Security Level:

Seminario AGCOM "LTE per il mobile broadband: tecnologia, regolamentazione, ecosistema e mercato" Roma, 24 Febbraio 2012

PARTE II: Tecnologia LTE

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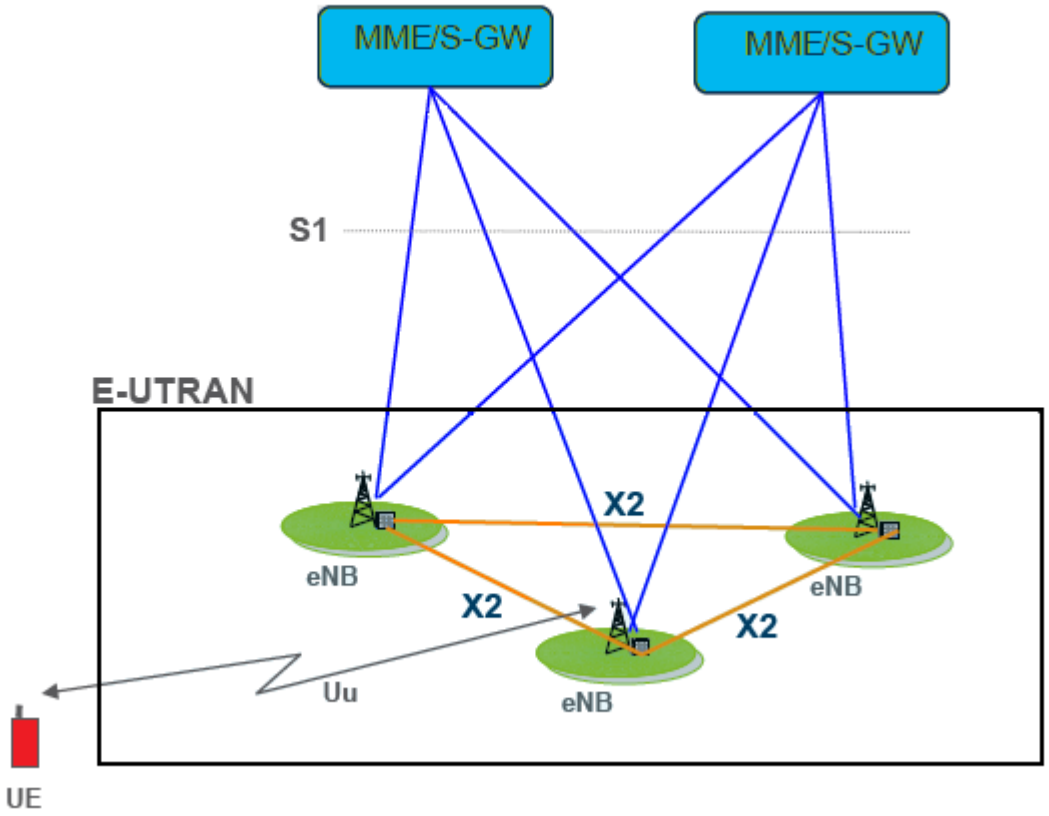
Contents

LTE Flat Architecture

- 3G RNC (inherited from the 2G BSC) disappears from eRAN
  - › eNB directly connected to ePC (S1 i/f)
  - › RNC features distributed between eNB and ePC (MME and S-GW)
- Simpler architecture (fewer nodes of different types) → simplified operation
- Termination of L2 @ eNB → lower latency
- 3GPP does not require any physical architecture for ePC implementation but typically one platform for User Plane (S-GW & P-GW) and one for Control Plane (MME)



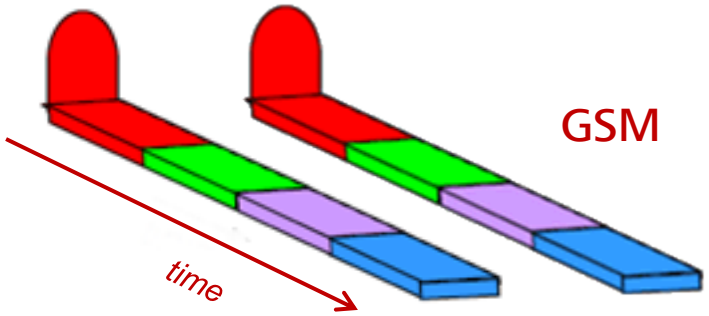
Evolution of Radio Interface

Frequency Division Multiple Access

TACS

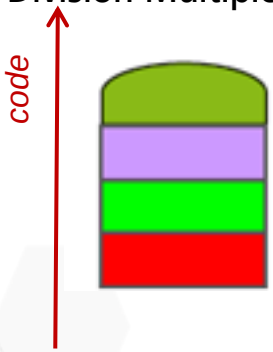
Time Division Multiple Access

GSM



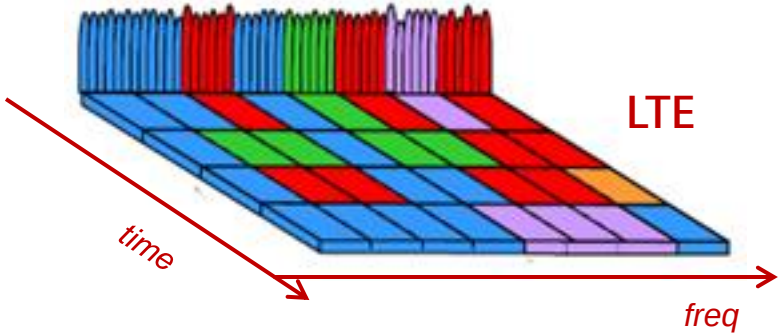
Code Division Multiple Access

UMTS



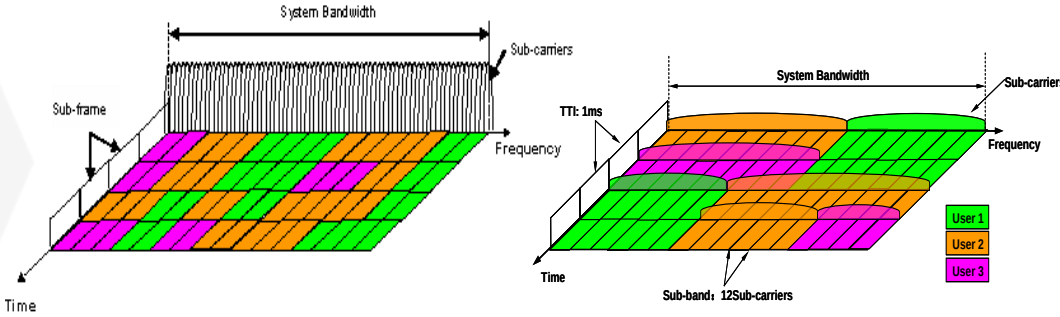
Orthogonal Frequency Division Multiple Access

LTE



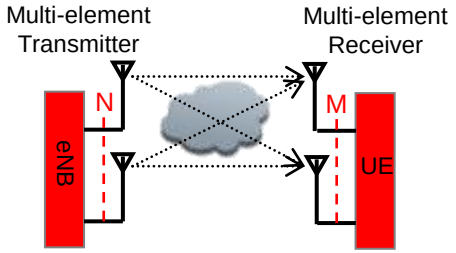
LTE fundamentals

- Radio Interface
  - DownLink = OFDMA
  - UpLink = SC-FDMA

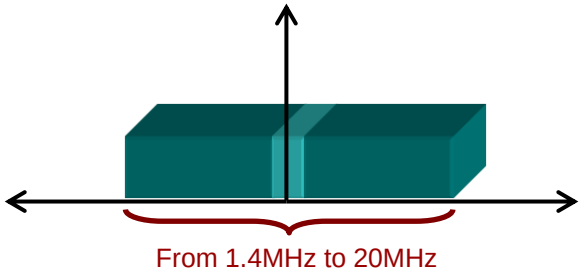


DL UL

- Antenna System Solutions
  - Diversity
  - Multi-port transmission (MIMO)
  - Beam-forming

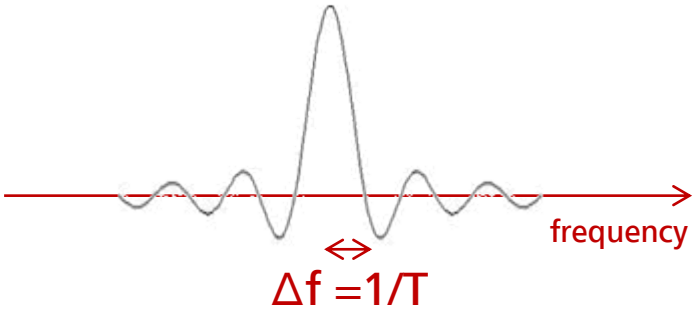


- Spectrum Flexibility
  - Flexible bandwidth
  - New and legacy bands
  - FDD and TDD technology

