



Initial thoughts on LTE Advanced for 3GPP Release 10

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LTE World Summit, Berlin, May 19th 2009

Background Nomor Research

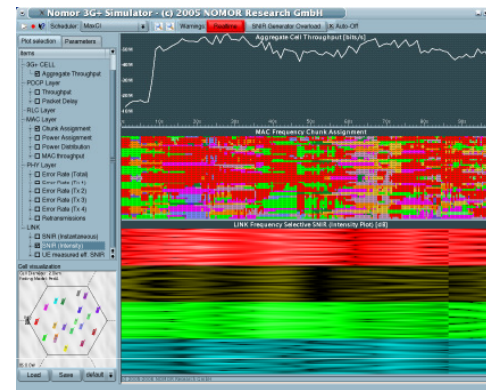
- ▶ Industry: IT Telecommunication
- ▶ Headquarter: Munich, Germany
- ▶ Founded: September 2004
- ▶ Worldwide business, profitable from day one
- ▶ Spin off from Munich University of Technology
 - First real-time simulations GPRS/UMTS for Siemens in 1999
 - Strategic collaboration Nokia Siemens Networks
- ▶ 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

Examples LTE development

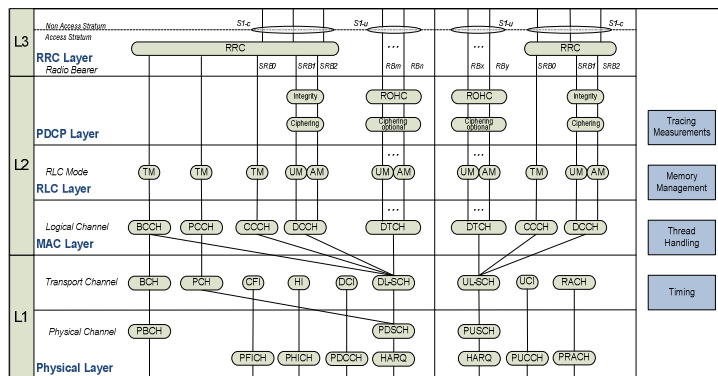
World First Live LTE Demo (2006)
Collaboration Siemens Networks



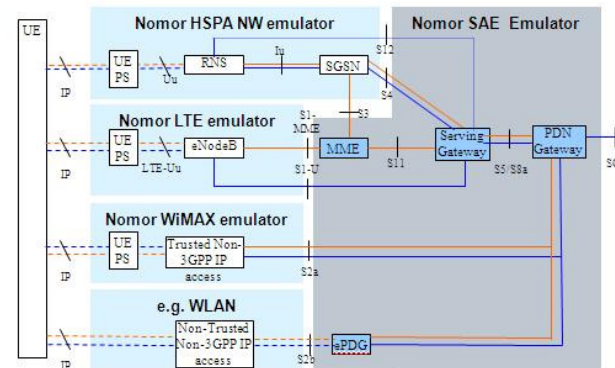
Advanced Mobile Radio Emulator LTE/LTE-A
Collaboration Nokia Siemens Networks



LTE eNB Protocol Stack
Licensing, first customer 2008



Multi-radio access testbed
First inter-RAT handover 2009



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 = 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!)

