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WiMAX and 3GPP LTE

How are they related?

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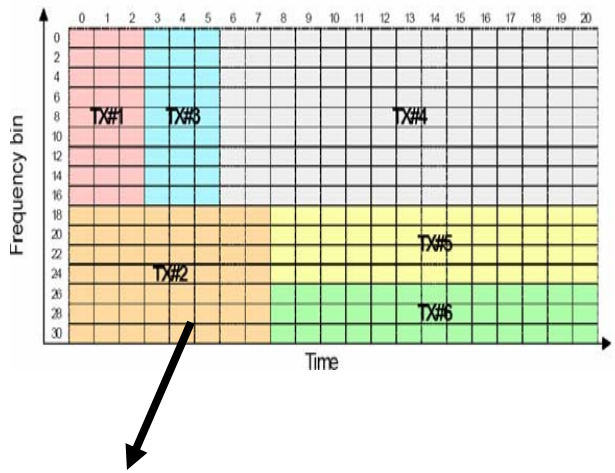
Outline of Presentation

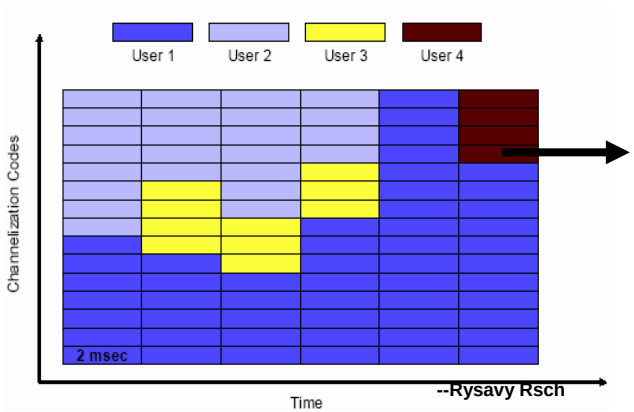
- WiMAX & LTE salient features
- Air-Interface
- Network Architectures
- Identify some major research issues
- Answer the question “ *how are they related”*

WiMAX Basics

- **Basic WiMAX**
  - Designed for speeds up to ~70 Mb/s
  - OFDM, OFDMA
  - Data-centric
- **Realities of NLOS propagation**
  - 30 miles >>> 2 miles
  - 70 Mbps >>> few Mbps
- **3G: High-Speed Downlink Packet Access**

OFDMA





HSDPA

	Domain	Thrput	Range
WiMAX (802.16e)	MAN	*Up to* 30 Mbps	1 – 3 miles
WCDMA/UMTS HSDPA	WAN	*Up to* 10 Mbps	1-5 miles
CDMA2000 1x EV-DO	WAN	*Up to* 2.4 Mbps	1-5 miles

3G

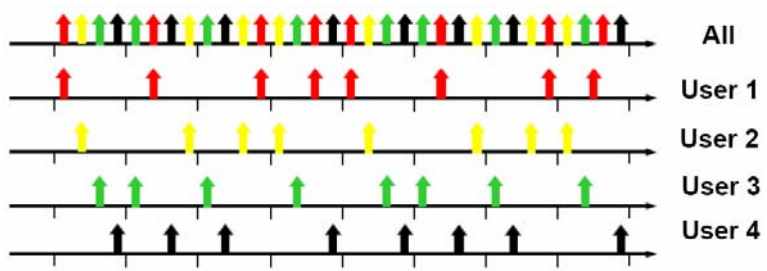
- **Optimization for data vs optimization for voice**
- **MAN + Handover + Roaming = WAN?**