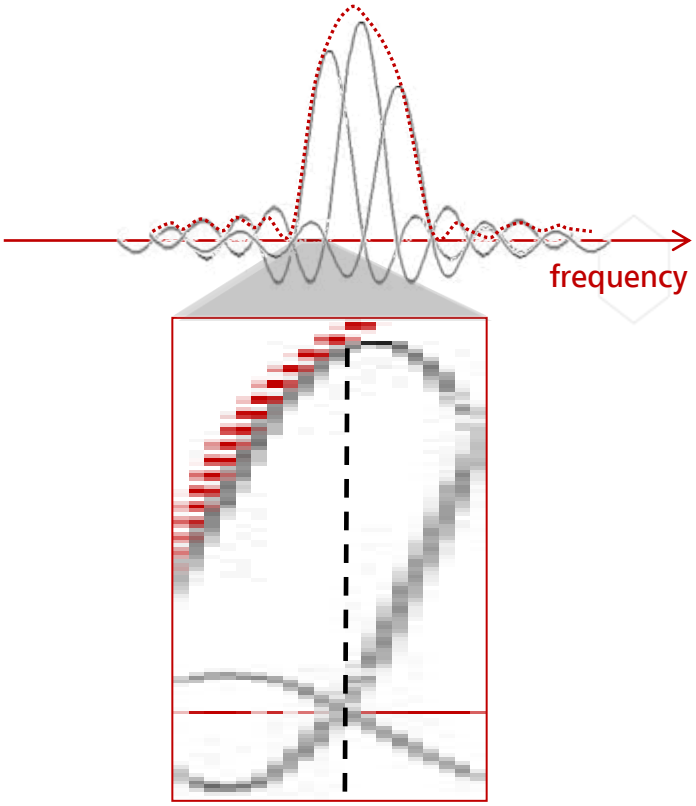


OFDM basics

- The basic “module” of OFDM is the narrow-band subcarrier or tone

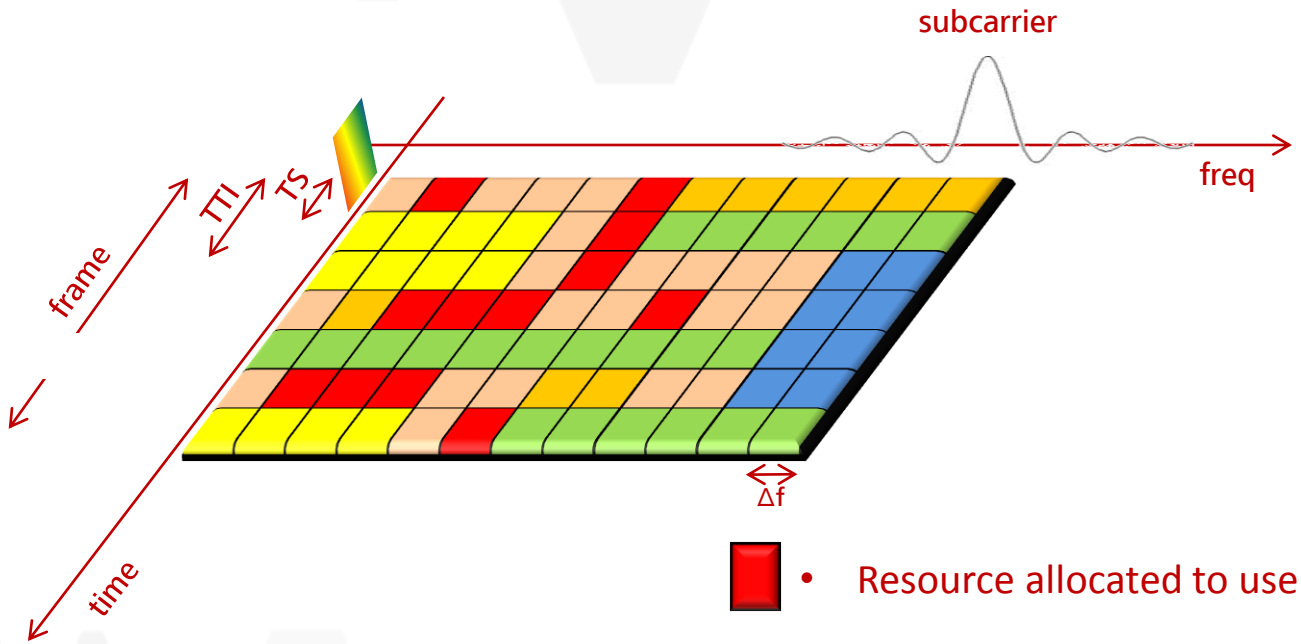


- Each OFDM symbol consist of the sum of N orthogonal subcarriers with 15KHz granularity



- At each freq instant, only one subcarrier is different from zero → orthogonal tones

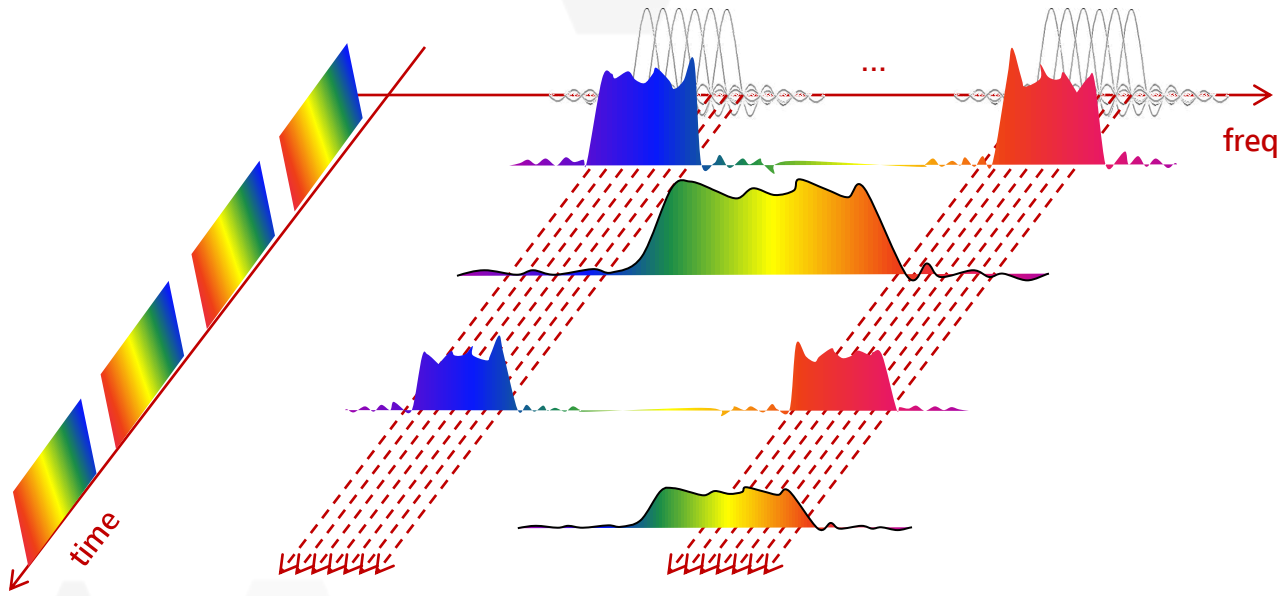
OFDM (Orthogonal Frequency Division Multiplexing) as Multi-User Access technique



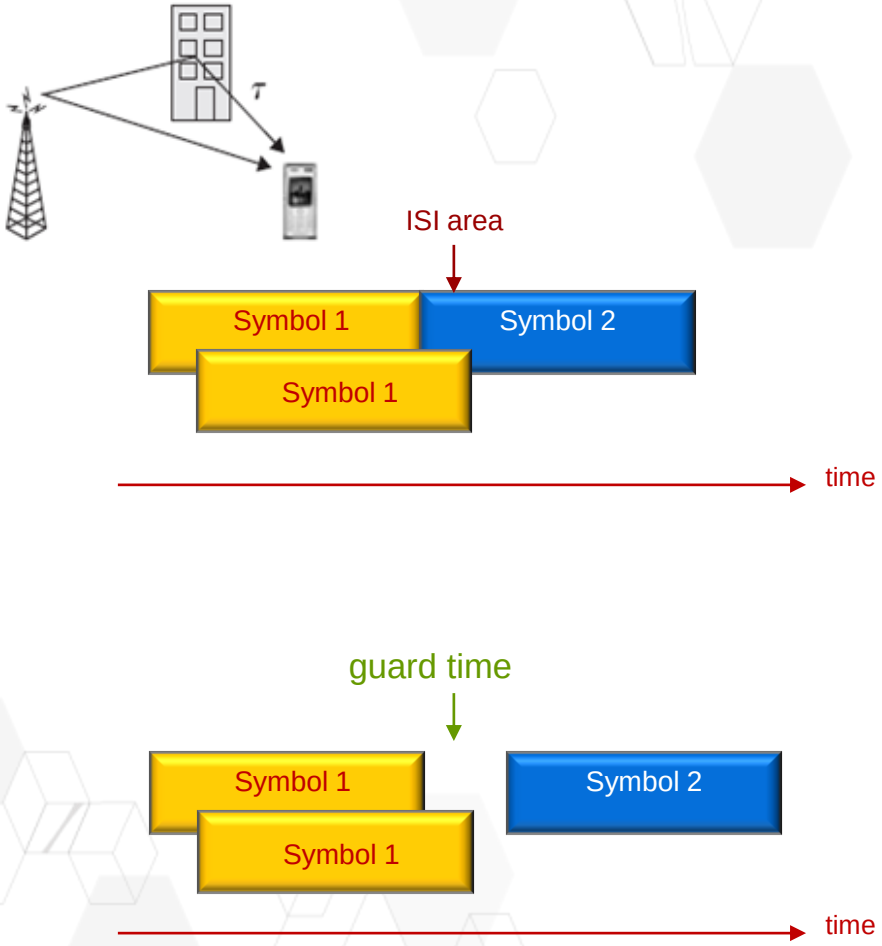
- Resource allocated to user “red”

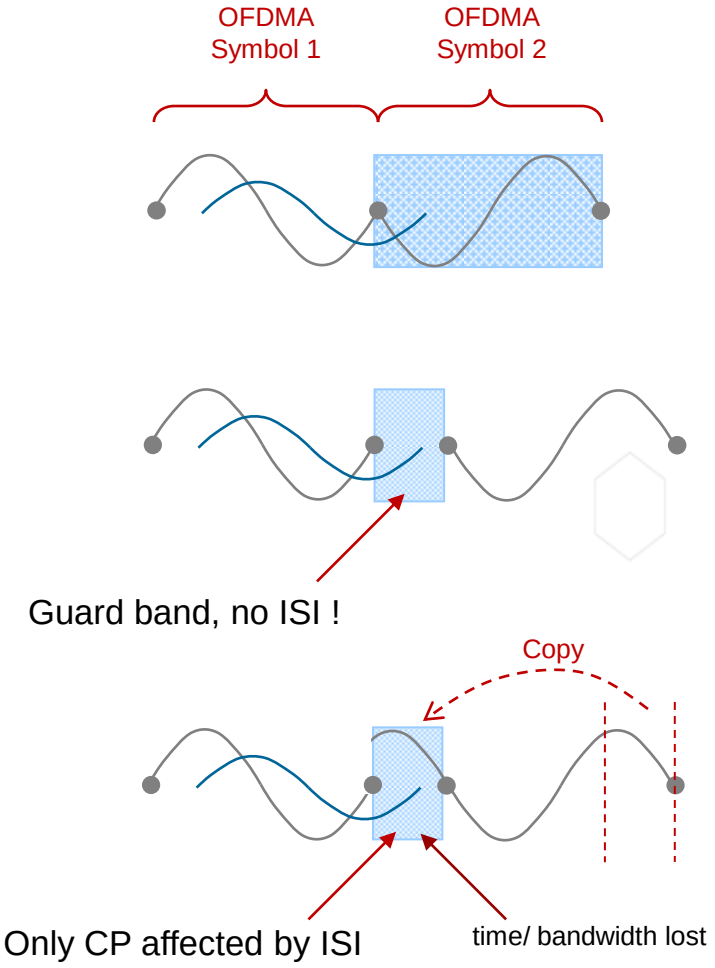
timeslot (TS =0.5 msec)
subframe TTI (= 2 TS = 1 msec)
frame (= 10 TTI = 20 TS = 10 msec)
Δf = 15KHz ($T_{sampling}$ =32,5nsec)

