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Initial thoughts on LTE Advanced for 3GPP Release 10

Eiko Seidel, CTO

LTE World Summit, Berlin, May 19th 2009

Background

- Industry: IT Telecommunication
- Headquarter: Munich, Germany
- Founded: September 2004

- Worldwide business, profitable from day one

- Spin off from Munich University of Technology
  - First real-time simulations GPRS/UMTS for Siemens in 1999
  - Strategic collaboration Nokia Siemens Networks

- Business areas
  - Consulting – LTE research, prototyping, simulation, standardisation
  - Product – LTE eNB protocol stack development and emulation

- Staff
  - 20 highly qualified engineers at office in Munich, Germany
  - Development resources in Pakistan and China

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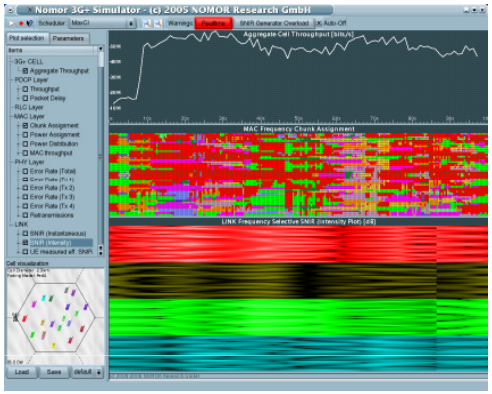
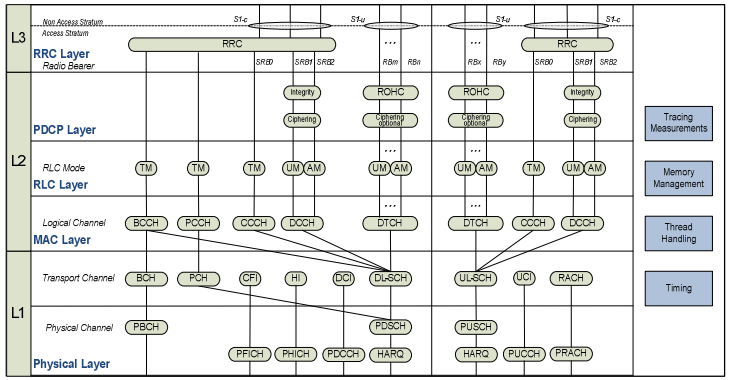
Examples LTE development

World First Live LTE Demo (2006)
Collaboration Siemens Networks

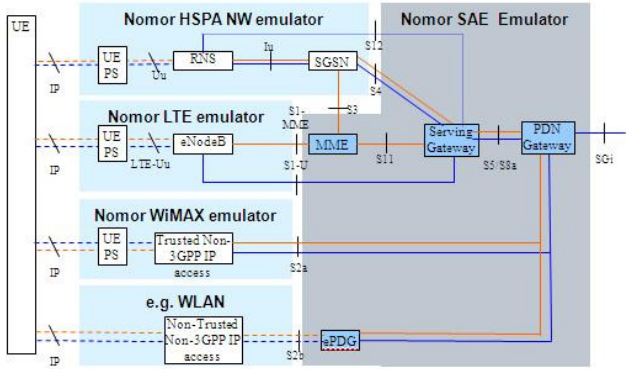
Advanced Mobile Radio Emulator LTE/LTE-A
Collaboration Nokia Siemens Networks



LTE eNB Protocol Stack
Licensing, first customer 2008



Multi-radio access testbed
First inter-RAT handover 2009



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Outline

- Background 4G and ITU-R
- LTE Advanced Standardisation
- LTE Advanced Technologies
  - Carrier aggregation
  - MIMO technologies
  - Cooperative base stations
  - Relaying

What is 4G really?

LTE ?

WiMAX ?

