public) CELTIC / CP5-026, Wireless World Initiative New Radio – WINNER+; 07.04.10D1.9.doc**

Innovation Areas, cont‘d

Carrier Aggregation (CA): supports higher peak data rates and copes with effects deriving from fragmented spectrum ownership of operators.

Example of contiguous intra-band carrier aggregation [W D2.2]



Different spectra are being used synchronously by means of CA. Support for scalable bandwidth up to and including 40 MHz is required.

a. Contiguous spectrum aggregation
b. Single-band size non-contiguous spectrum aggregation
c. Multiple-band sizes non-contiguous spectrum aggregation (most complex)

• Significant advantage of non-contiguous over contiguous CA, but increased hardware complexity.

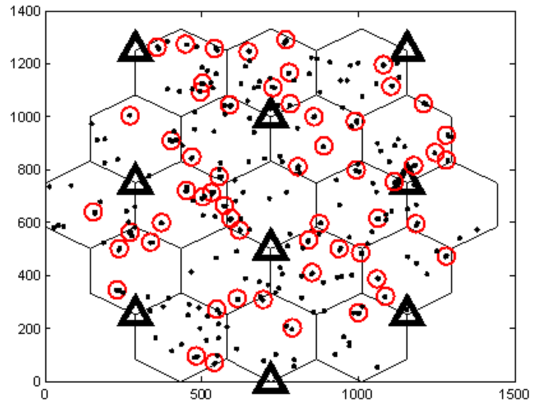
Innovation Areas, cont'd

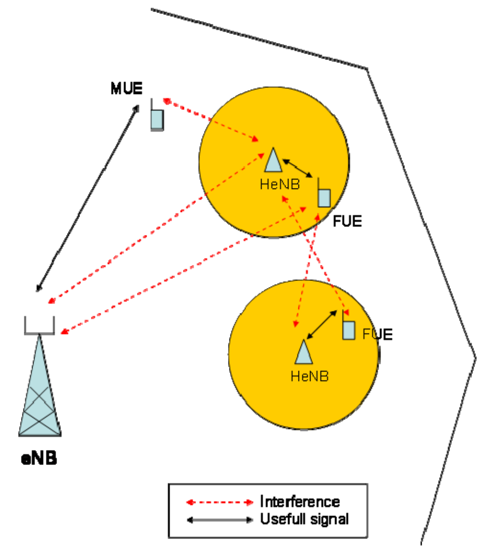
Femtocells (with and without interference coordination)

A femtocell is self-organized operated (indoors) inside a sector of a donor (outdoor) cell, re-using its radio resources to connect adjacent UEs via DSL line to the core network.

Left:

Example of randomly deployed femto cells (red circles) [WIN+ D2.2]





Right:

The interference problem with femto cells [WIN+ D 2.2] H=Home, F=Femto, M=Macro

For reducing mutual interference, interference coordination by scheduling of radio resources of the donor (macro) cell to be used by a femto cell is proposed (reducing capacity of the donor cell).

Femtocells behave like multi-hop relays operated out of band (no radio resources used to connect a femto cell to the core network, but inband mutual interference to base station.

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Innovation Areas, cont'd

Multi-hop Relays in 3GPP LTE Rel. 10 (LTE-A)

- are placed throughout the macro cell deployment.
- operate at layer 3 and contain a certain amount of intelligence.
- span up their own cell, transmitting their own cell ID & reference signals
- rely on a wireless backhaul to forward user data to a given donor eNB
- behave transparently to the UEs thus making it easy to ensure backwards compatibility.
- improve (if backhaul links are operated with antenna gains at significantly higher SNRs)
    - the coverage of high data rates at low cost.
    - cell-edge throughput.
    - group mobility, e.g., of UEs in trains.
    - temporary network deployment.

Relays, in view of

- the NGMN group are an interesting option in achieving a more targeted and homogeneous distribution of signal energy in the field.
- infrastructure manufacturers are temporal network elements to be replaced by base stations when the load evolves in a cellular network.

Innovation Areas, cont'd

Interference between relay node (RNs) and serving base station (BS) in cellular networks is avoided when applying resource partitioning, where radio resources are, **exclusively**, assigned to BS and RNs.

Intra-cell IF in LTE-A is avoided owing to othogonal resources used. Inter-cell IF is the critical component to overcome and minimize.