OFDM (Orthogonal Frequency Division Multiplexing) Principles

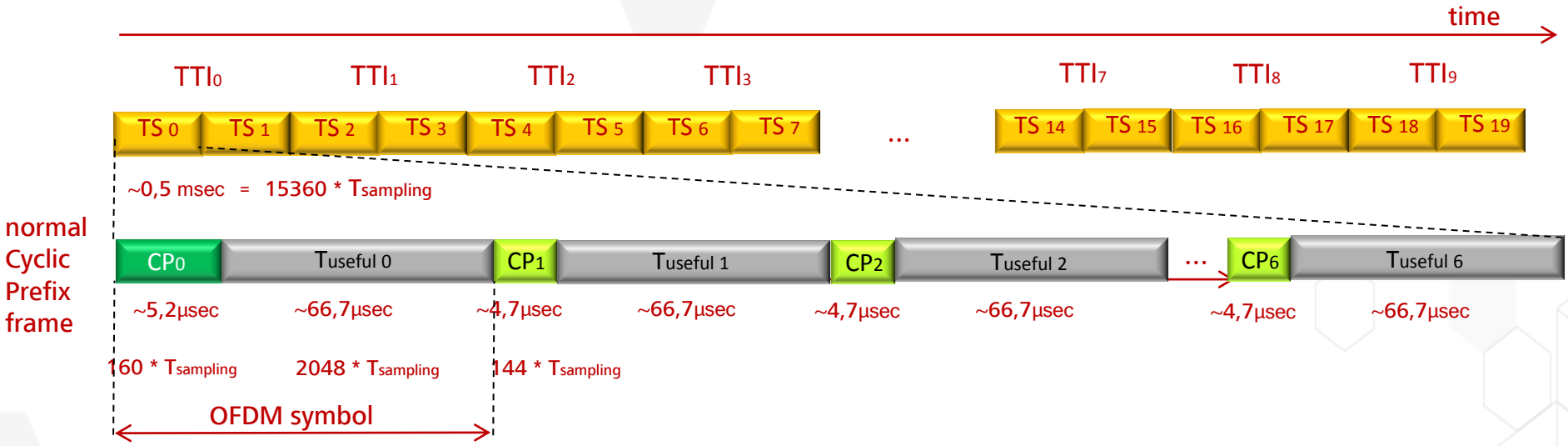


Inter-Symbol Interference – Cyclic Prefix



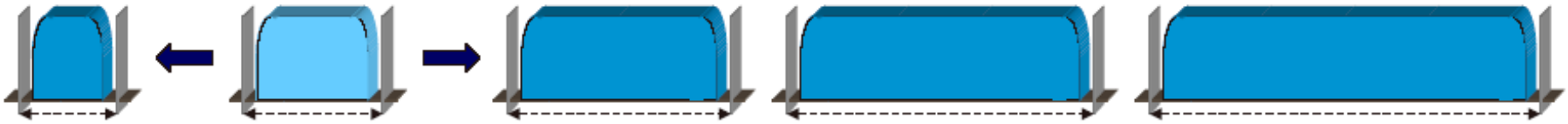


Time frame structure

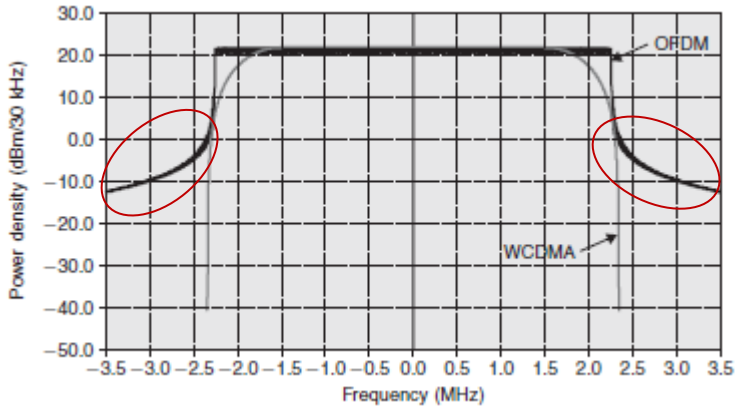


- The normal CP frame consists of 7 OFDM symbol
- An extended CP frame also exist (ECP =~16,7µsec; 6 OFDM symbol)
- Cyclic Prefix acts as “time guard” against inter-symbol interference but of course implies to decrease radio efficiency

Bandwidth Flexibility



1.4 MHz 3MHz 5MHz 10 MHz 15 MHz 20 MHz



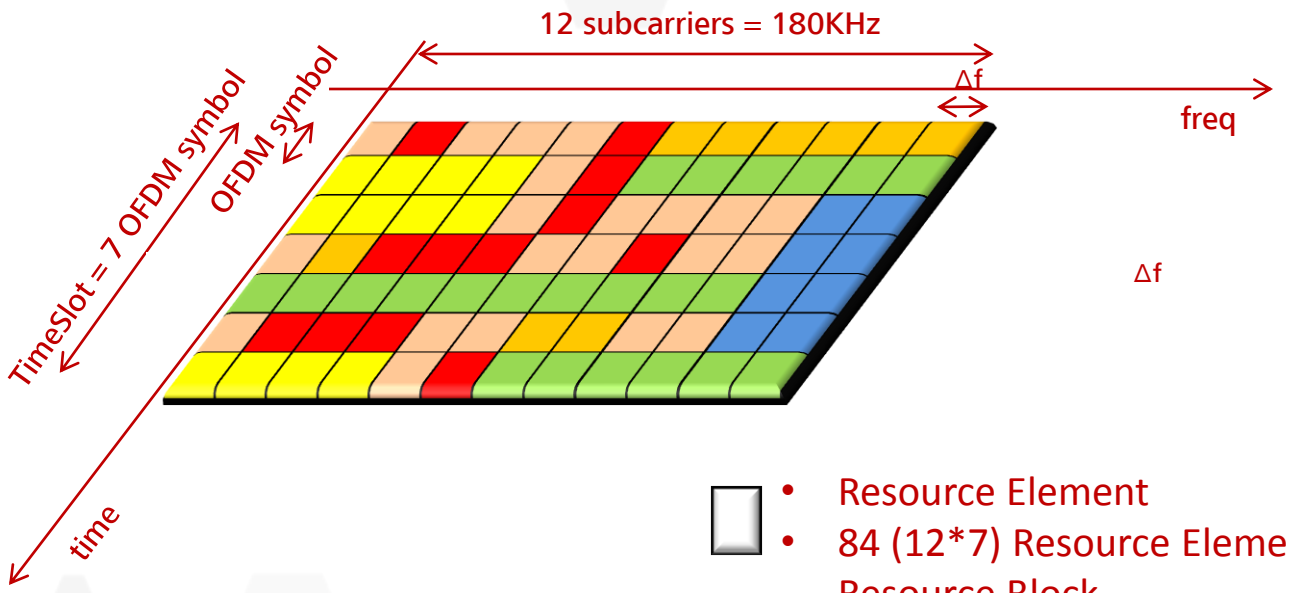
- Higher out-of-band emission wrt WCDMA
- 10% of guard bands to be considered
- One subcarrier “occupies” 15KHz (Δf)

	1.4MHz	3MHz	5MHz	10MHz	15MHz	20MHz
Theroretical number of subcarriers	~93,3	200	~333,3	~666,6	1000	~1333,3
Number of occupied subcarriers *	**72**	**180**	**300**	**600**	**900**	**1200**
Effective BW allocated	1.08MHz	2.7MHz	4.5MHz	9MHz	13.5MHz	18MHz

* = DC subcarrier non considered

Resource Block

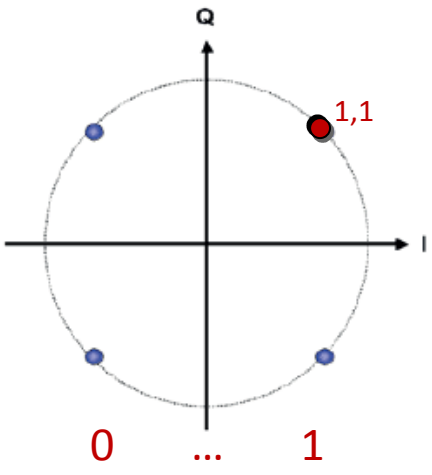
Resource block consists of 12 consecutive subcarriers (180KHz) and one timeslot



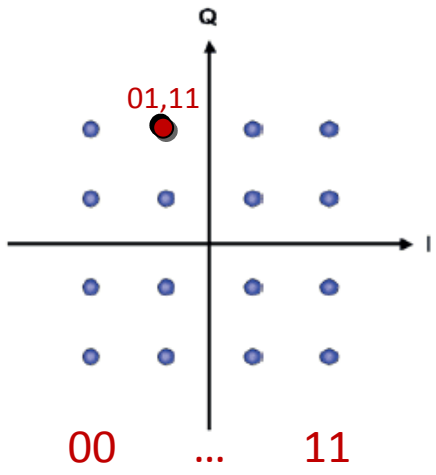
- Resource Element
- 84 (12*7) Resource Elements per Resource Block

	1.4MHz	3MHz	5MHz	10MHz	15MHz	20MHz
Number of occupied subcarriers *	72	180	300	600	900	1200
Number of Resource Blocks	**6**	**15**	**25**	**50**	**75**	**100**