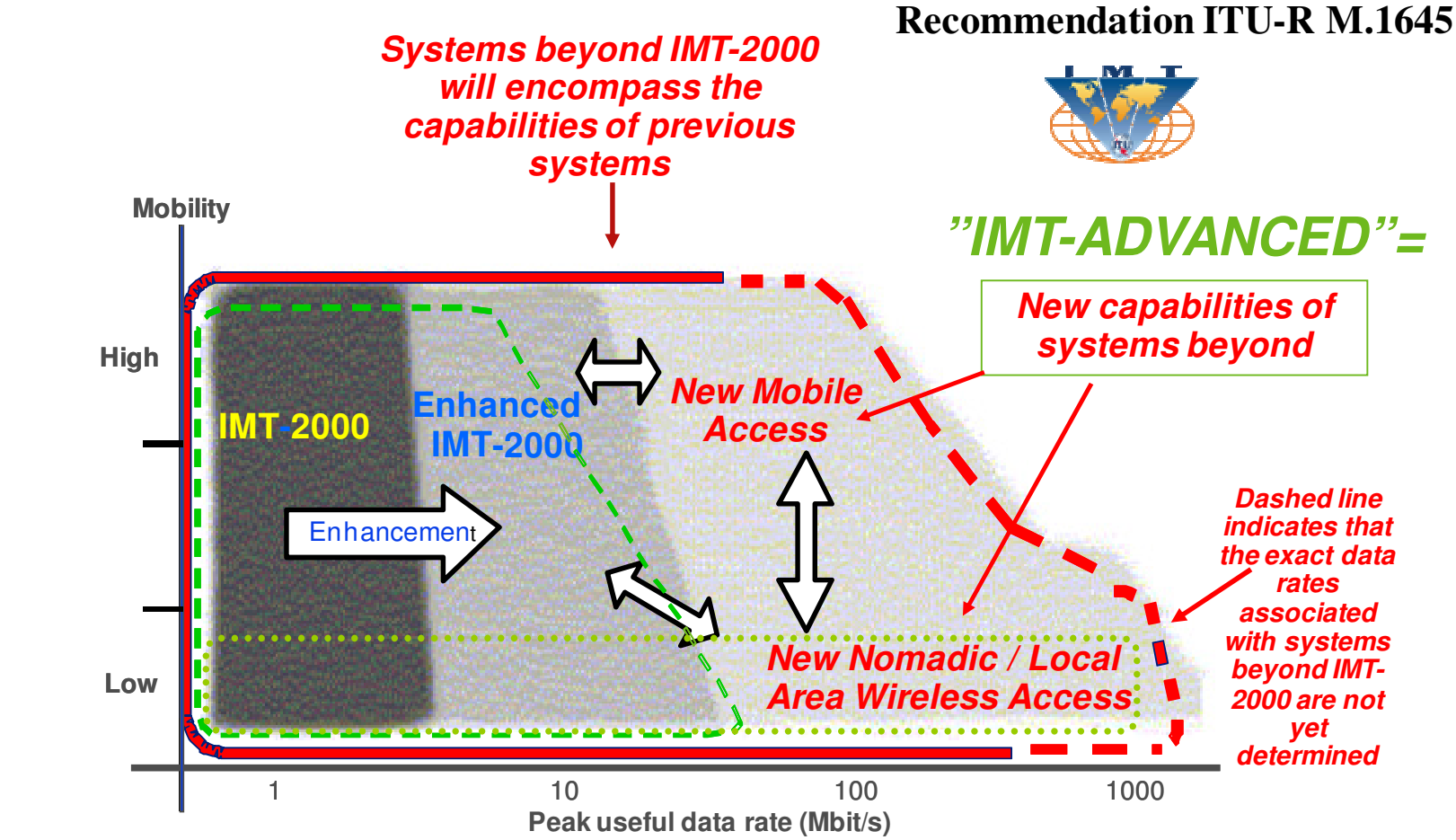
?

ITU-R Standardization

- ITU = International Telecommunication Union
- ITU-R = ITU – Radio Communication Sector

- Mission:
  - ensure interference free operations of radio communication systems by means of radio regulations and regional agreements
    (Interference requirements, global harmonization)
  - radio standardization establishes ‘Recommendations’ intended to assure the necessary performance and quality
    (High level performance requirements!)
  - examination of frequency assignment notices submitted by administrations for inclusion in the formal coordination procedures **(Frequency assignments!)**

IMT2000-3G and IMT Advanced-4G



ITU-R Work on 4G (IMT Advanced)

- ITU-R Foundation Activities Have Led The Way:
  - "Vision" work for *IMT-Advanced* began in 2000
  - "Spectrum" work for *IMT-Advanced* began in 2003
  - "Process" work for *IMT-Advanced* began in 2006
- ITU-R Future Spectrum Decisions Are Important Aspect:
  - World Radio Conference (WRC-07) took decisions in November 2007 impacting 3G and beyond 3G (that is *IMT-2000*, *IMT-Advanced* and/or collectively – "*IMT")*
- ITU-R issued a Circular Letter to invite submission of candidate Radio Access Technologies. Furthermore IMT Advanced baseline requirements have been agreed by ITU-R WP5 in 2008
- ITU-R and Industry is partnering in the next steps:
  - "Technology" work for *IMT-Advanced* began end of 2008
- After proposal evaluation the ITU-R Technology Specification Recommendations on IMT-Advanced is expected year end 2010

Important Decisions at WRC'07

- IMT-2000 was changed to IMT (IMT = IMT-2000 and IMT-Advanced)
- In total around 400 MHz identified to IMT
- Out of this 136 MHz that was globally allocated to IMT
  - *Bands; 450-470 MHz, 790-806 MHz, 2300-2400 MHz*
- Additional low frequency bands for wide area coverage
  - *UHF Bands 698-790 MHz, 790-806 MHz, 806-862 MHz*
  - *Attractive to operators for coverage extentions*
- 3400-3600 MHz band allocated to mobile service in some countries in all the three Regions
  - *Band will be allocated to UMTS/LTE pretty soon*
  - *3GPP will start working on specification*
  - *Attractive for operators to improve broadband data rates with small size cells and low mobility users*
- 3600-3800 MHz is identified as a possible additional or alternative frequency band, might get available from 2012