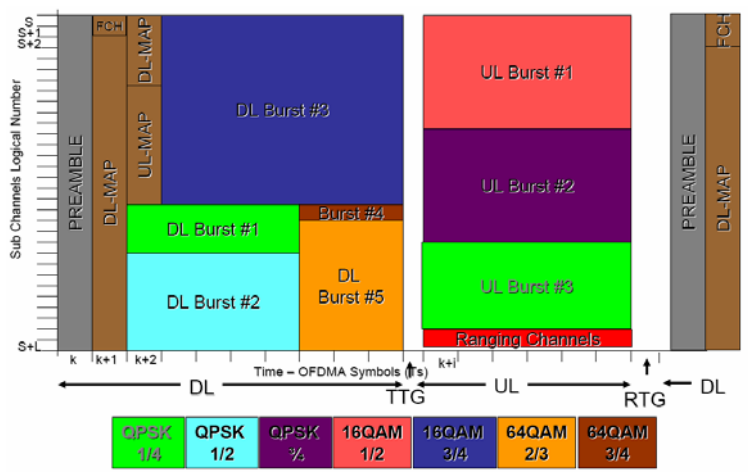
WiMAX features

- **Scalability**
  - Scalable PHY for capable of 1.25-20 MHz.
  - Flexible frequency re-use schemes for network planning
- **High Data Rates**
  - Larger MAC frames with low overhead
  - Adaptive modulation
  - H-ARQ for reducing packet loss
  - Full MIMO and Beamforming
- **QOS**
  - Traffic types
  - Adaptive Modulation & Coding
  - ARQ
  - H-ARQ
- **Mobility**
  - Secure Optimized Hard Handover
  - Fast BS Switching Handover
  - Power Management with Sleep and Idle modes

WiMAX: OFDMA TDD Frame Structure

- Flexible subchannelization
  - Pseudo-random permutation for diversity
  - Contiguous permutation for selectivity
- Operation in varying channel widths
  - 1.25 MHz, 2.5, 5, 10, 15 and 20 MHz channels
- Diversity permutation
  - Downlink FUSC
  - Downlink PUSC
  - Uplink PUSC
- Contiguous permutation
  - Downlink Band AMC
  - Uplink Band AMC



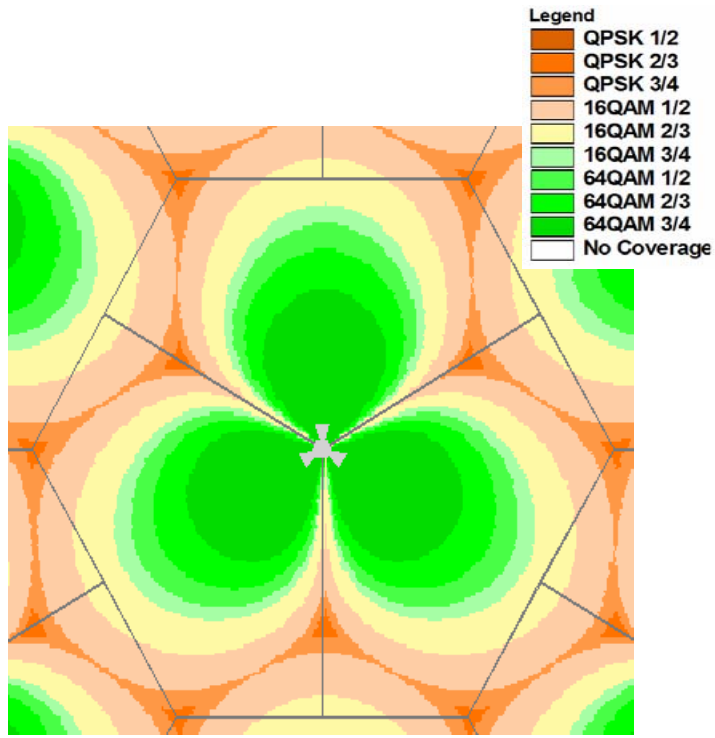


WiMAX-Power Control

- **Open loop power control**
  - UL interfenrece+noise level broadcasted in DL Map
  - Path loss estimate based on channel reciprocity
  - Power offset based on ACK/NACK
  - Fast power control (by UL-MAP)
- **Close loop power control**
  - Power adjustment sent in DL power control
  - Power adjust in 0.25dB step
- **Power adjustment by periodical ranging**

WiMAX Features

- Tradeoff between link robustness and capacity
- Adaptation on a burst by burst basis
  - **Modulation formats:**
    - **BPSK**
    - **QPSK**
    - **16QAM**
    - **64 QAM**