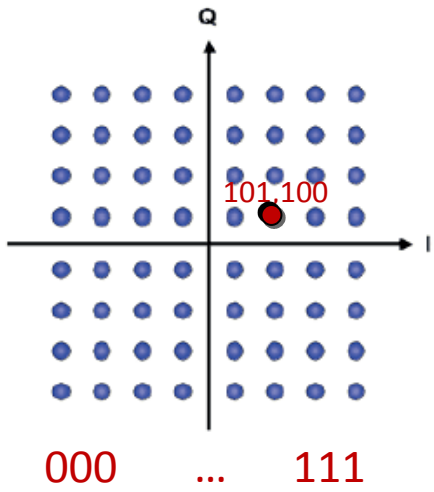
Modulation Schemes



QPSK
- 2 bits/symbol

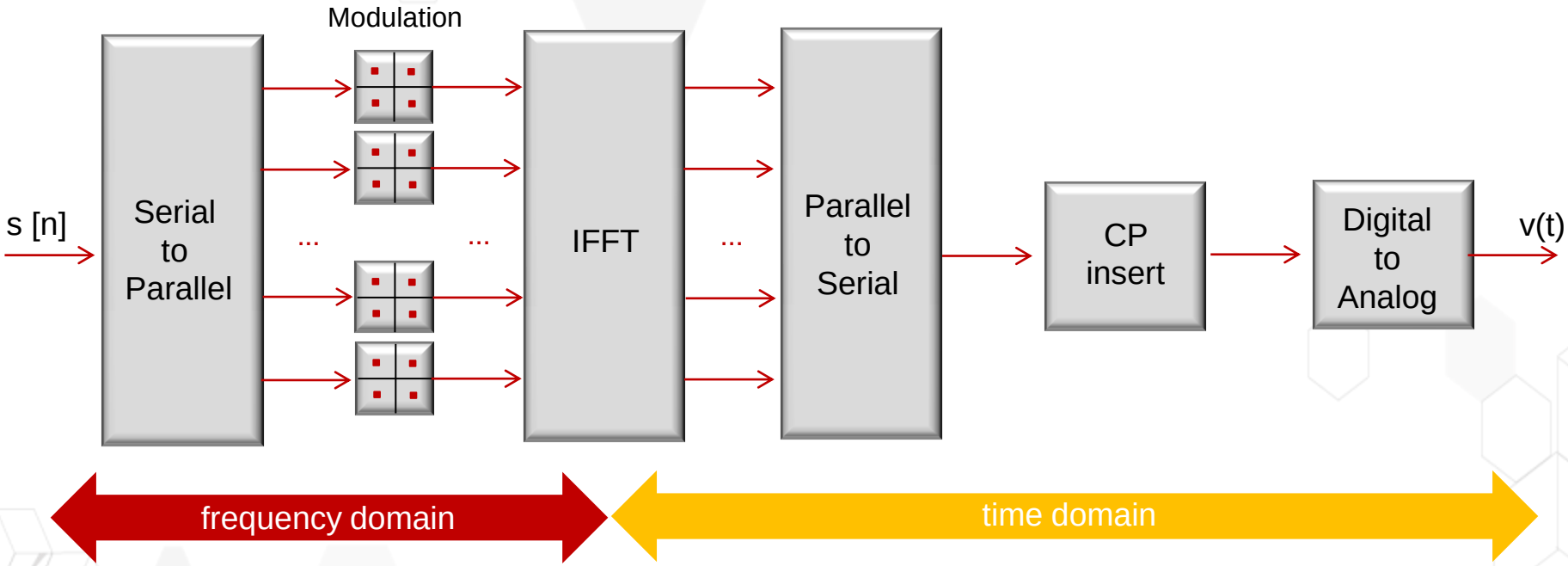


16 QAM
- 4 bits/symbol



64 QAM
- 6 bits/symbol

OFDM Transmitter

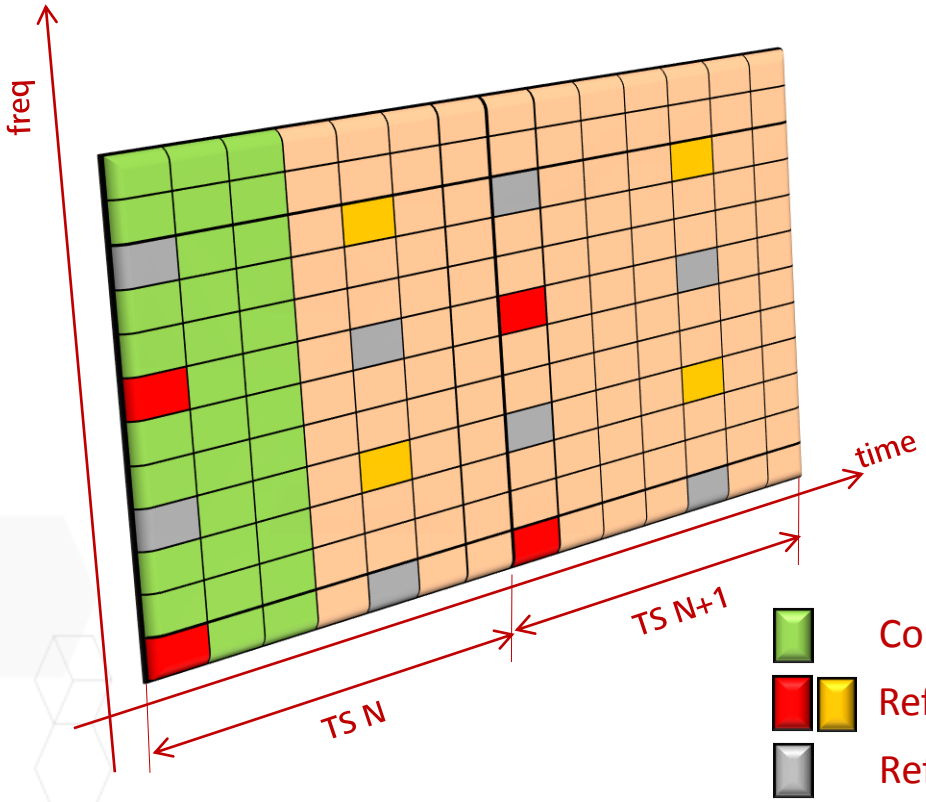


MIMO technology

- Different data streams sharing same frequency and time
- 3GPP Standard consider different MIMO combination 2x2, 4x2 , 4x4,.. which can theoretically increase 2-4 times the throughput of a single transmission
- For MIMO 2x2 (2 antenna ports at Transmitter and 2 RX antenna porta at receiver), the common implementation is to use the two different polarization of a X-pol antenna

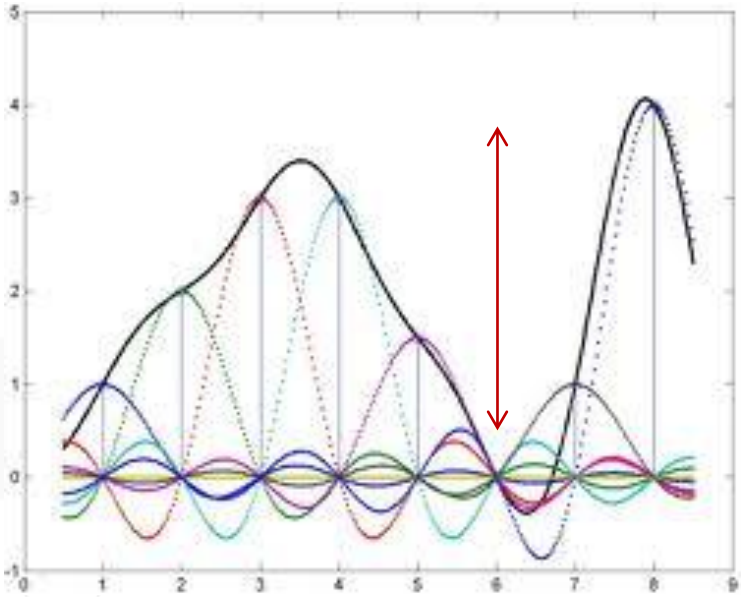
Control Resources and Reference Signals

- The first 3 OFDM symbols of every second TS (with exception of Reference Elements) are used for control channels.



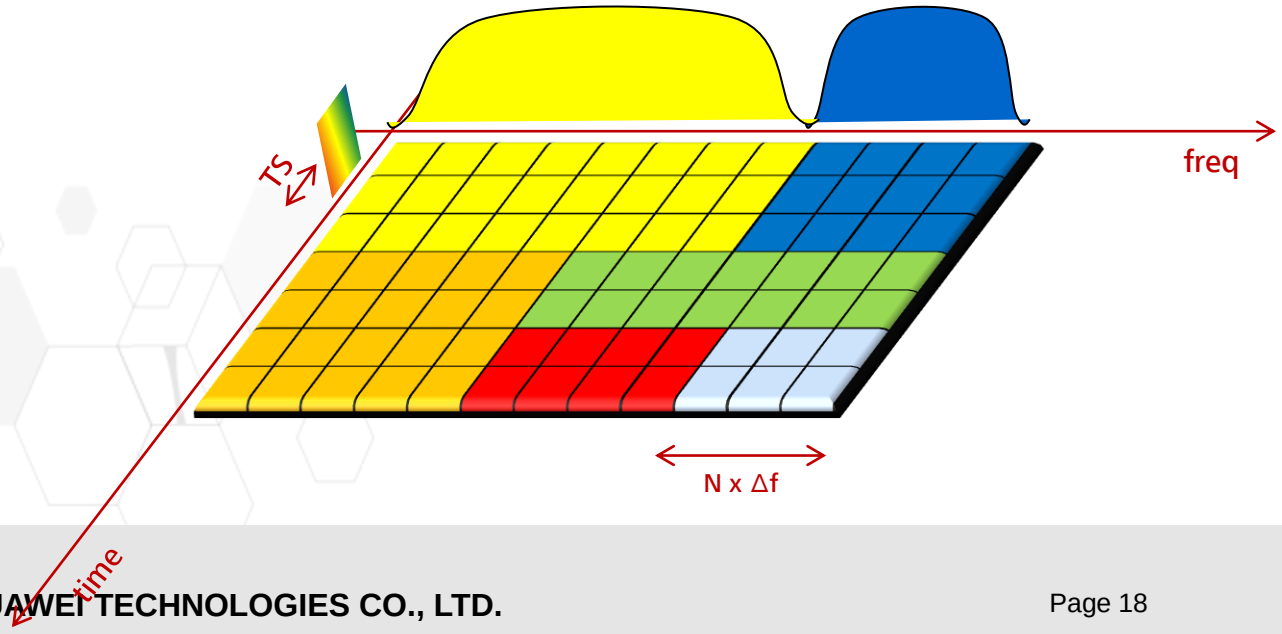
OFDM – Peak to Average Power Ratio

- OFDM signals have a higher peak-to-average ratio (PAR)—often called a peak-to-average power ratio (PAPR)—than single-carrier signals do. The reason is that I
- In time domain, a multicarrier signal is the sum of many narrowband signals., thus OFDM symbols have a higher peak-to-average power ratio (PAPR)
- High value of PAPR implies high level of linearity and power consumption for transmitters. This can be critical for UEs.
- In UPLINK a slight different mechanism of OFDM has been developed, called Single Carrier FDMA

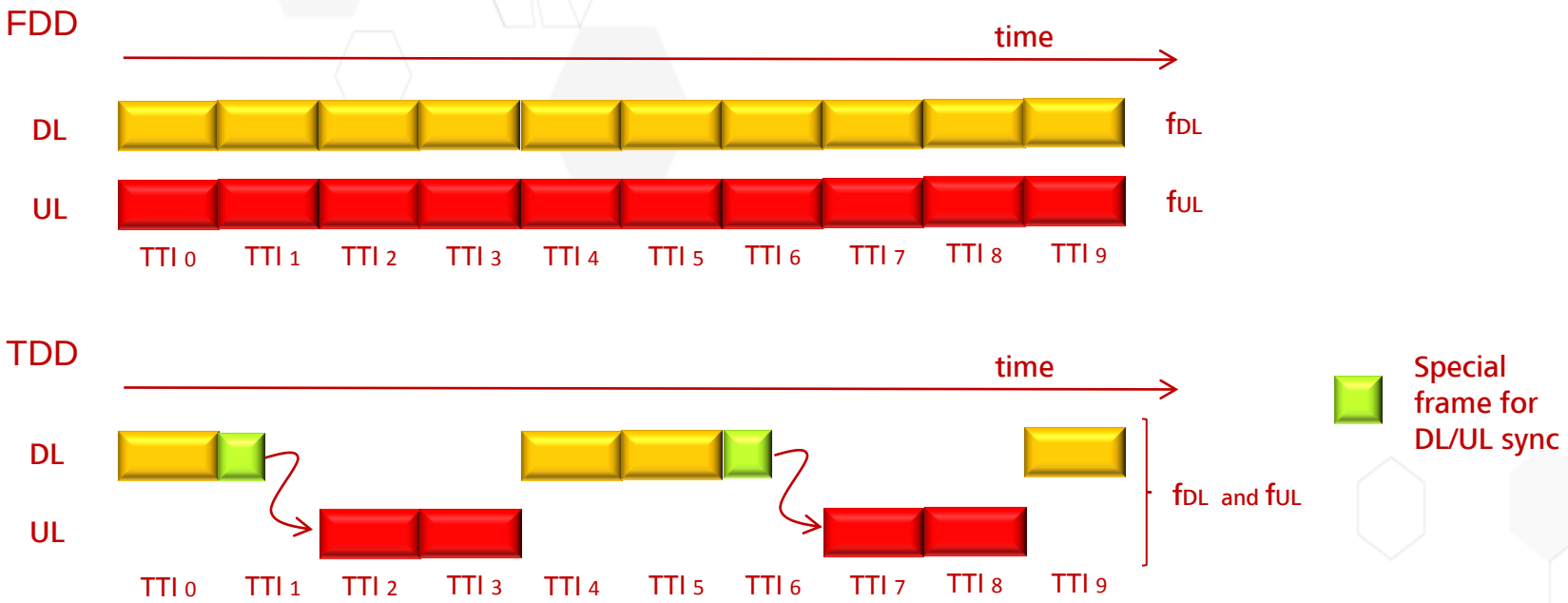


Single Carrier FDMA (UL)

- SC-FDMA can be viewed as a special OFDMA system with the user's signal pre-encoded by discrete Fourier transform (DFT), hence also known as DFT-pre-coded OFDMA or DFT-spread OFDMA.
- One prominent advantage of SC-FDMA over OFDMA is the lower PAPR (peak-to-average power ratio) of the transmit waveform , which benefits the mobile users in terms of battery life and power efficiency.
- The same modulation schemes of DL are considered for UL, but currently UEs don't support yet 64QAM (Cat 5)