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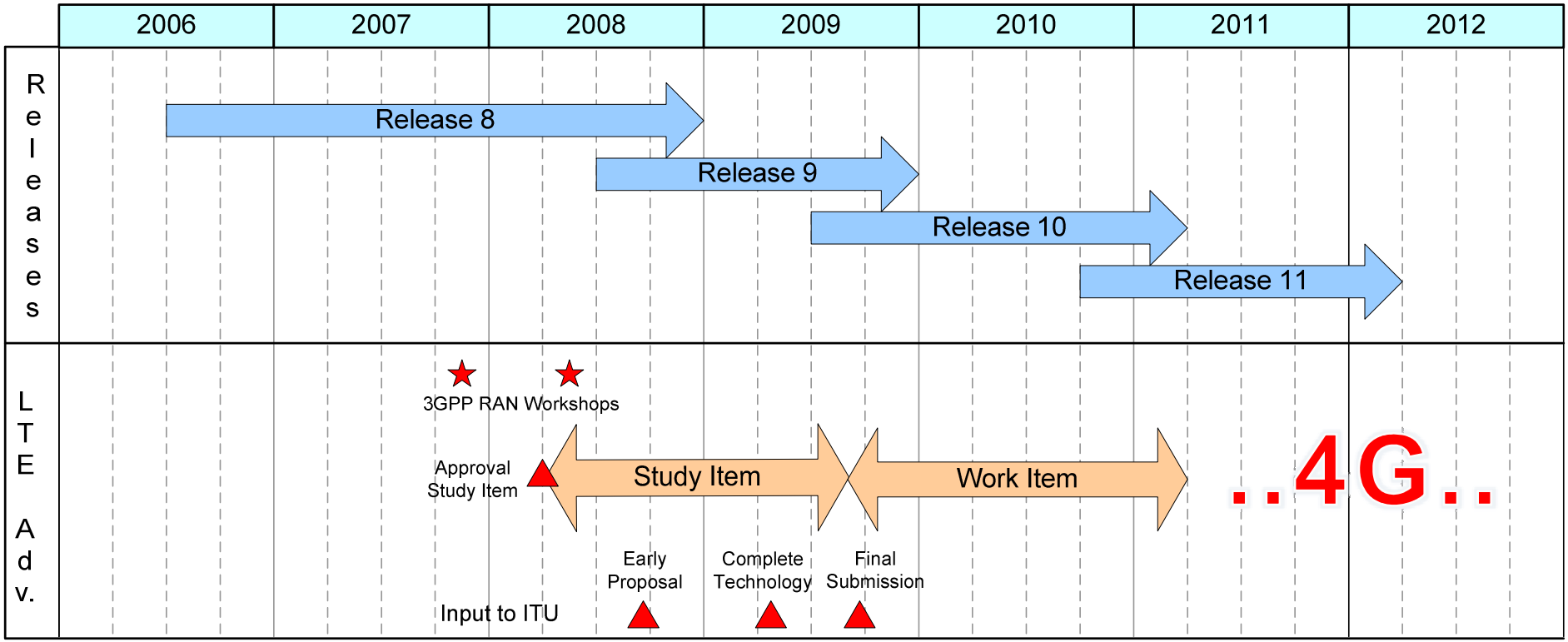
LTE Advanced Standardisation and Requirements

3GPP Schedule towards 4G



- Harmonized schedule between 3GPP and ITU
- LTE Release 9 = minor improvements
- LTE Release 10 = major changes for LTE Advanced

State of standardization of LTE Advanced

- Work on requirements is completed
  - LTE requirements are the baseline
  - TS36.913 Requirements for Advancements for E-UTRA
  - 3GPP inputs requirements to ITU
- New technical report was endorsed as Version 1.0.0
  - TR 36.814 Further Advancements for E-UTRA Physical Layer
  - First submission to ITU in June, final submission Sept. 2009
- Evaluation methodology agreed
- First principle technical decisions have been taken
- Radio Access Network working groups, mainly Physical Layer, continuously spend time on LTE Advanced

3GPP LTE-A Requirements

- LTE-A must support the requirements of IMT-Advanced and shall have same or better performance then LTE
- Peak data rate (peak spectrum efficiency)
  - Downlink: 1 Gbps, Uplink: 500 Mbps
- No specific targets for cell edge user throughput, average user throughput or capacity (spectrum efficiency) have been defined
- Peak spectrum efficiency
  - Downlink: 30 bps/Hz, Uplink: 15 bps/Hz
- Somewhat higher requirement for C-plane latency
- Same requirements as LTE for mobility, coverage, U-plane latency, synchronization, spectrum flexibility etc.

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LTE Advanced Technology Proposals

Can we be more radio efficient?

- LTE is a well designed very advanced system
- Radio functions are very fast, fully adaptive
- Access scheme OFDMA/SC-FDMA
  - No Intracell Interference in uplink and downlink
  - Scheduler exploits channel in time and frequency
- MIMO antenna technology
  - Exploits diversity, beam forming and spatial multiplexing gain
- Shared channel gives instantaneous access to high rate
- Very high number of “always on” users
- Link performance operates close to the Shannon limit