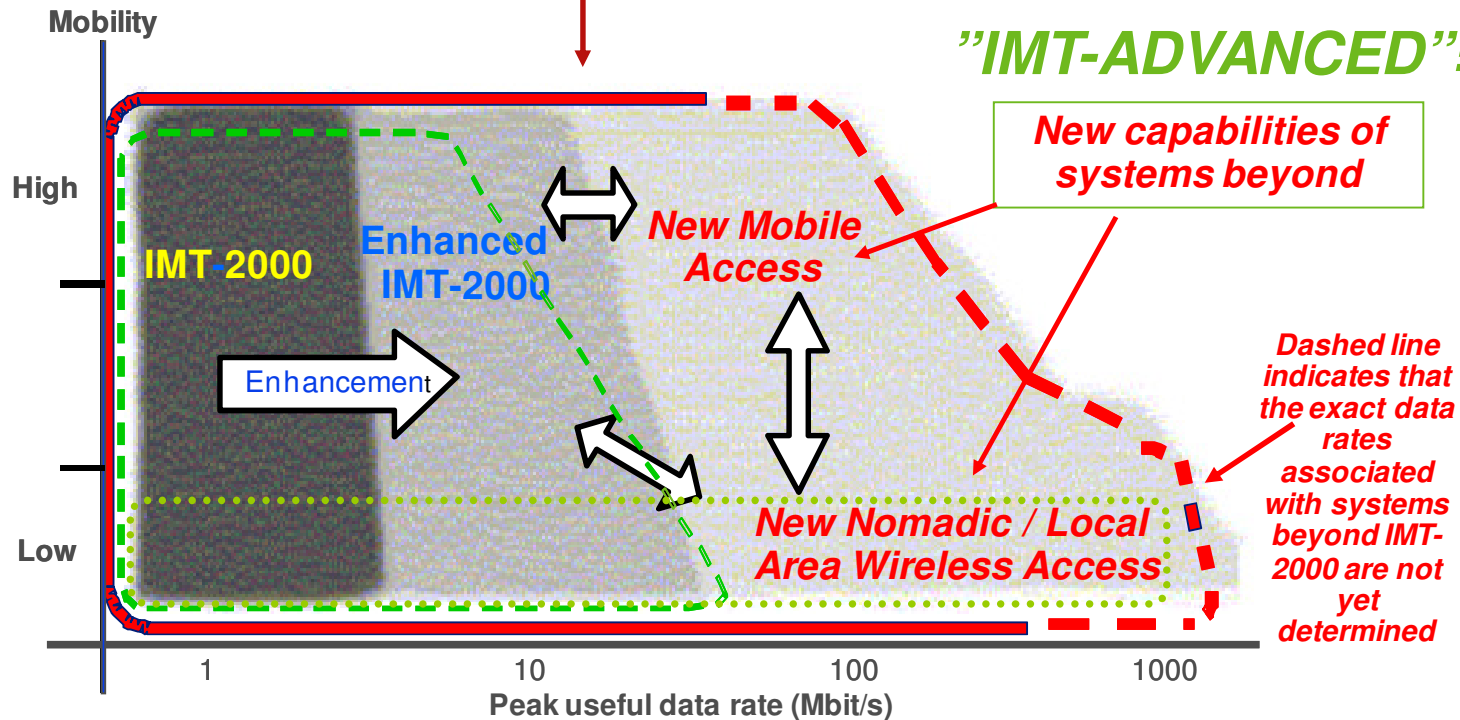
IMT2000-3G and IMT Advanced-4G

Recommendation ITU-R M.1645



Systems beyond IMT-2000 will encompass the capabilities of previous systems

"IMT-ADVANCED" =



New capabilities of systems beyond

Dashed line indicates that the exact data rates associated with systems beyond IMT-2000 are not yet determined