FDD and TDD frame structure

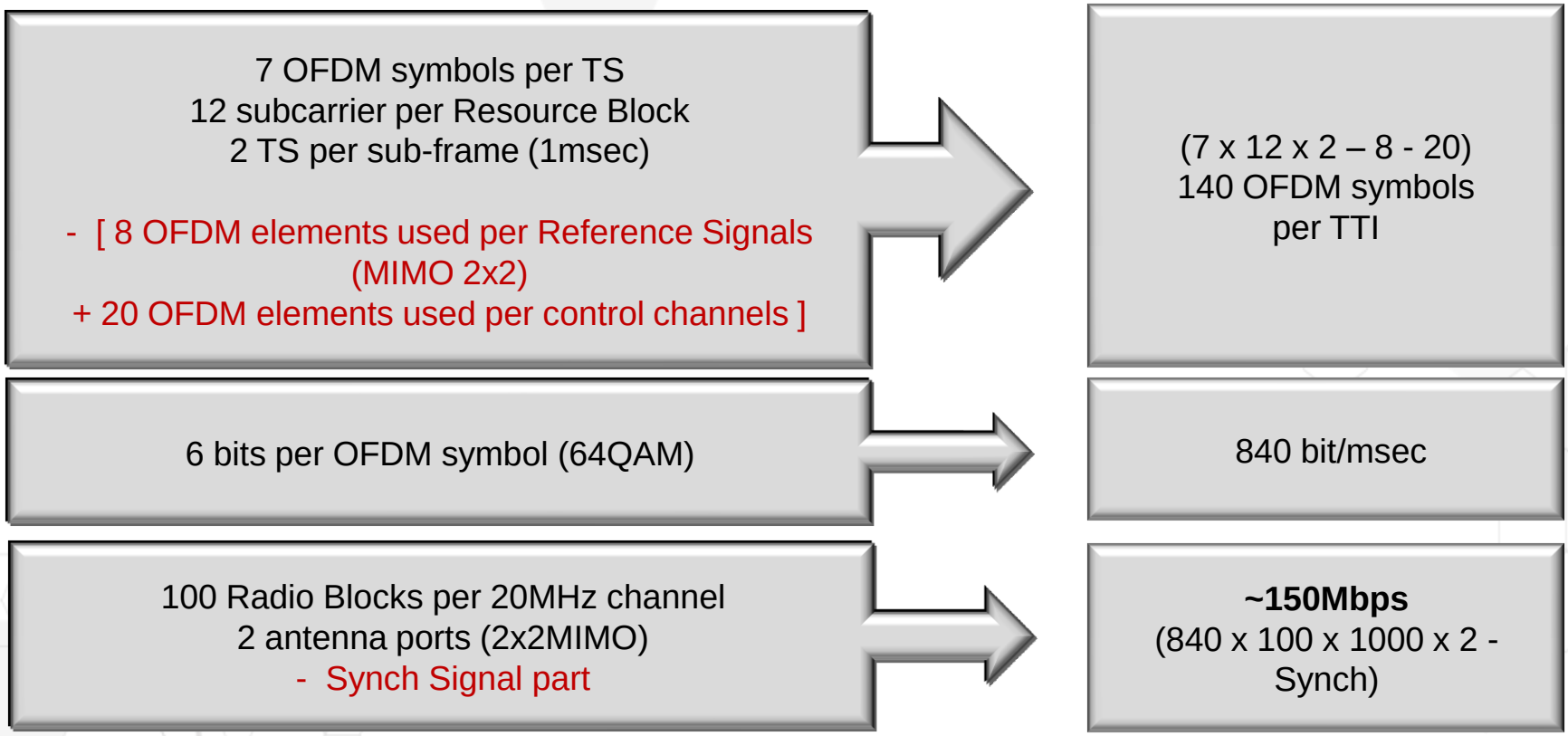


- The sampling rate in both FDD and TDD is the same and both technologies operate under a 1-ms sub-frame and 0.5ms timeslot definition.
- Main differences between the two modes are
  - Frame 0 and frame 5 (always downlink in TDD)
  - Frame 1 and frame 6 is always used as for synchronization in TDD
  - Frame allocation for Uplink and Downlink is settable in TDD
- Several frame combinations are defined for TDD standard

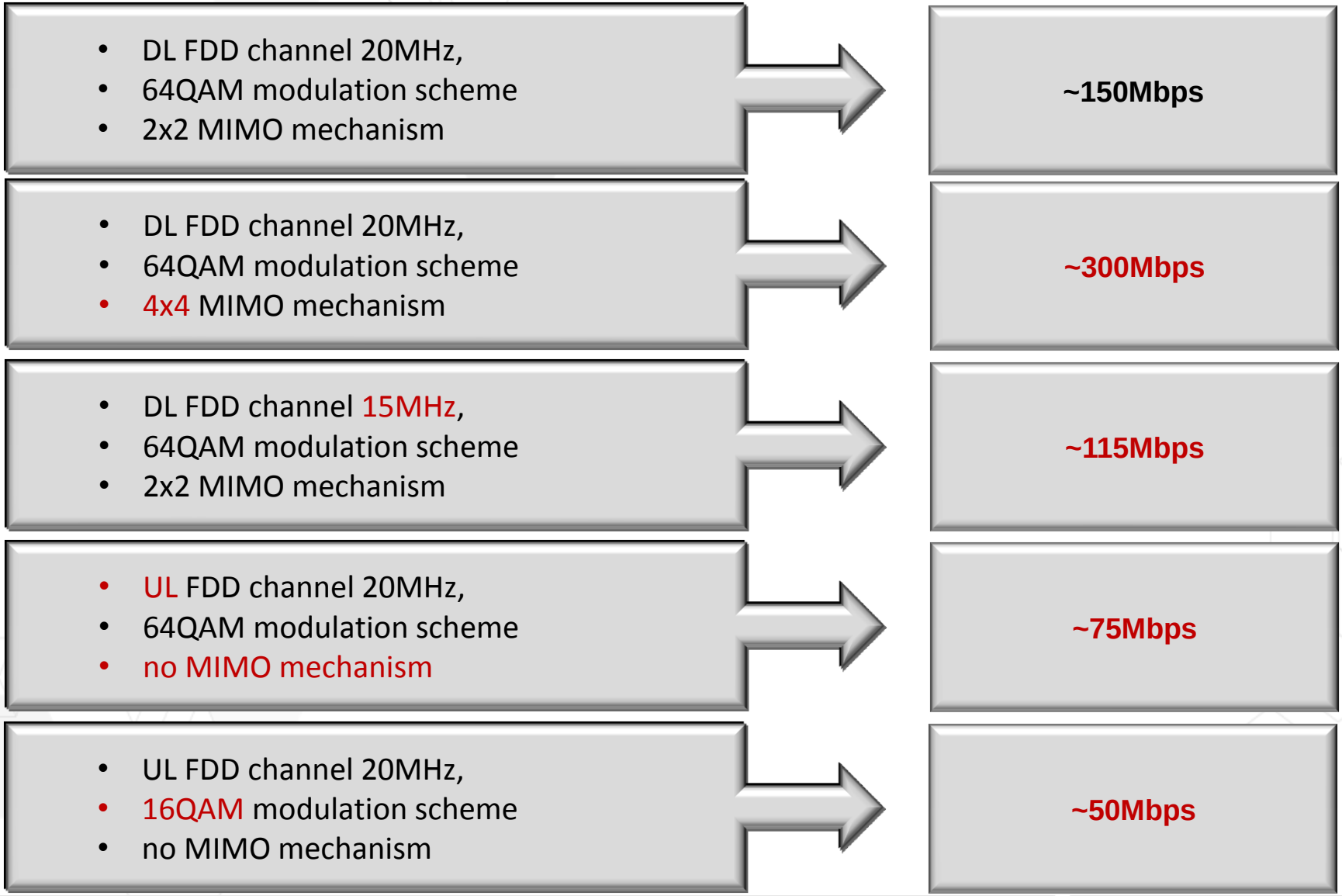
LTE FDD DL peak throughput - calculation example

Working assumption:

- FDD channel 20MHz,
- 64QAM modulation scheme
- 2x2 MIMO mechanism



LTE FDD peak throughput - examples



Note: Cat 3 UE support 100/50Mbps (DL/UL)

Contents

Part I

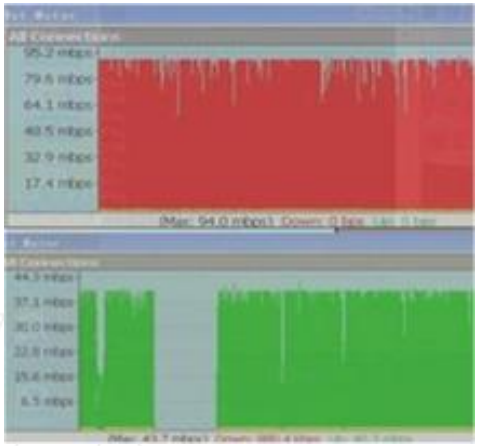
- LTE Regulation
- LTE Market
- LTE Ecosystem

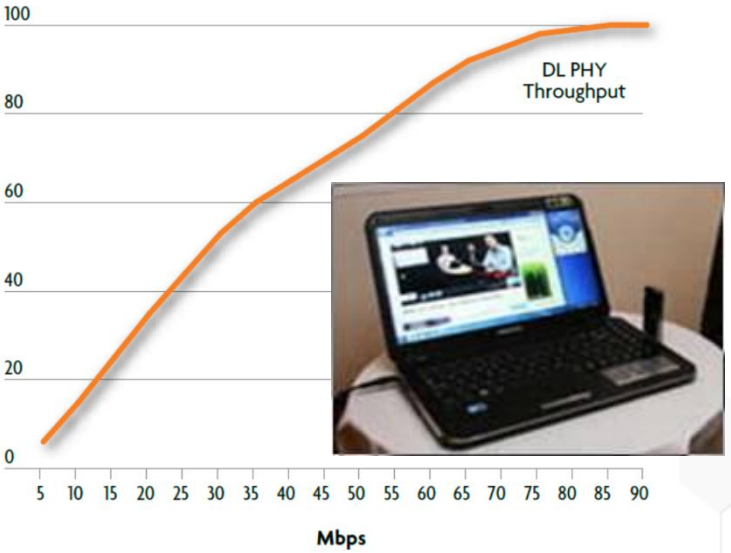
Part II

- LTE basics
- LTE field performance
- Interference
- LTE –A evolution

Field results – an example

- **LTE commercial networks already launched in Dec 2009 in Scandinavia**
- **Peak throughput of 100Mbps** reached in early stage deployment, already in 2010
- Average throughput have continuously been improved



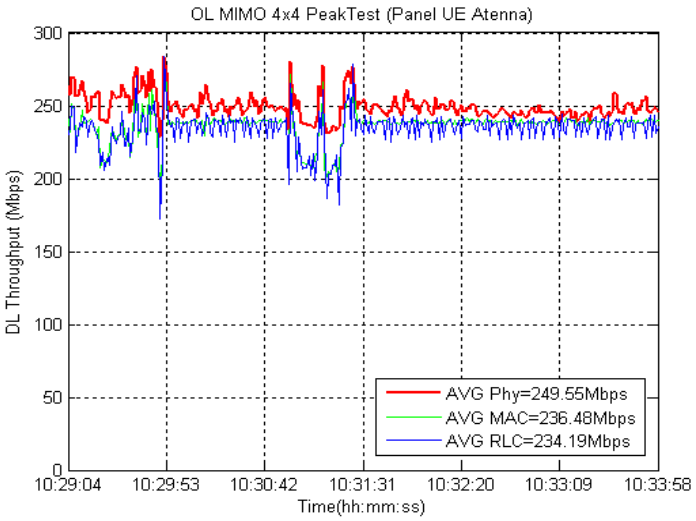


Oslo network in February 2010 reported by TeliaSonera
Source: Signals Research Group
(Signals Ahead publication, March 2010).