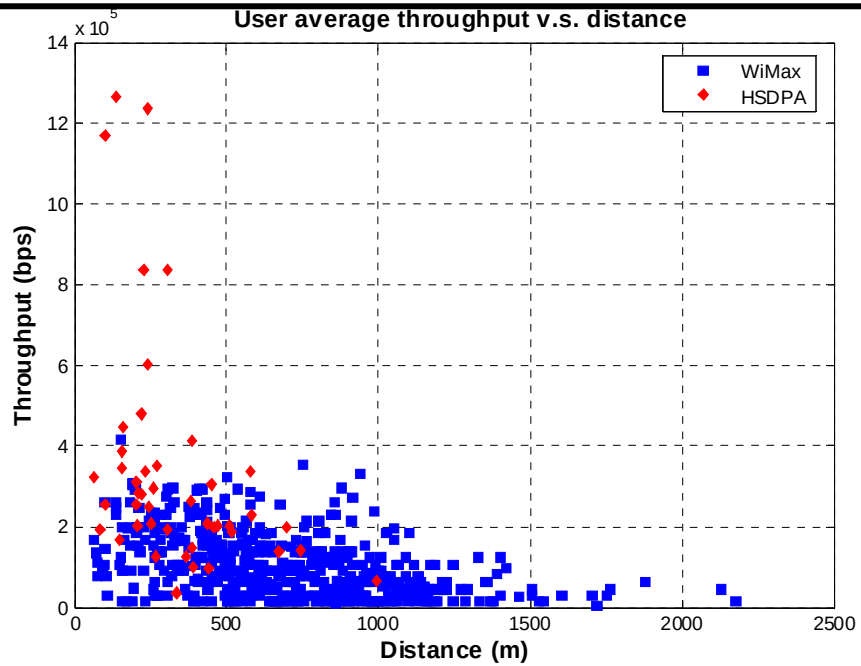
Advanced Antenna System

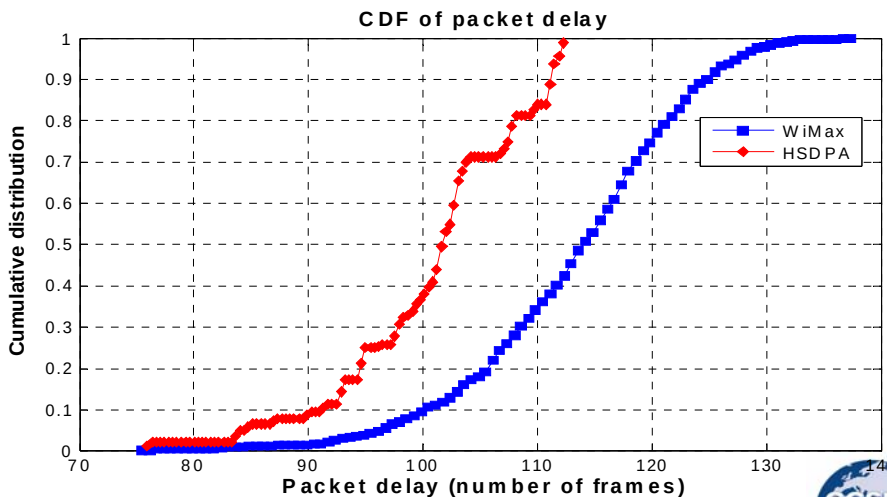
- AAS (beamforming)
- Space time code (STC)
- Spatial multiplexing (SM)
- Adaptive MIMO switch (AMS)
- Space Time Block Codes and Spatial multiplexing
- Collaborative Spatial Multiplexing (CSM)
- Dynamic band allocation for AMC sub-carrier mapping

WiMAX

- **Modulation: BPSK, QPSK, 16 QAM, and 64 QAM.**
  - Bit Detection:
    - Soft-input soft-bit de-mapper based on MAP criterion
    - MRC combining for multiple Rx antenna (if STBC is switched off)
- **FEC coding:**
  - convolutional tail biting code (CCTB), convolutional zero padded (CCZP), convolutional turbo code (CTC), and Low Density Parity Check (LDPC)
  - CCTB,CCZP, and CTC Rates: 1/2, 2/3, 3/4, 5/6 (through puncturing)
  - LDPC rates: 1/2, 2/3, and 3/4
- **Repetition Coding**