↔ Interconnection

○ Nomadic / Local Area Access Systems

○ Digital Broadcast Systems

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

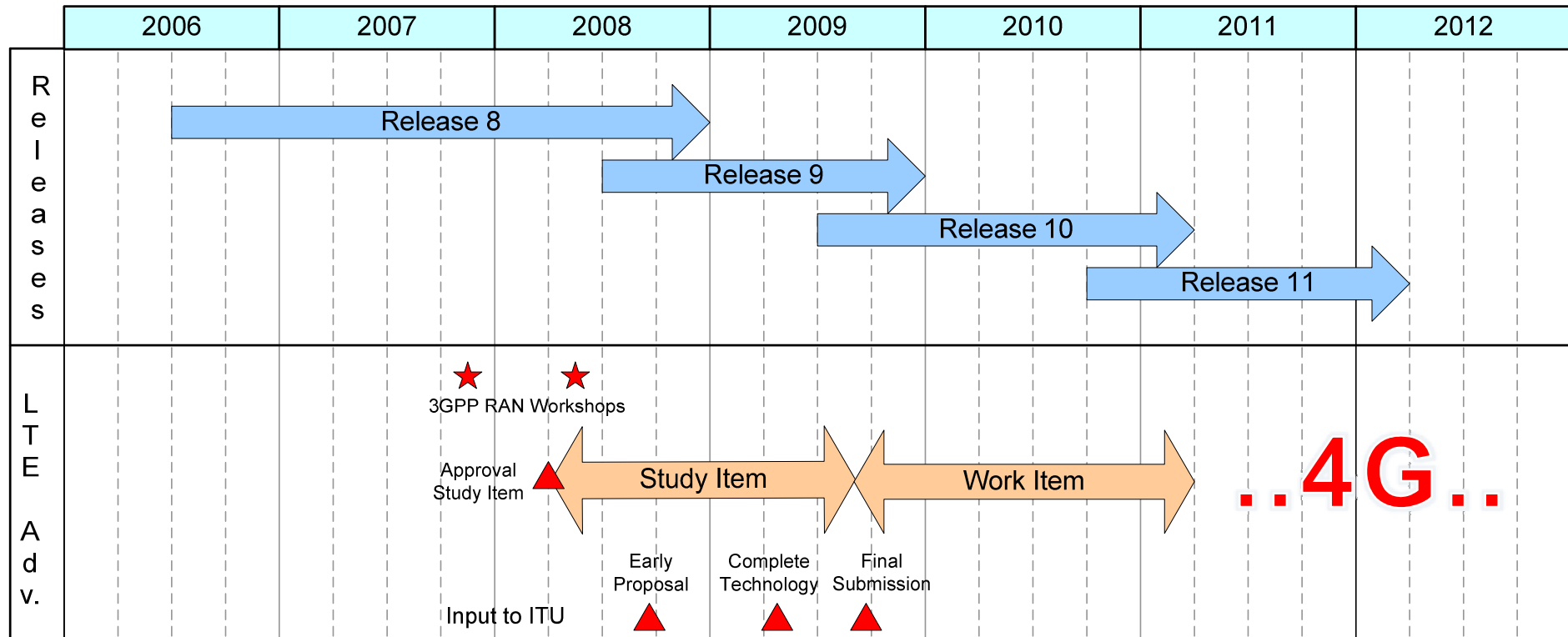
- ▶ IMT-2000 was changed to IMT (IMT = IMT-2000 and IMT-Advanced)
- ▶ In total around 400 MHz identified to IMT
- ▶ Out of this 136 MHz that was globally allocated to IMT
 - *Bands; 450-470 MHz, 790-806 MHz, 2300-2400 MHz*
- ▶ Additional low frequency bands for wide area coverage
 - *UHF Bands 698-790 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





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 than 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.



LTE Advanced Technology Proposals

Can we be more radio efficient?

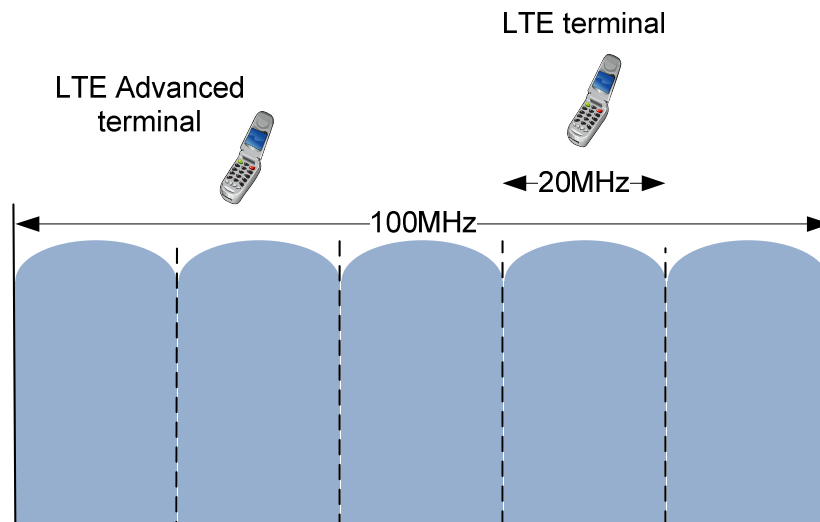
- ▶ LTE is a well designed very advanced system
- ▶ Radio functions are very fast, fully adaptive
- ▶ Access scheme OFDMA/SC-FDMA
 - No Intracell Interference in uplink and downlink
 - Scheduler exploits channel in time and frequency
- ▶ MIMO antenna technology
 - Exploits diversity, beam forming and 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