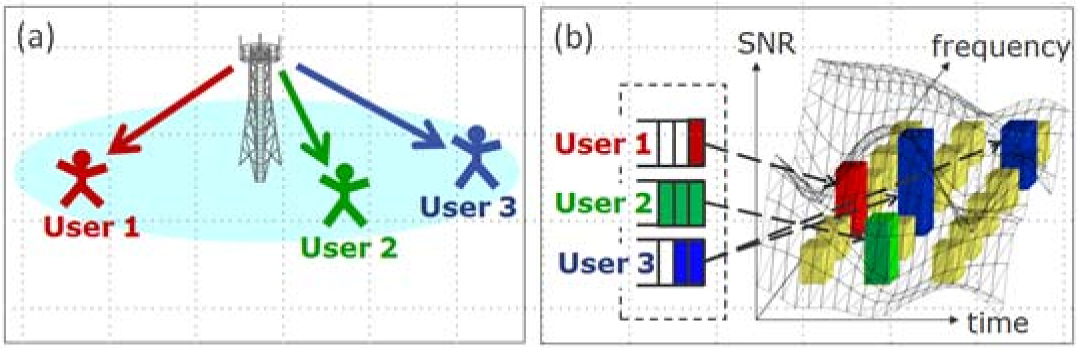
Measures to reduce inter-cell IF are:

- Scheduling of radio resources across adjacent cells (applying CoMP).
- Cooperative relaying - combined with MU-MIMO.
- Distributed space time coding.
- Distributed FEC coding.

Relays introduce more complexity to the system architecture of a cellular network.

Innovation Areas cont‘d

- **Multi-User Multiple-Input-Multiple-Output** systems (esp. Channel State Information (CSI) acquisition; optimisation possible without standardisation).
- **Quality of Service (QoS) control** (efficient scheduling, cross-layer design).



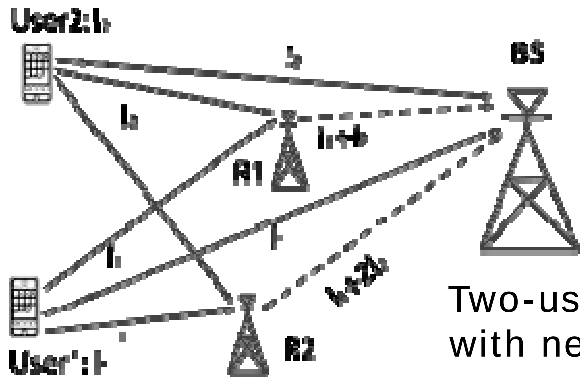
OFDMA multi-user resource allocation with QoS constraints. An eNB serving multiple users (a) assignes user data with various QoS requirements to resources in time and frequency taking into account the channel conditions. [WINNER+ D2.2]

I_1
I_2
$I_1 + I_2$ and

Innovation Areas cont‘d

- **Network Coding** (may provide a diversity order of 3, but major signalling and architecture changes to the network are required).

The method consists of using non-binary network codes on top of channel codes to rebuild source information from the minimum possible set of coded blocks. In this sense, the network codes achieve the min-cut capacity for mobile or fixed relaying networks, which have the dynamic topology due to block erasures in channels.



Two-user two-relay networks
with network coding. [WINNER+ D2.2]

The “+” operations are conducted in the finite Galois field GF(4). Thus, it will not cause any more bandwidth or extra power consumption. The relaying and local messages are encoded by network codes in the relay. The network codes are designed such that any two successfully received blocks out of four transmission blocks can rebuild two source message blocks. In the 1. time slot, the two source nodes use channel coding to transmit their own messages in different frequency-orthogonal channels. In the 2. time slot, if both relay nodes succeed to decode the channel codes, the transmitted messages for user 1 and user 2 are encoded, respectively.

Innovation Areas cont'd

- Spectral efficiency with 3GPP LTE R8 will be about 1,6 bps/Hz.
- Shannon: C = M * B * log2 (1 + SINR)
  (B= Bandwidth, M = number of transmission channels in B)
- Current MIMO schemes in LTE R8 support up to M=4 layers in B=20 MHz (layer = data stream, spatially separated from others).
- In R 10 (LTE-A) this will be extended to M=8 on DL, partly by increasing B through carrier aggregation (from 20 MHz up to 100 MHz), partly by introducing CoMP – the most complex new feature.
- Owing to high traffic asymmetry of DL:UL = 9:1 most interest is in DL capacity increase.

Innovation Areas cont‘d

Coordinated Multipoint (CoMP)

CoMP: new family of features, based on the common idea of introducing coordination schemes for radio transmission/reception.

CoMP targets on interference (SINR) reduction in cellular networks, thereby increasing capacity, see Shannon law, above.

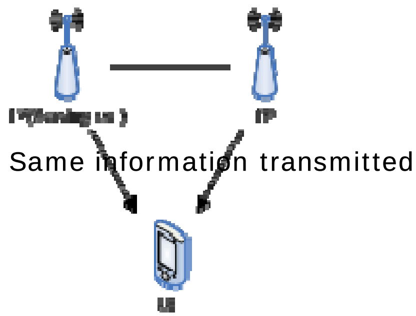
SINR = intra-cell IF + inter-cell IF + thermal noise

Intra-cell IF in LTE is avoided thanks to OFDM orthogonality
Inter-cell IF is the critical component to overcome and minimize.