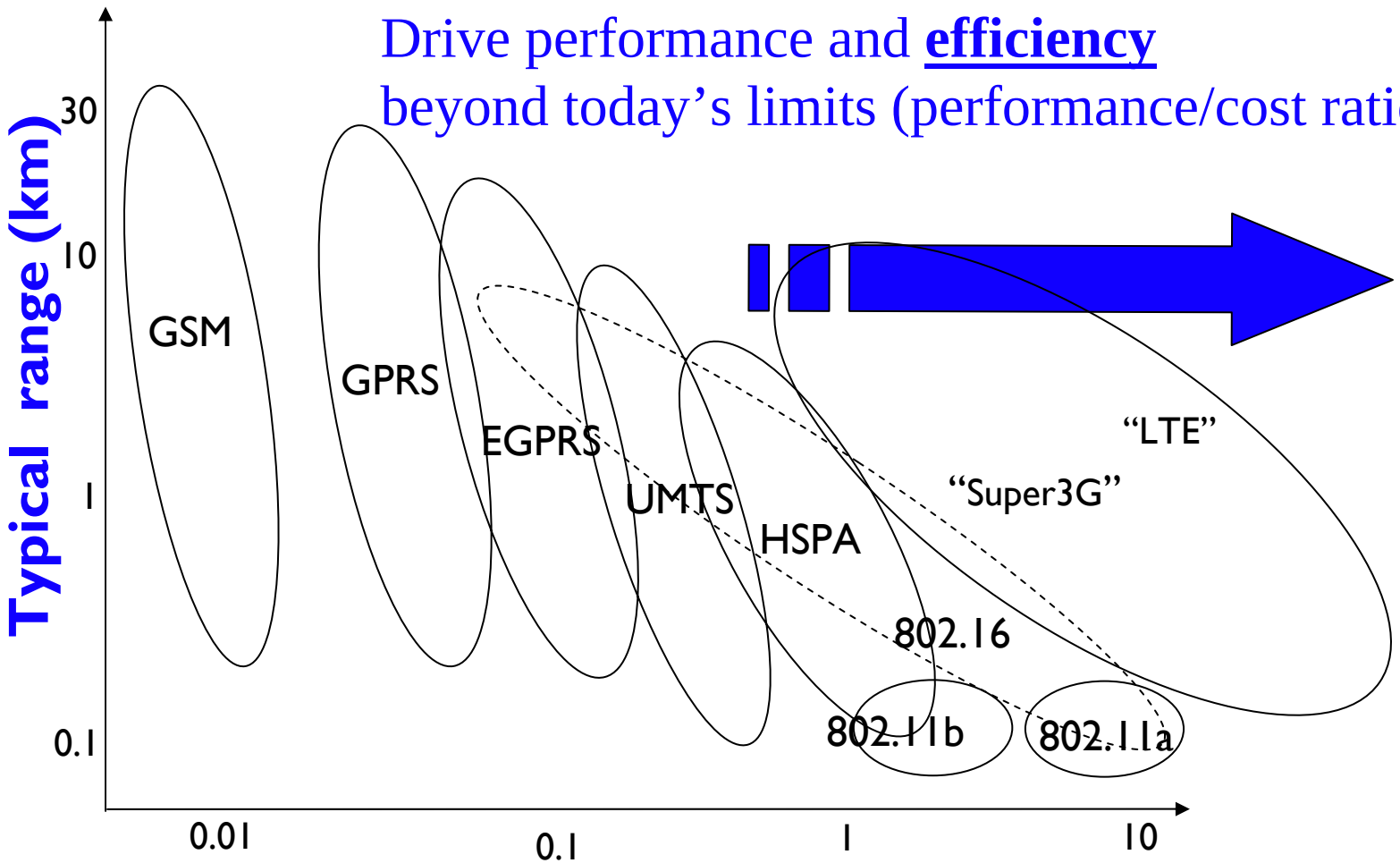
Throughput, Cell Range, Quality





Capability Evolution

Drive performance and **efficiency**
beyond today's limits (performance/cost ratio)