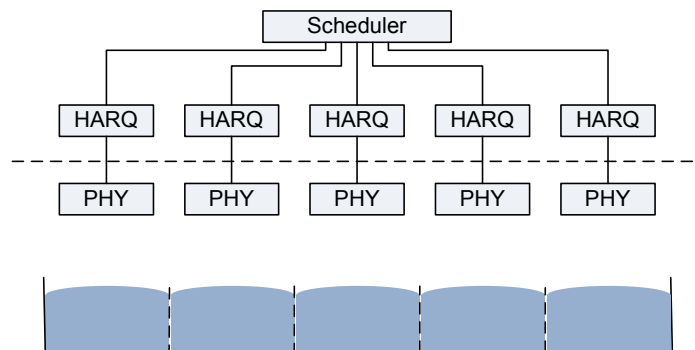
Challenges for 100 MHz terminal

- 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

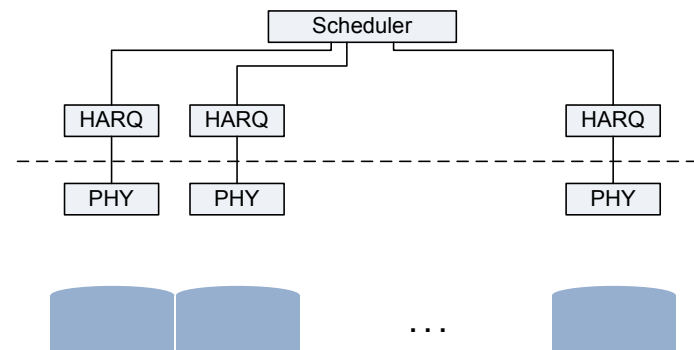
Multi-carrier operation

- ▶ 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 allocation



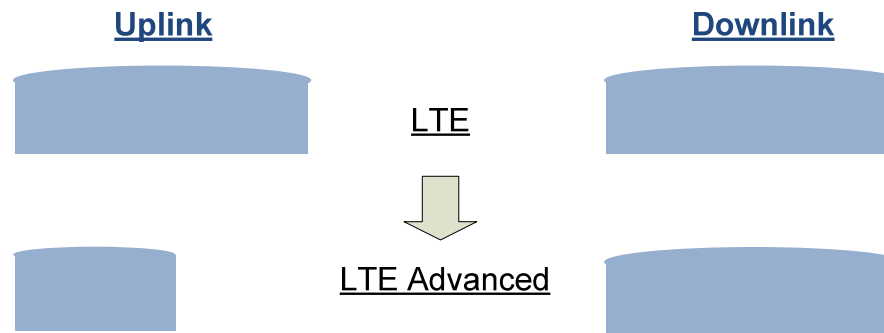
Non contiguous allocation



Bandwidth allocation

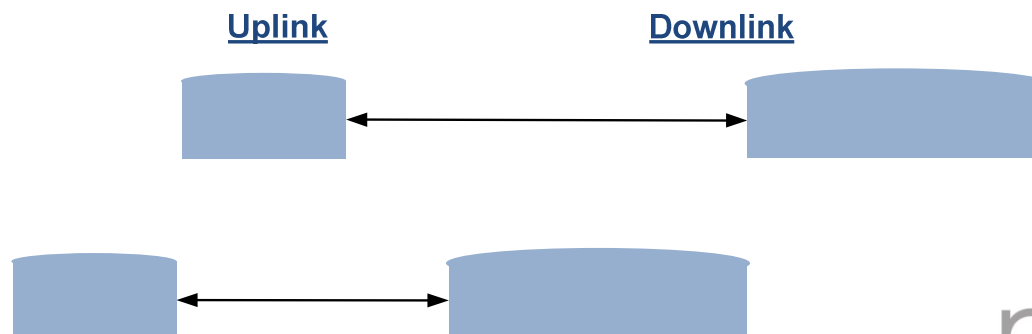
▶ Asymmetric bandwidth allocation