➔ **No major technology breakthrough foreseen yet**

➔ **LTE Advanced will be a Evolution**

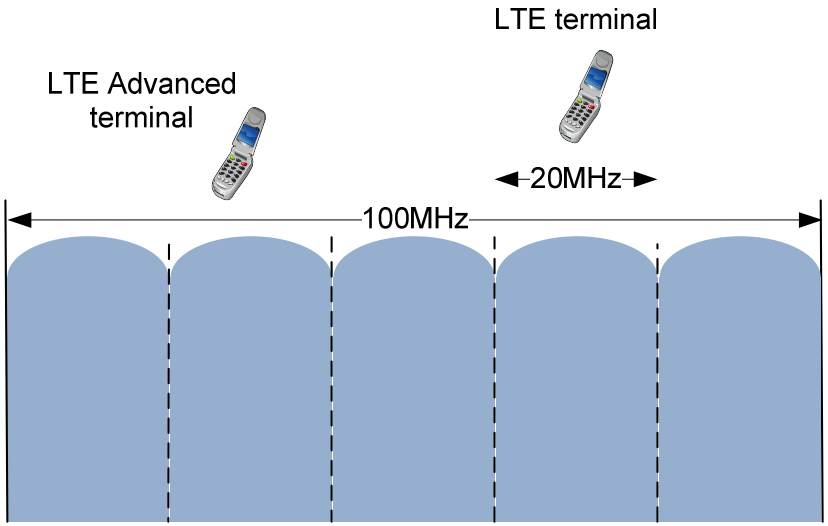
➔ **Improving SINR in cellular system can be the only driver**

Technology Proposals

- Bandwidth Aggregation
- MIMO Enhancements
- Cooperative Multi-site Transmission
- Relays and Repeater

Scalable bandwidth/carrier aggregation

- OFDM provides means to increase bandwidth
- Backwards compatibility must be ensured
- Scheduler must consider a mix of terminals
- Used bandwidth might not be contiguous



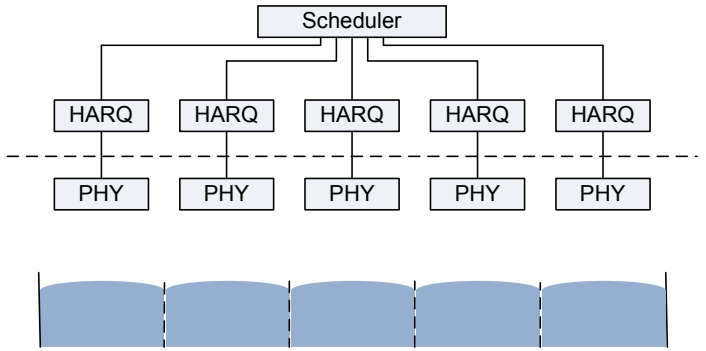
Challenges for 100 MHz terminal

- Potential of commercial-level RF filter
  - Effective bandwidth range
- Potential of commercial-level ADC
  - Sampling rate and quantization resolution
- Decoding complexity
  - Channel decoding and soft buffer size

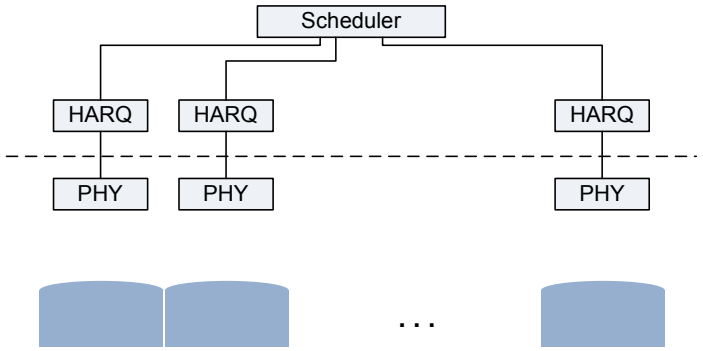
Multi-carrier operation

- Resource Allocation, MIMO, Link Adaptation, HARQ etc will be performed per carrier
  - ➔ Minimum changes are required for the system
  - ➔ Improved performance (better link adaptation and HARQ)
- No changes to higher layer protocols are required
- Scheduler needs to operate across the whole band