3G LTE- Motivation

- **Continuous growth of Mobile Communications-towards Broadband personal communications**
  - Higher capacity
  - Reduced delay
  - Higher data rates
  - Automatic planning capability
  - Simplified network management
  - Always on
  - Multi/Broadcast capability

LTE Specifications

- **Data Rates:**
  - 30Mbps(UL), 100Mbps (DL)
  - Speed: walking to bullet train
- **High performance/cost ratio**
  - Spectral efficiency target 5bps/Hz
- **Reduced latency**
  - TTI latency <0.5ms
  - Interactive gaming, VoIP
- **Optimised for packet switching**
  - PS only
  - IP routing (CN & RAN)
  - Better support of VoIP, Data
- **Cost efficient deployment**
  - Re-use of 3G/2G spectrum
  - Bandwidth flexibility (1.25, 2.5, 5, 10, 15, 20MHz)
  - Minimum network operation cost

PHY layer Key Technologies

- Downlink-OFDM
- Uplink-Single Carrier FDMA
- Multiple antenna techniques for high capacity
- Inter-cell interference mitigation
- Multicast and Broadcast services
- Channel Frequency & Time domains exploitation for rate and/or power adaptation

Downlink

- **OFDMA (1.25, 2.5, 5, 10, 15, 20MHz)**
- **Sub-frame duration: 0.5ms**
- **Sub-carrier spacing: 15KHz**
- **FFT size –Occupied Sub-carriers: 128-76 (1.25MHz), 256-151, 512-301, 1024-601, 1536-901, 2048-1201**
- **NUM. OFDM Symbols per sub-frame:**
  - ❑7 (with short CP)
  - ❑6 (with long CP)

UPLINK

- **Power-efficient Coverage**
  - Low peak-average power ratio
  - Low power consumption by UE
  - Supporting wide area coverage
- **Support scalable bandwidth and flexible scheduling**
  - FDMA
- **Similar frame structure as downlink**
  - Flexible Cyclic prefix (CP) structure
- **Orthogonality among uplink users, Cyclic prefix to account for relative timing difference**

Advanced Antenna System

- **Single data stream per user**
  - Beamforming
    - Coverage, longer battery life
  - Spatial Division Multiple Access (SDMA)
    - Multiple users in same radio resource
- **Multiple data stream per user**
  - Diversity
    - Link robustness
  - Spatial muliplexing
    - Spectral efficiency, high data rate support

Diversity and Multiplexing

- **Basic 2 Tx, 2Rx**
- **Spatial multiplexing**
  - Different modulation/coding per stream
  - Multiuser MIMO
  - Closed loop with feedback
- **Spatial diversity**
  - **Open loop transmit diversity**
    - » **Cyclic delay diversity**
    - » **Space time coding**
  - **Closed loop transmit diversity**
    - » Beamforming
    - » Antenna selection

Interference Mitigation

- **Objective**
  - One cell freq. re-use for simplified planning
- **Problems**
  - Cell edge users suffer interference from neighbouring cells
- **Possible solutions**
  - Inter-cell interference randomisation
  - Inter-cell interference cancellation
  - Inter-cell interference co-ordination

Inter-cell Interference Mitigation

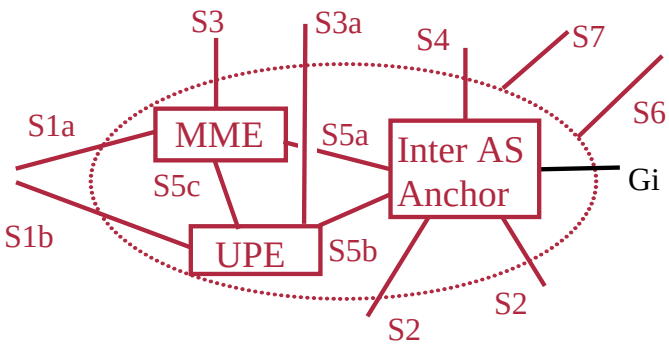
- **Inter-cell Interference Randomization**
  - Cell-specific interleaved division multiple access (IDMA)
    - » Interleaving pattern depends on cell-ID
  - Frequency hopping
- **Inter-cell Interference cancellation**
  - Spatial suppression by beamforming
  - Interference cancellation with IDMA
- **Inter-cell Interference Coordination**
  - Flexible Soft Freq. re-use (SFR)
    - » Primary and secondary freq. bands
    - » Primary band: reuse > 1, higher TX power
    - » Secondary bands: Remainng spectrum
    - » Cell-edge users: Use primary band good SIR
    - » Cell-centre users: use entire band high data rates
  - Supported by means of frequency domain scheduling