- 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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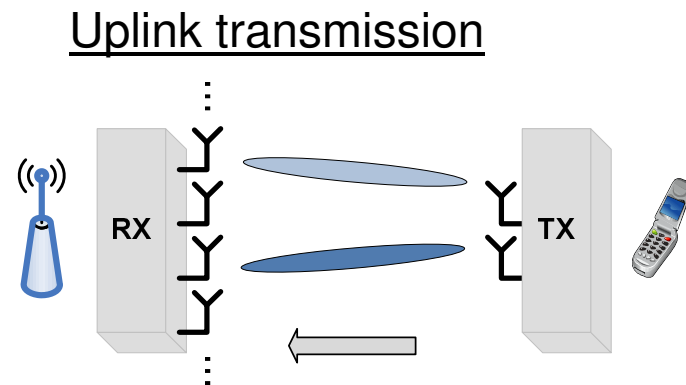
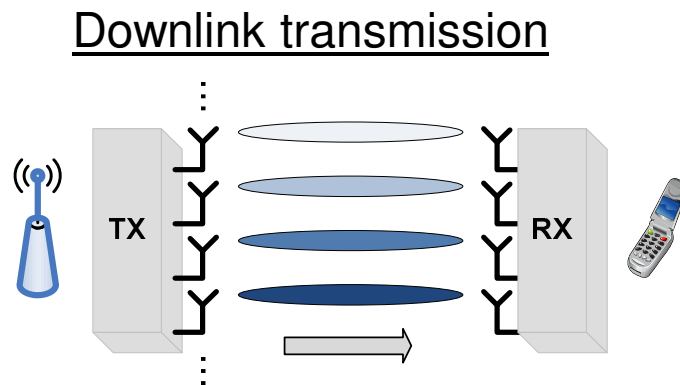
MIMO enhancements

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





Coordinated multi-point transmission (CoMP)

Inter-cell interference

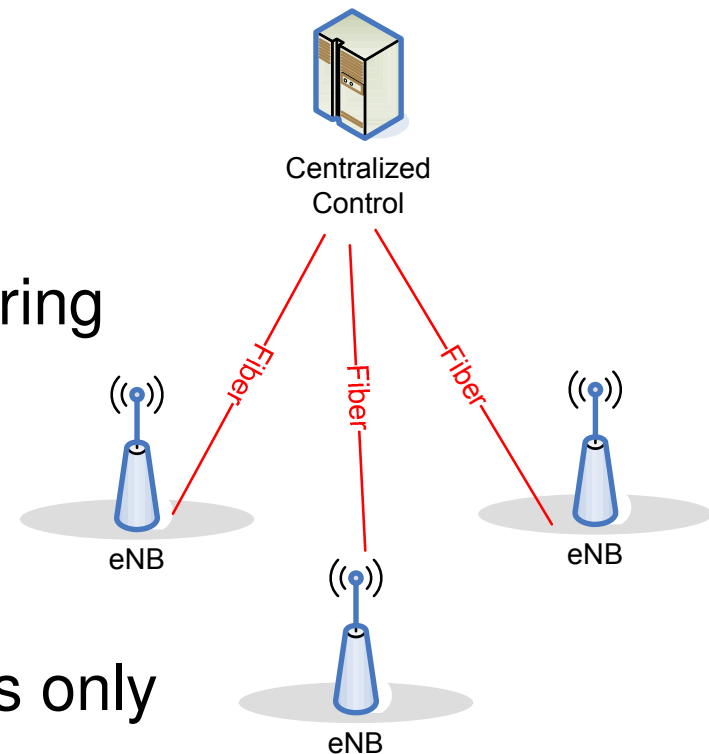
- ▶ Full frequency re-use is beneficial, but difficult to handle
- ▶ Slow Interference coordination is already supported