DL Peak Data throughput ~100Mbps, DL average throughput > 30Mbps

4x4 MIMO field trial

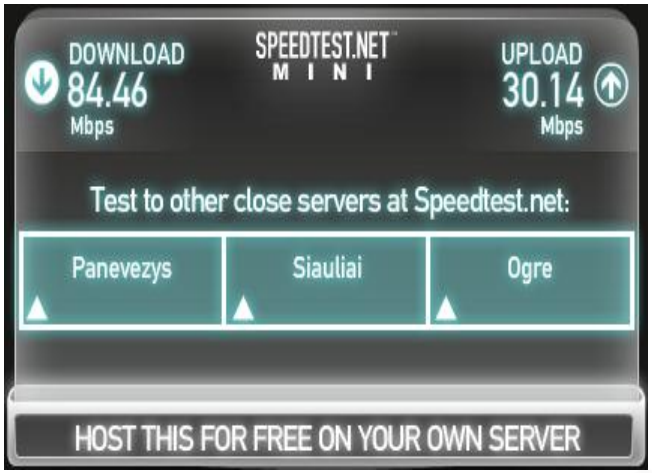
- **World's 1st LTE 4x4 MIMO field trial on commercial LTE network** using Huawei SingleRAN LTE solution **in 2011**
- Downlink performance **stable peak throughput of 250Mbps** reached with Huawei test UE Cat5
- Uplink performance is improved significantly through UL 4Rx tested

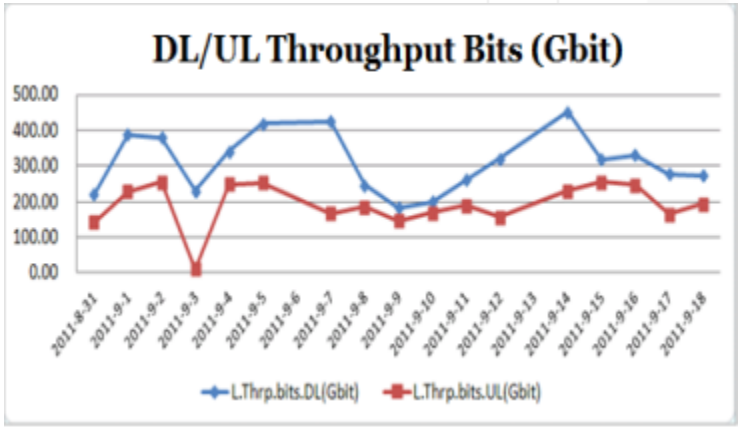


Data throughput ~250Mbps

First high loaded LTE event

- World's 1st time to serve top International Sports Game - European Basketball Championship of 2011 with a commercial LTE ntw
- **DL 85Mbps, UL 33Mbps** rate achieved throughout the game period in all arenas & gymnasiums
- **Many users in each LTE cell (> 10 rich data user)**
- Huge traffic burst in busy hours: **>50Gb per hour per gymnasium before & after game**





Stable performance under heavy load traffic.

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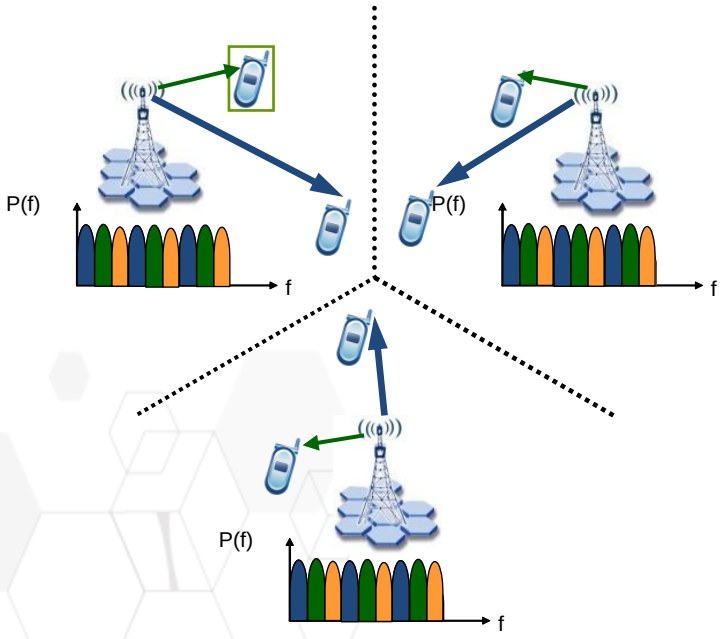
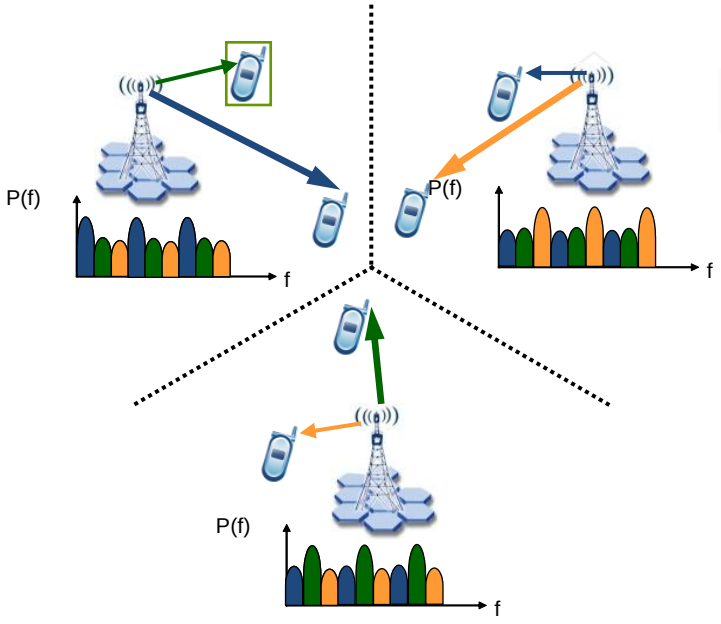
Inter-Cell Interference Coordination (ICIC)

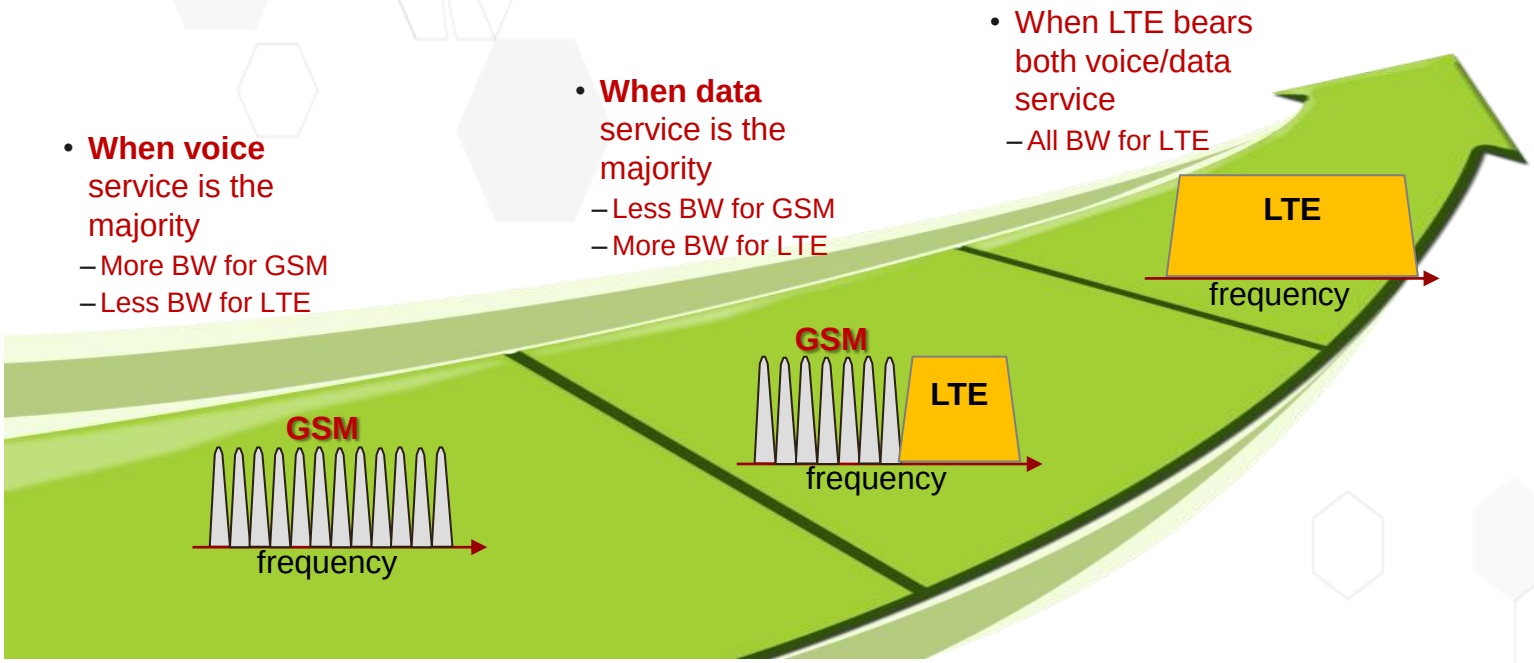
Without ICIC: eNBs use the same frequency segments with high power which may cause high inter-cell interference



With ICIC: eNBs use different segments with high power to reduce the inter-cell interference