Contiguous alloation

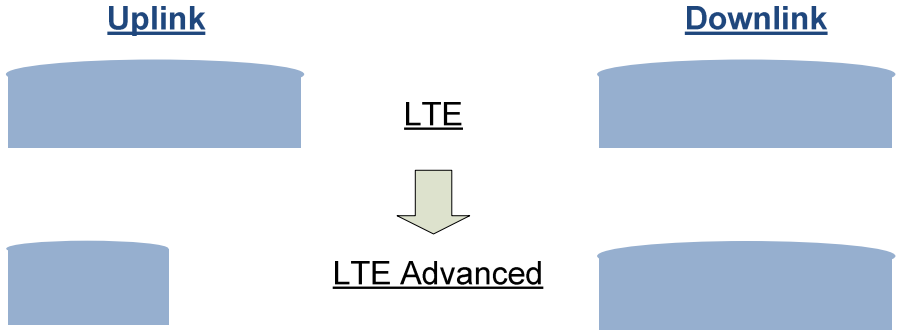


Non contiguous allocation

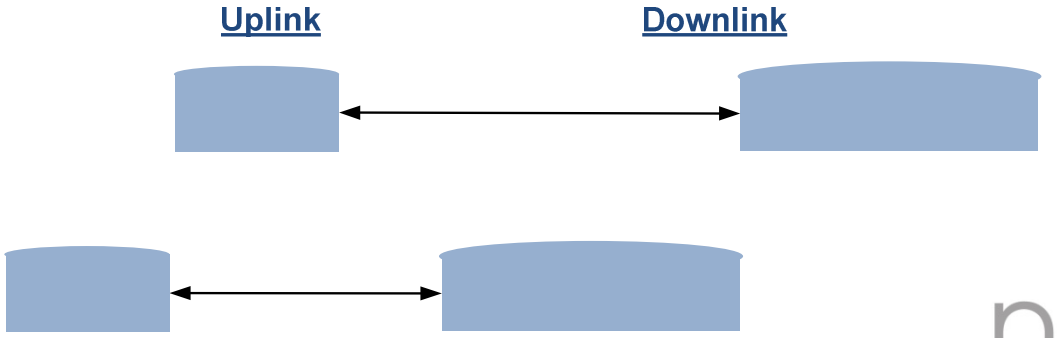


Bandwidth allocation

- Asymmetric bandwidth allocation
  - Traffic is still asymmetric between DL & UL
  - Paired spectrum might not be symmetric



- Flexible duplex distance
  - Additional signalling on the broadcast channel required



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MIMO enhancements

Improved MIMO transmission

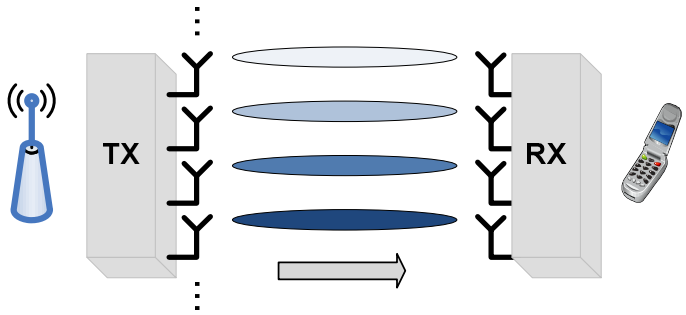
- Gain for additional diversity becomes smaller
  - Anyway not always wanted e.g. frequency selective scheduling
- Gain from spatial multiplexing only is questionable
  - limited to hotspot and indoor environments (small cells, scattered propagation environment, very low user mobility)
  - Still the only way to achieve the very high peak data rates
- Spatial multiplexing in general needs high SNR regions

➔ Use of beam forming combined with spatial multiplexing within different beams could be most beneficial

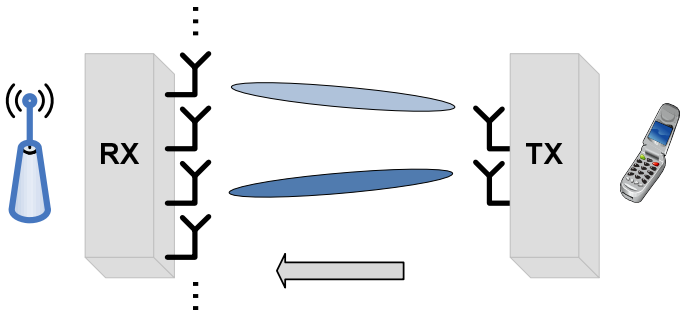
MIMO Enhancements for LTE-Advanced

- Downlink MIMO transmission
  - 4 UE receive antennas and 4x4 MIMO could become baseline
  - Downlink peak data rates achieved by the use of 8x8 MIMO (reference signals for 8 antennas required)
- Uplink MIMO transmission
  - 2 UE transmit antennas and 2x2 MIMO could become baseline
  - Uplink peak data rates achieved by the use of 4x4 MIMO
- Increase peak data rate, but also coverage and capacity

Downlink transmission



Uplink transmission



Coordinated multi-point transmission (CoMP)

Inter-cell interference

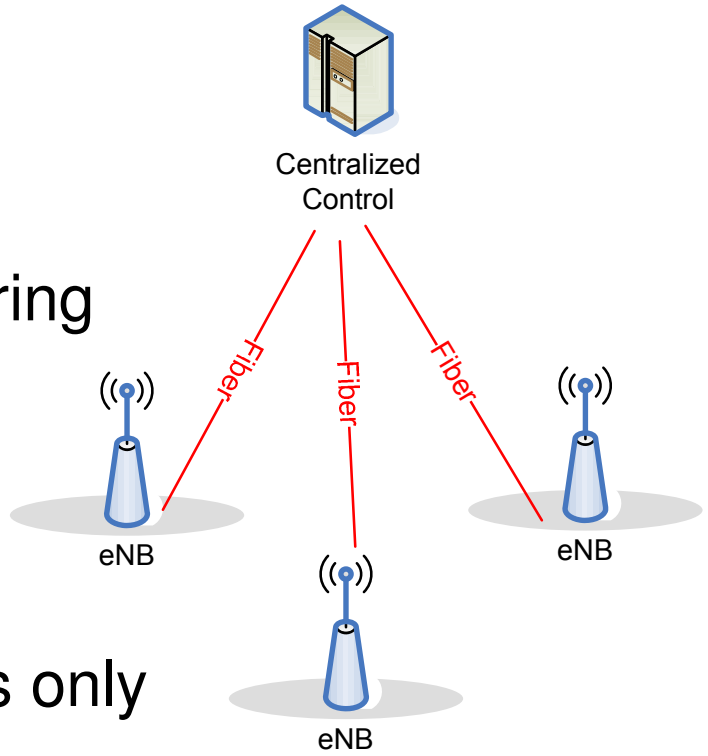
- Full frequency re-use is beneficial, but difficult to handle
- Slow Interference coordination is already supported

Orthogonality		UMTS	LTE	LTE-A
Orthogonal Intra-cell	DL	Yes, partly	Yes	Yes
	UL	No	Yes	Yes
Orthogonal Inter-cell	DL	No	No	Yes, partly?
	UL	No	No	Yes, partly?