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

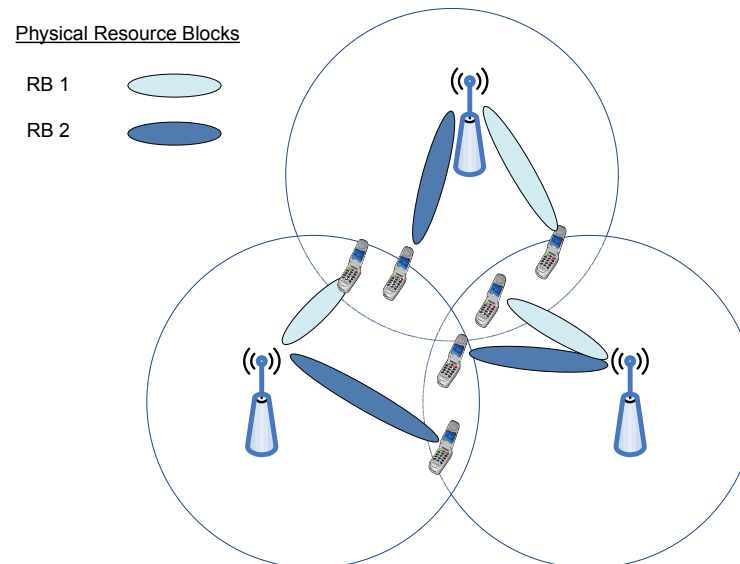
Cooperative base stations

- ▶ 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



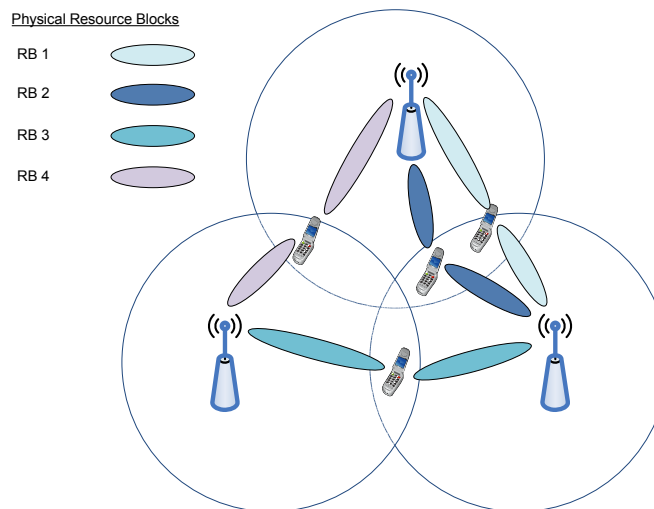
Coordinated Multi-site Beam Forming

- ▶ **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)