LTE System Architectures 4X4

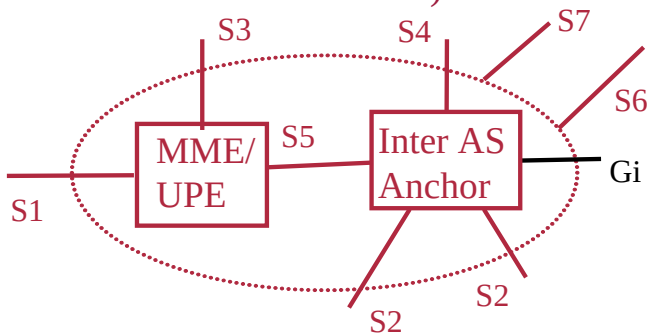
- **4 protocol options**
  - GTP-U tunneling based mechanism
  - GTP-U Tunneling + MIP based mechanism
  - GTP-U Tunneling + PMIP based mechanism
  - Pure MIP based mechanism
- **4 Packet Core Architecture Options**
  - Option 1 (Full Split)
  - Option 2 (Traditional SGSN/GGSN like)
  - Option 3 (Combined User Plane Node)
  - Option 4 (All in One)

SAE Evolved Packet Core Architecture Options

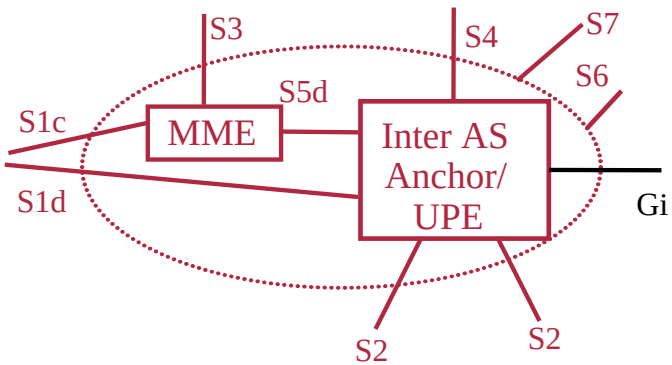
Option 1 ("Full Split"):



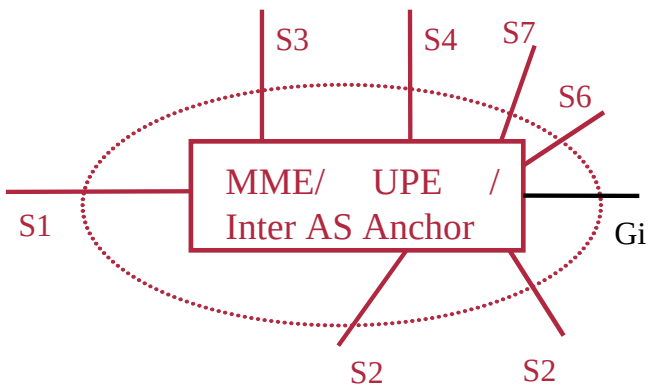
Option 2 ("Traditional SGSN/GGSN-like"):