- Inter-cell interference is key to increase system capacity
- In case fast eNB connections are available (e.g. fiber) fast coordination is no fairy tale anymore
- Control might be centralized (RNC like) or not

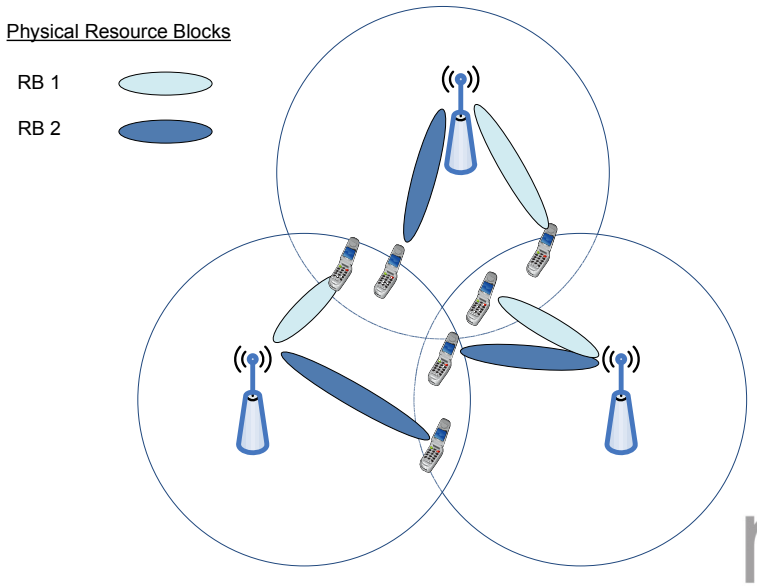
Cooperative base stations

- Different technologies are possible
  - Coordination of scheduling
  - Multi-site beam forming
  - Information exchange for inter cell interference cancellation
- Different level of information sharing (no, partial and full availability)
  - Data availability
  - Channel knowledge
  - Scheduling decisions
- Might be used for cell edge users only



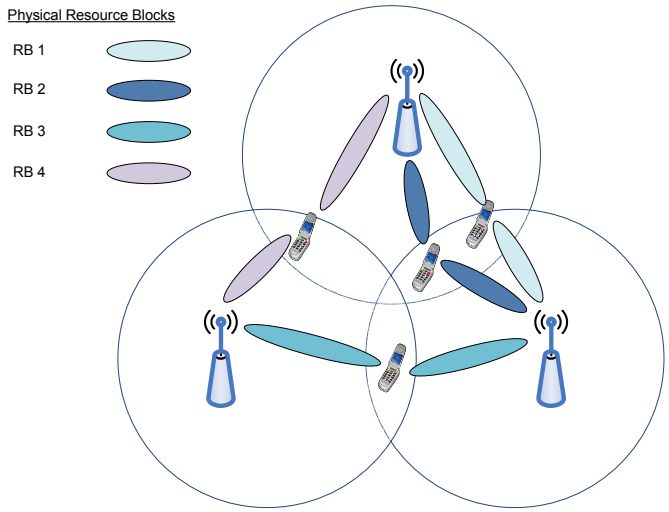
Coordinated Multi-site Beam Forming

- **Interference reduction** by **coordinated scheduling**
- Enhance the signal quality particularly of cell-edge UE
- Reduces interference caused to/by other UEs
  ➔ Coordination considering Direction of Arrival
- No impact on radio standardization, just X2 interface
- Some added load on backhaul (forwarding of signalling)



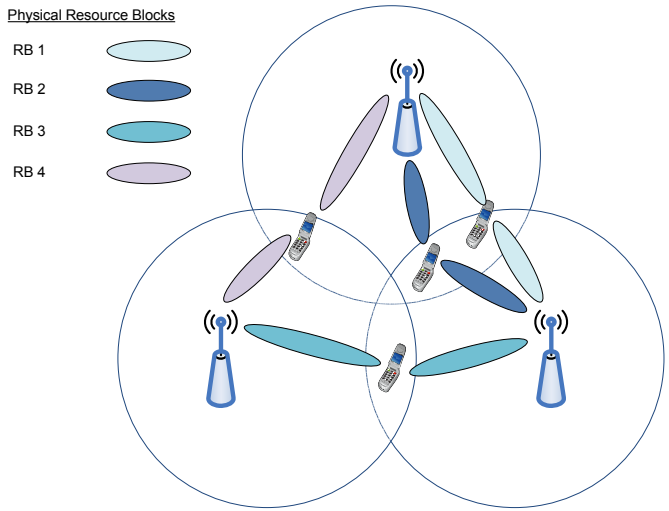
Combined Multi-site Beam Forming

- **Signal strengthening** by **joint transmission**
- eNBs jointly schedule data to the UEs using different weights
- Increase of backhaul load (data forwarding), but beneficial over air
- UE specific reference signals must be used
  - Same ID from different eNBs possible
  - Reporting of a joint channel state possible
- UE might actually be unaware of network cooperation