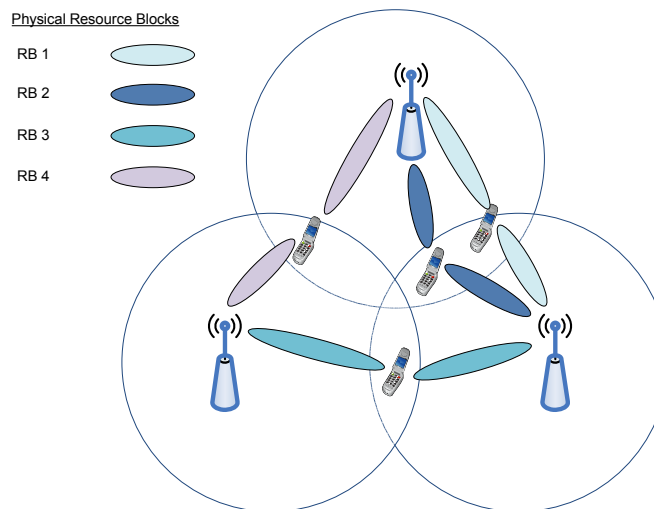
Combined Multi-site Beam Forming

- ▶ **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

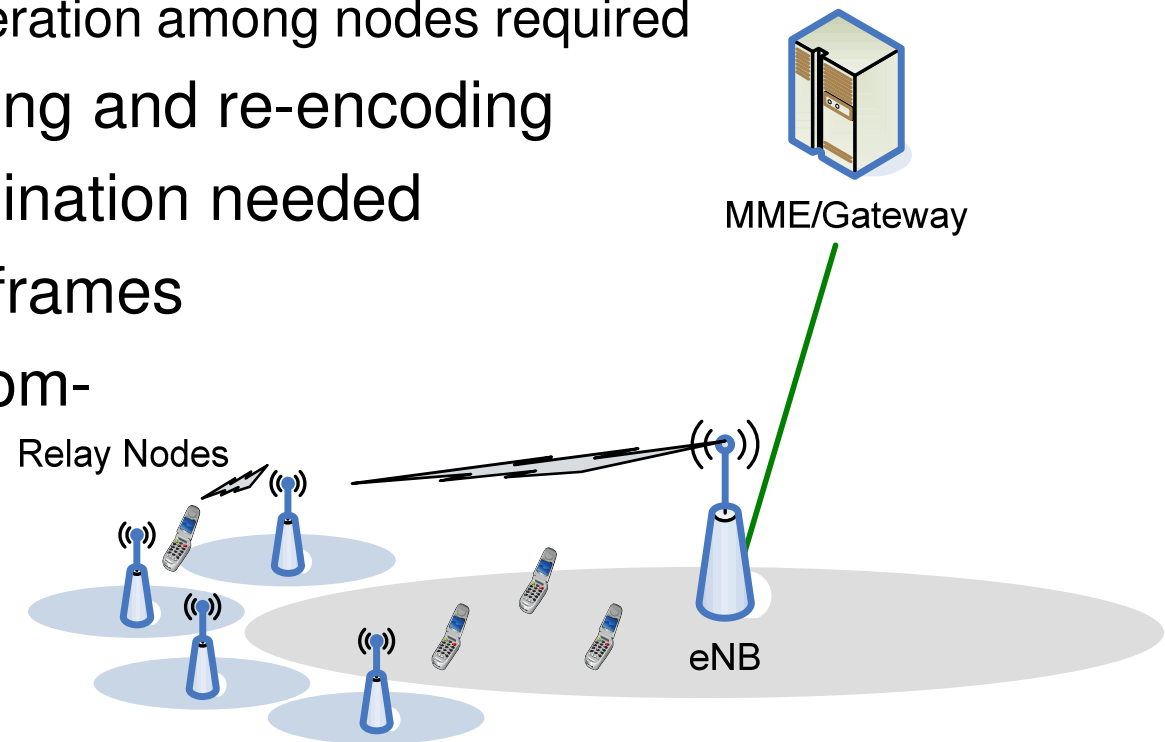
- ▶ Coverage problem increases for high spectrum
- ▶ Significant capacity increase can only be archived by smaller cell sizes

Introduction repeater (layer 0/1 relay)

- ▶ Used for coverage extension or to 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” repeaters use power control or self cancellation
- ▶ Alternatively signal can be forwarded at other frequency