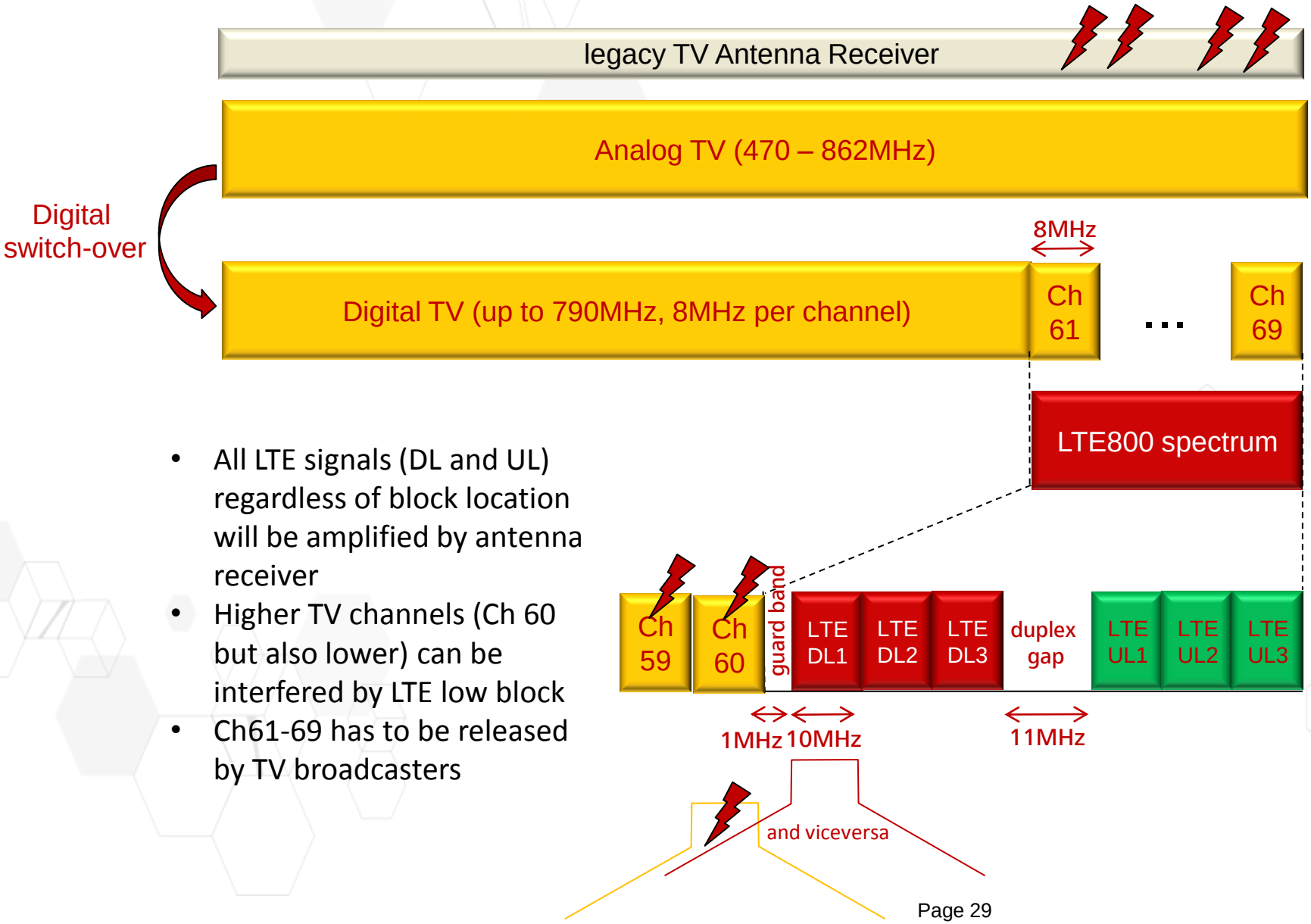


Band 1800MHz – Multi Standard Radio



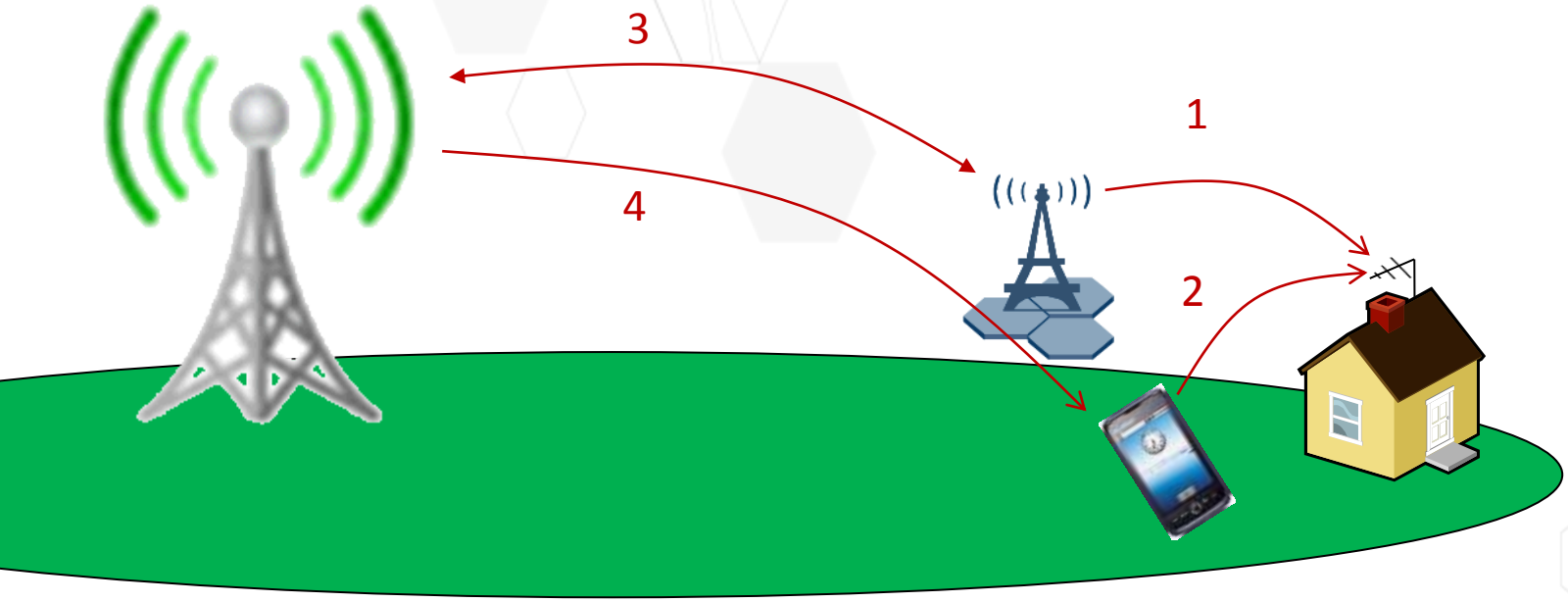
- Multi Standard Radio (MSR) enables the flexible spectrum sharing between GSM and LTE (or UMTS)
- With MSR introduction, spectrum can be flexibly shared between GSM and LTE according to voice / data traffic load or operators' strategies.
- MSR (contiguous spectrum) standard was approved by ETSI in Jul,2011

Band 800MHz issues



- All LTE signals (DL and UL) regardless of block location will be amplified by antenna receiver
- Higher TV channels (Ch 60 but also lower) can be interfered by LTE low block
- Ch61-69 has to be released by TV broadcasters

LTE – TV interference



Case 1-2

The DVB-T receiver detects and amplifies all the signal at antenna including the LTE DL and UL due to a wide band RX filter which covers all the current DVB-T band. The worst situation is when TV signal is low and LTE signal is high and aligned with TV TX antenna

Case 3

The LTE BTS receives out-of-band emission from TV Transmitter. The worst situation is when LTE BTS is close and pointing to TV transmitter (one cell impacted)

LTE – TV interference solutions

The natural solution is to apply extra filters at LTE BTS and/or TV receivers

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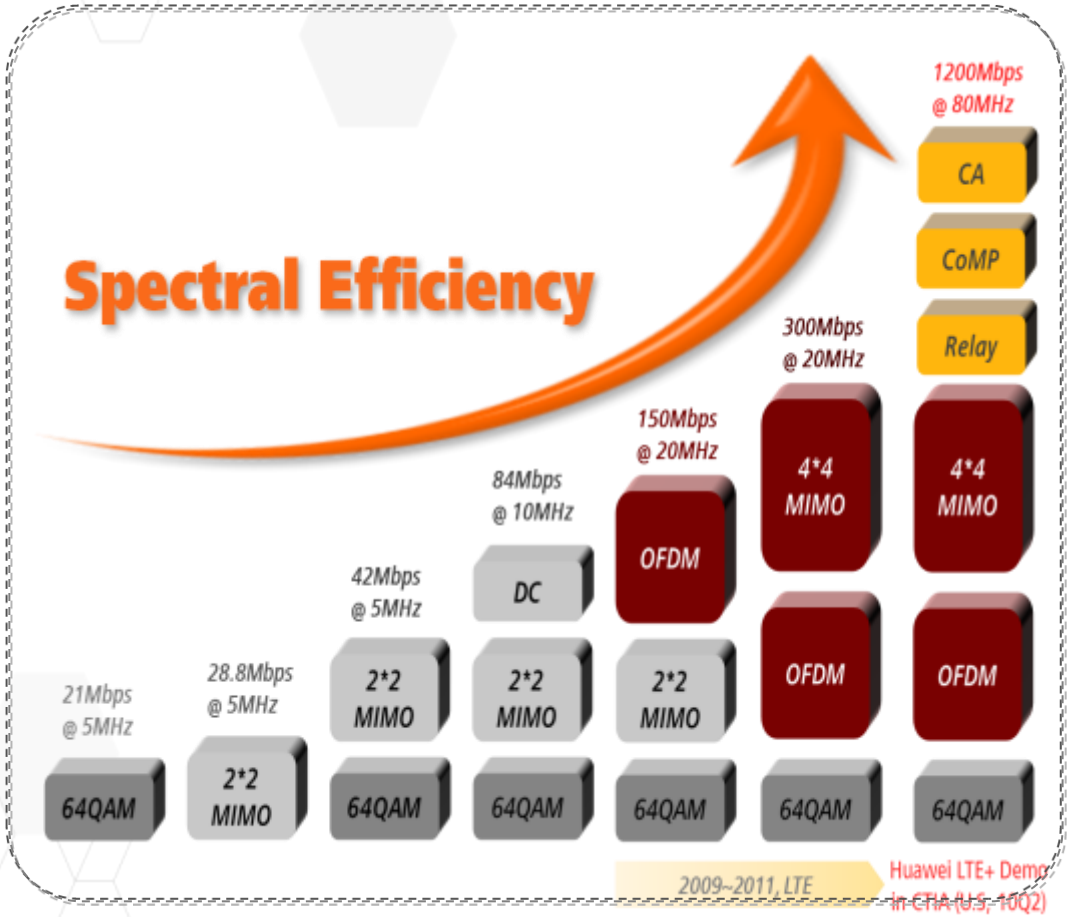
Radio Interface evolution



Carrier Aggregation

- **Concept**

  Multiple carriers can be utilized for transmission simultaneously

- **Benefit**

  Wider frequency resources (up to 100MHz) can be utilized for high-rate transmission