Multi-cell MIMO

- **Increased throughput** by **spatial multiplexing** from multiple sites
- eNBs use same resource to same UEs, transmitting multiple streams
- Independent channels ➔ less co-channel interference
  - Better cell edge performance (higher data rates possible)
  - Can be used in UL and DL
- Increased signalling overhead due to required feedback information
- UE synchronization to more than one cell and synchronized network is required



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Relaying

Introduction Repeater

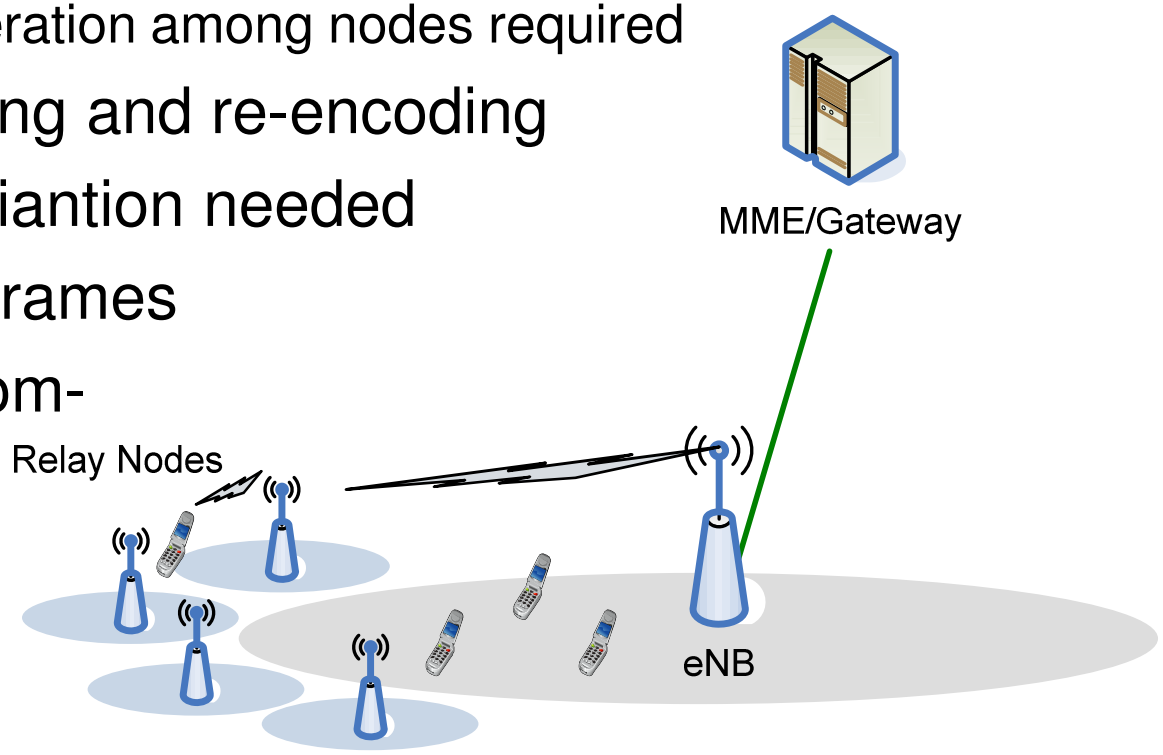
- Coverage problem increases for high spectrum
- Significant capacity increase can only be archived be smaller cell sizes

Introduction repeater (layer 0/1 relay)

- Used for coverage extension or cover isolated areas
- Amplify-and-forward devices based on analog signal
  - Desired signal can not be separated
    ➔ interference and noise is amplified as well
  - Immediate forwarding is done (within the CP length)
    ➔ Neglectable delay, looks like multipath
  - Strong RF isolation required to minimize the leakage
    (larger device size, higher hardware and installation cost)
  - Repeater gain is at least limited by the RF isolation
- “Smart” repeater use power control or self cancellation
- Alternatively signal can be forwarded at other frequency