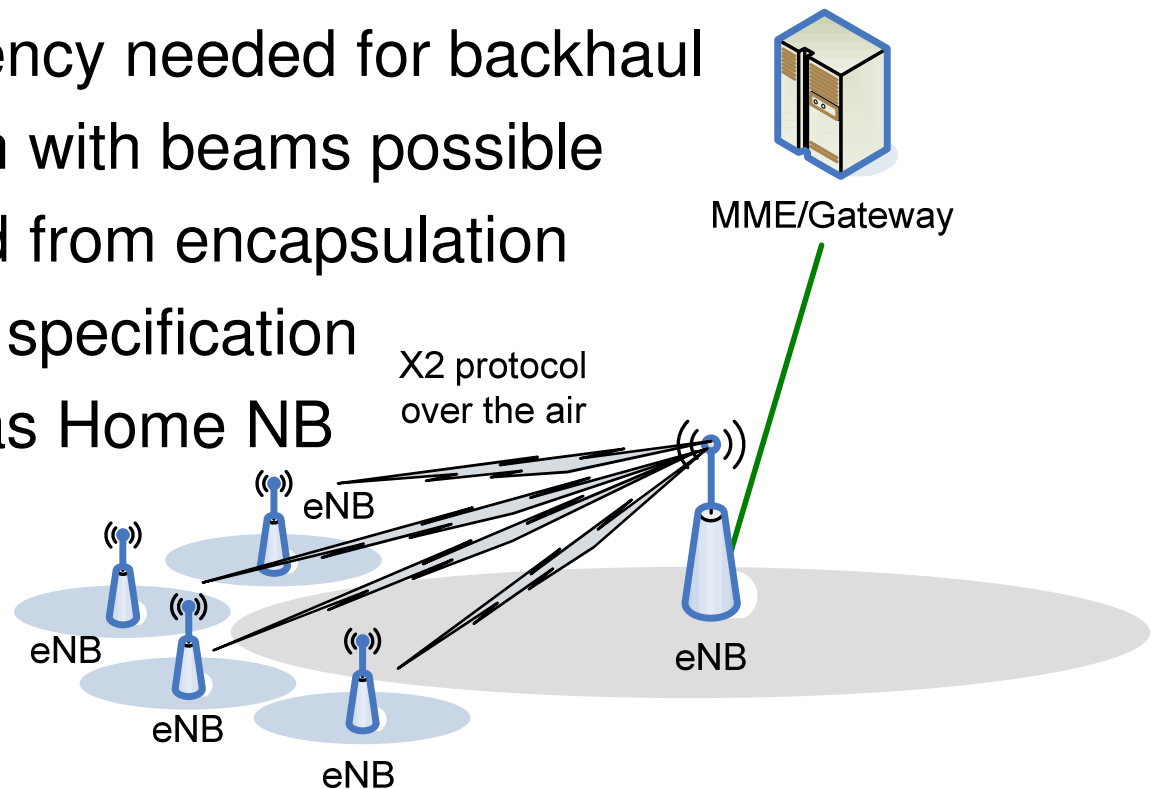
Decode and Forward (layer 2 relay)

- ▶ 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-ordination needed
- ▶ Delay of a few subframes
- ▶ Clear advantage compared to layer 1 repeater must still be seen



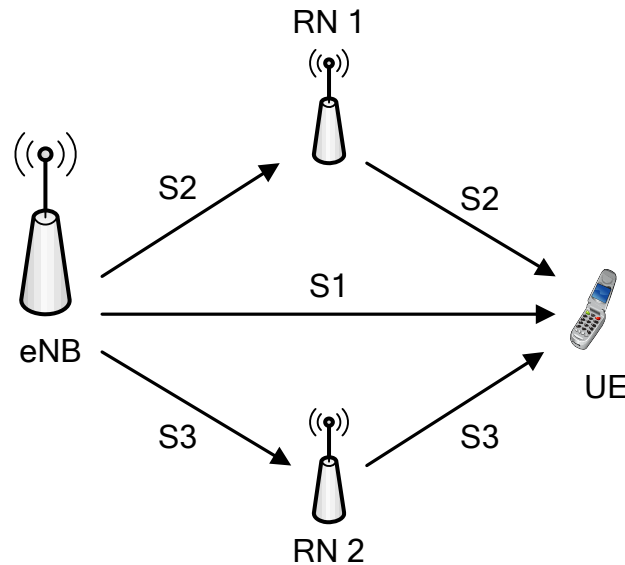
Self Backhauling (layer 3 relay)

- ▶ 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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