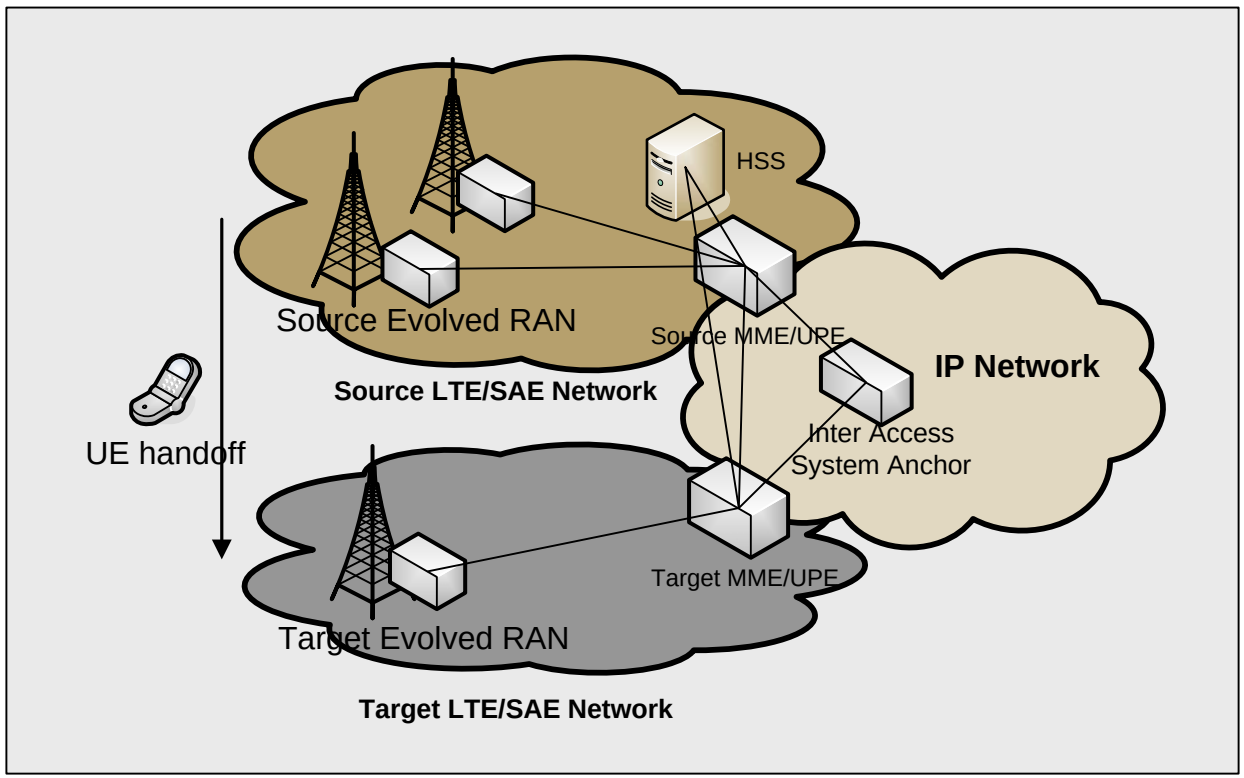
Option 3 ("Combined User Plane Node"):



Option 4 ("All in One"):



Inter- SAE LTE mobility



Research Issues

- **Minimum capacity per user similar to xDSL (8Mbps)**
- **Capacity at cell edge**
  - ❑ Interference mitigation schemes
  - ❑ Intelligent schedulers
- **Self-optimisation and planning**
  - ❑ A multidimensional and multivariable problem
  - ❑ Positioning technique
- **Multihop communications**
- **Wireless Mesh Backhaul**
- **Evaluation of Network architecture options**
  - ❑ Mobility management (fast vertical handover)
  - ❑ QoS, Security
  - ❑ IP to e-Node B
  - ❑ Scalability
  - ❑ Cross-cells resource management and self-organised network operation
- **Always on and end-to-end delay optimisation**

How are they related?

- **Not related**
- **LTE is an e-2-e system whereas WiMAX is an Radio Access technology**
- **WiMAX should be considered as 2nd Generation of Wireless LAN**
  - Wifi with mobility
  - Good solution for Fixed operators enter mobile business
- **3GPP LTE is a step towards 4G Cellular system, ITU-R IMT-Advance**
- **Looking at AI options, LTE is much simpler whereas WiMAX has many options but not necessary leading in significant performance difference**
- **LTE addresses main concerns of cellular operators with backward compatibility, enhancing performance/cost ratio through self-organisation and network management**