Innovation Areas cont'd: CoMP has two approaches:

1. Joint Processing (JP): data is available at each of the geometrically separated points, involved, and PDCH transmission occurs from multiple points.

Cooperation of spatially separated transceivers improves SINR as seen at the receiving terminal (UE or eNB).



Theoretical radio performance figures for CoMP-JP show potential capacity gains of 82%, experiences in real deployments show about 27% gain.

JP introduces very complex requirements to the network:

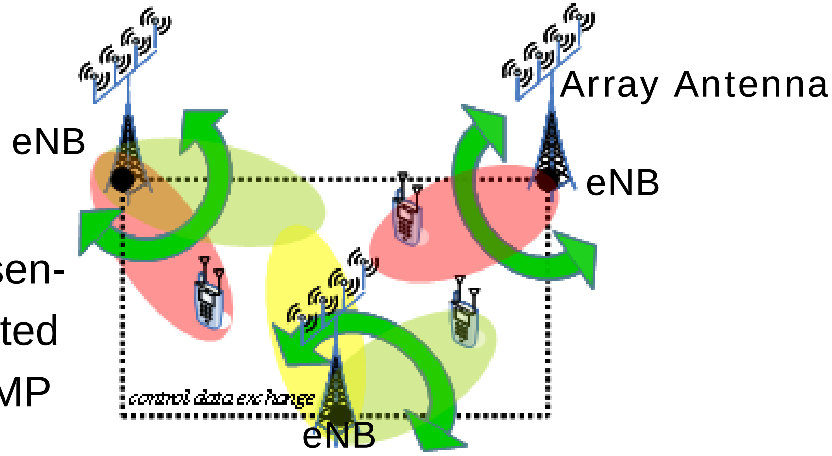
- Tight timing synchronisation of eNBs,
- low backhaul latencies in the order of milliseconds and
- high backhaul capacity to exchange data via X2 interface

are the most critical factors, for which it is unlikely that operators will implement JP across sites in the near future.

Innovation Areas cont'd: CoMP has two approaches:

2. Coordinated Scheduling/Beamforming (CS/BF): data is only available at serving cell (data transmission from that point) but user scheduling/beamforming decisions are made with coordination among cells.

Schematic representation of coordinated beamforming CoMP



Cooperation of eNBs is based on sole information exchange rather than real user data exchange; therefore CS/BF is likely to find ist way into real networks, first.

CS/BF appears a promising next step for further advancements in improved interference cancellation.

Simulation results for radio performance figures of CS/BF show potential capacity gains of 55%, experiences in real deployments show about 25% gain.

Conclusions

LTE-A (Rel.10) will be the most complex mobile radio technology ever seen.

Main features:

- OFDMA and MIMO/beamforming transmission on frequency channels of bandwidth of n*20 MHz.
- Relay Nodes (Fixed Wireless Routers) will be used to increase cell edge capacity.
- Coordinated scheduling of beams of adjacent eNBs (will be introduced, soo)
- Joint processing (may not be introduced, soon).
- New technologies like network coding and CoMP have very high complexity and cost, which may delay introduction.
- Spectral efficiency target of LTE-A is 3,4 bps/Hz under certain conditions.

Other facts:

- Physical layer overhead is about 45% in FDD operation for typical load scenarios.
- Protocol overhead may be 30% or more, resulting in overall efficiency of <40% of the spectral efficiency target, namely 1,1 bps/Hz.

Mobile broadband networks cannot keep pace with the growth of Internet traffic that doubles about every 2-3 years.

quo vadis retis communicationa

Bernhard Walke, ComNets

Statements

LTE-A (Rel.10) will be the most complex mobile radio technology ever seen.

Relay Nodes (Fixed Wireless Routers) will be used to increase cell edge capacity.

Coordinated scheduling of beams of adjacent eNBs will be introduced, soon.

New technologies like network coding and Coordinated Multipoint transmission (CoMP) have very high complexity and cost, which may delay introduction.

Spectral efficiency target of LTE-A is 3,4 bps/Hz, but taking signaling and protocol overhead into account, efficiency will remain close to 1 bps/Hz.

Mobile broadband networks operating in licensed freqency spectrum have much difficulty to keep pace with the exponential growth of Internet traffic. High density deployment of eNBs and much more spectrum will be necessary for this (at much higher cost).

There is a great opportunity for IEEE 802 based wireless broadband systems operated in license exempt bands.

Overlay and coexistence techniques will enter the market.