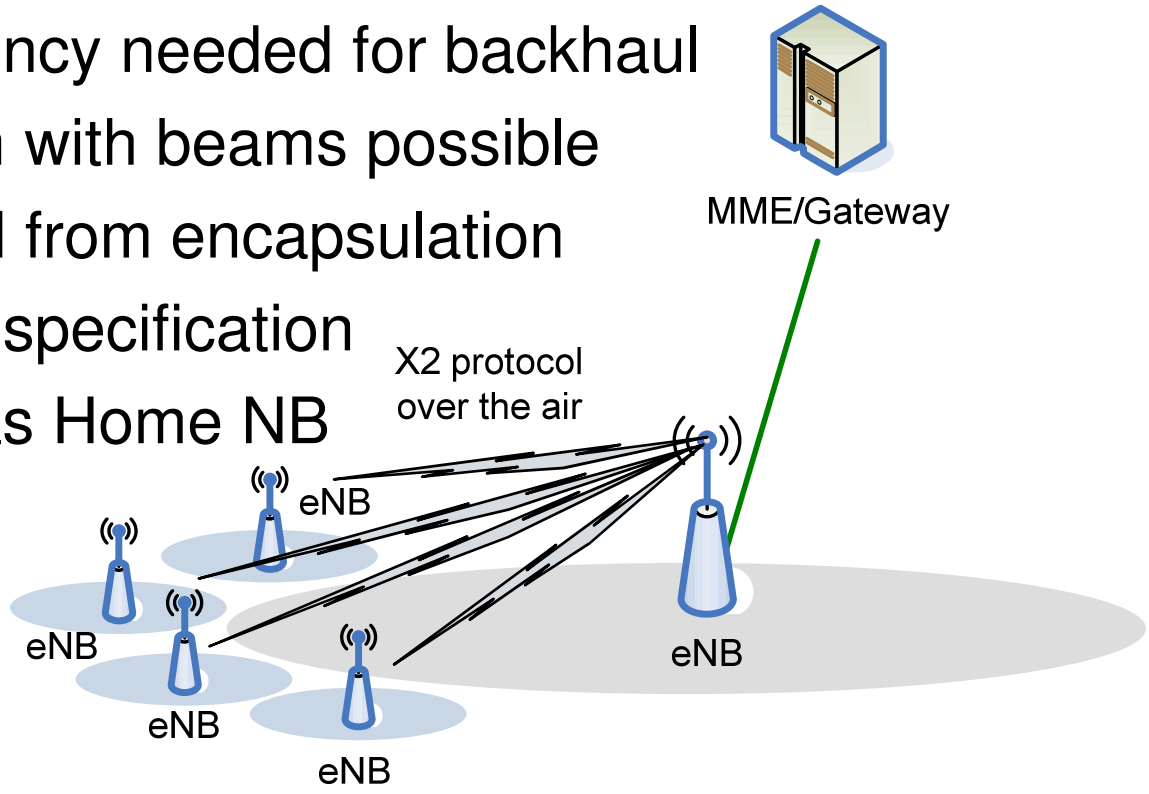
Decode and Forward (layer 2 relay)

- Relay Nodes (RN) are introduced at cell edge
- Rx and Tx times require some multiplexing
  - Time Division or Frequency Division Duplex
  - coordination/cooperation among nodes required
- Decoding, scheduling and re-encoding
- Interference co-ordiantion needed
- Delay of a few subframes
- Clear advantage compared to layer 1 repeater must still be seen



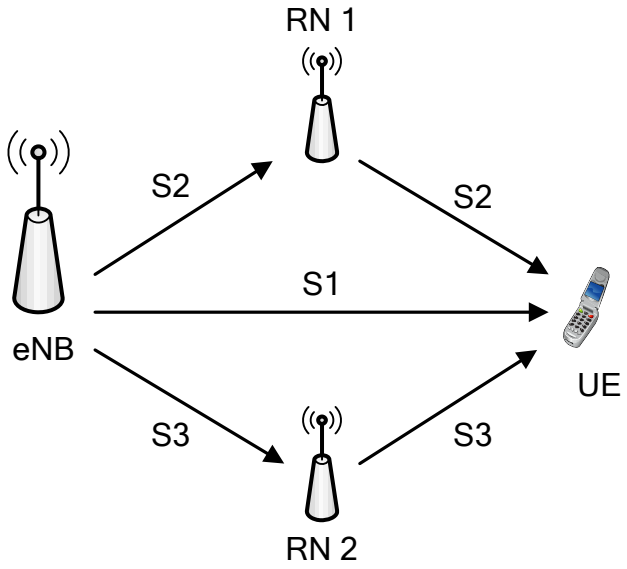
Self Backhauling (layer 3 relay)

- No new nodes defined, but new cells are created
- Backhaul via LTE technology; X2 protocol reused or S1
- Same or different spectrum could be used
- High spectral efficiency needed for backhaul
- Spatial coordination with beams possible
- Signalling overhead from encapsulation
- No need to change specification
- Relay as complex as Home NB
- Only solution for group mobility scenario



Cooperative Relaying

- Allows soft combining of several path
- Works simple with L1 relay that just forwards the data
- Tight coordination required if used with L2 or L3 relaying
  - Delay of S1 would be required compare to S2 and S3



Conclusion

- “LTE Advanced” = IMT Advanced = 4G
  - Data rates up to 1Gbps in stationary scenarios
  - Coverage enhancements for high frequency bands
- LTE Advanced will be a smooth evolution of LTE
  - Numerology and access technologies will be the same
- Bandwidth up to 100MHz supported
  - Contiguous and non-contiguous carrier aggregation
- New technologies are being proposed
  - Enhanced MIMO, cooperative transmission, relaying etc.
- 3GPP will contribute to ITU to standardize 4G
- Work required on PHY/MAC and network architecture
- Optimization for local area scenarios

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