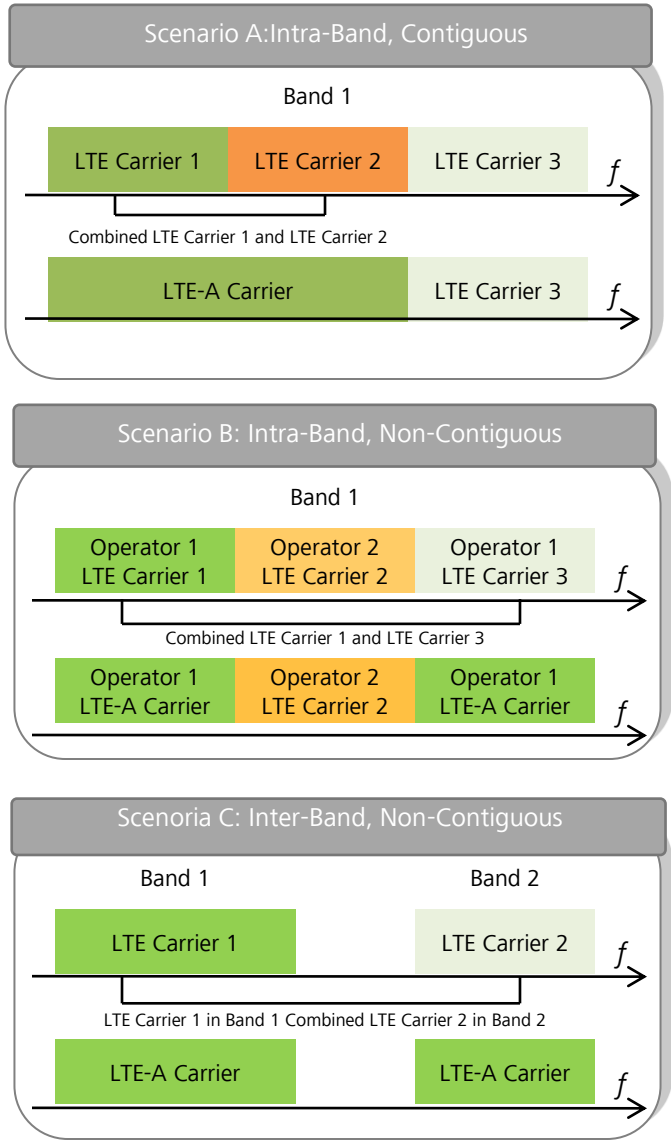
- **Features**

  Backward compatibility

  - Each component carrier can be regarded as one LTE carrier for LTE (Rel. 8) UEs

  Flexible aggregation

  - Several scenarios can be applied according to available spectrum resources (inter-band or intra-band)



High-order MIMO

- **Concept**

  More antennas can be deployed in UEs and eNBs to improve spectrum efficiency

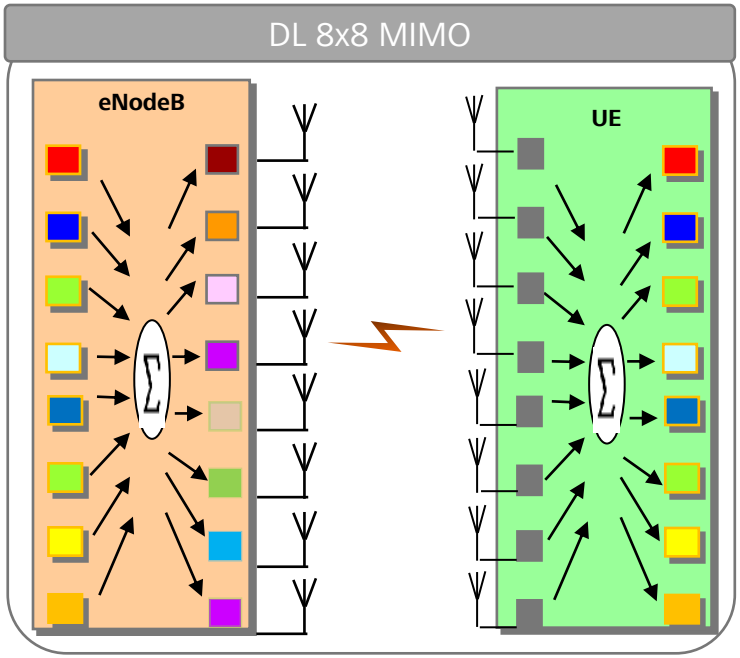
- **Benefit**

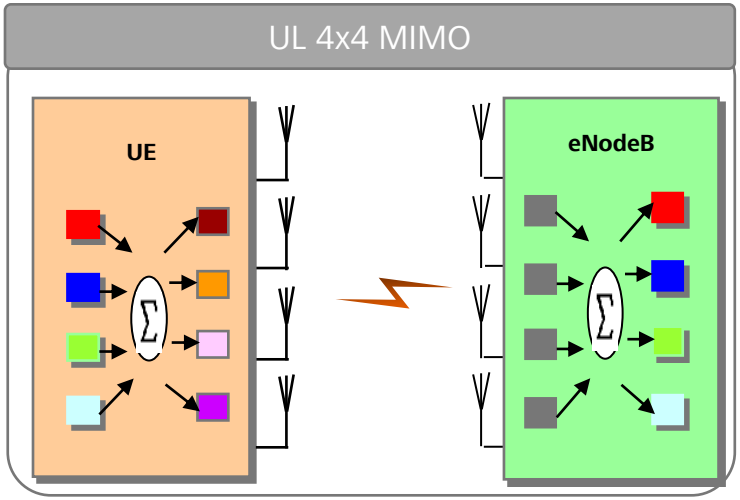
  Higher spectrum efficiency

- **Feature**

  Uplink: spatial multiplexing with up to 4x4 MIMO

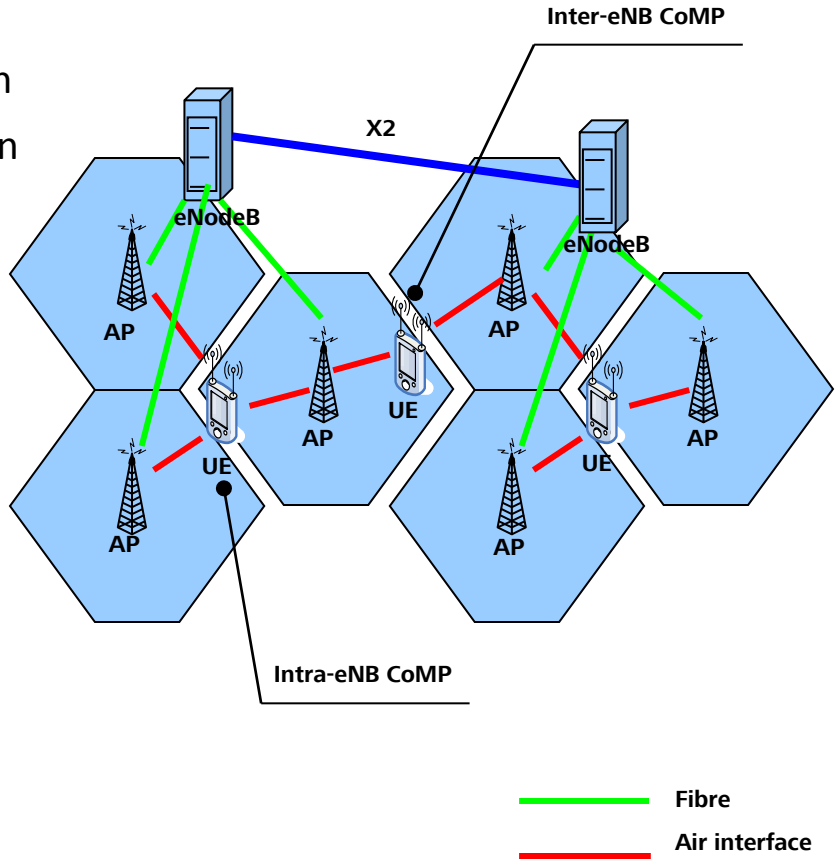
  Downlink: increase spatial multiplexing with up to 8x8 MIMO





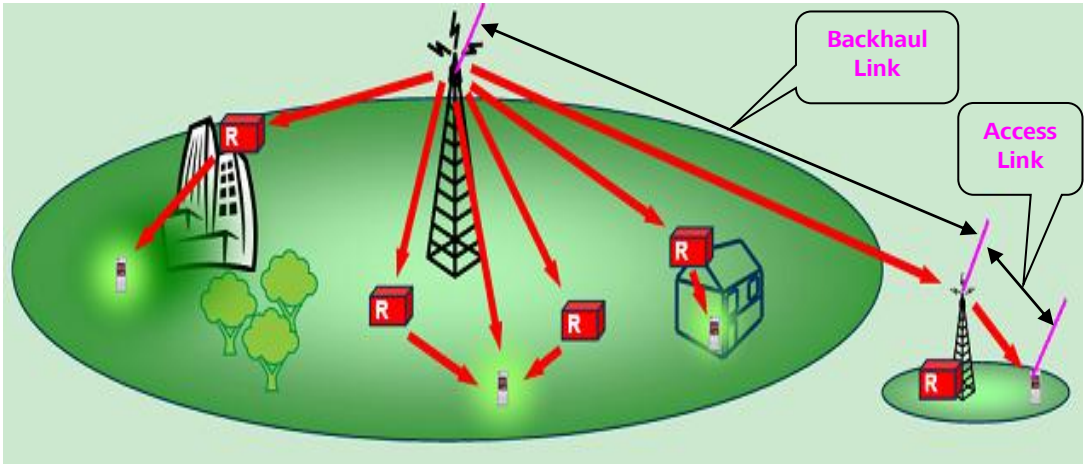
CoMP

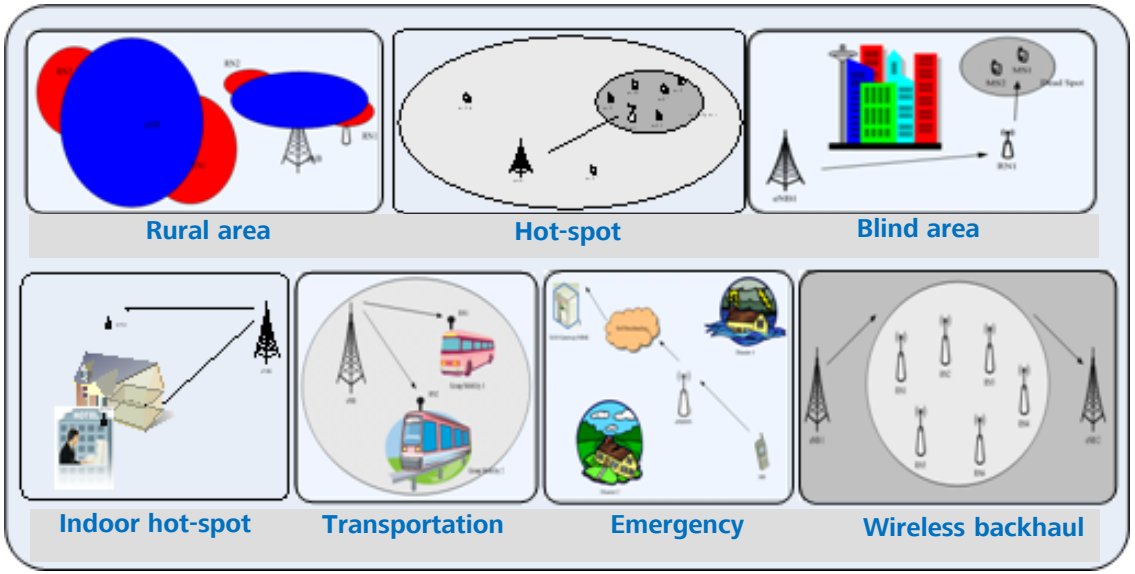
- **Concept**
  - Multiple geographically separated transmission points are coordinated to improve transmission to one UE
- **Benefit**
  - Interference from other transmission points is utilized to improve transmission
    - Improve SNR
    - Reduce inter-cell-interference
- **Feature**
  - Downlink CoMP: requires feedback of channel information to eNB
  - Uplink CoMP: easy to implement
  - Intra-eNB CoMP: low requirement to backhaul
  - Inter-eNB CoMP: high flexibility, large improvement



Relay

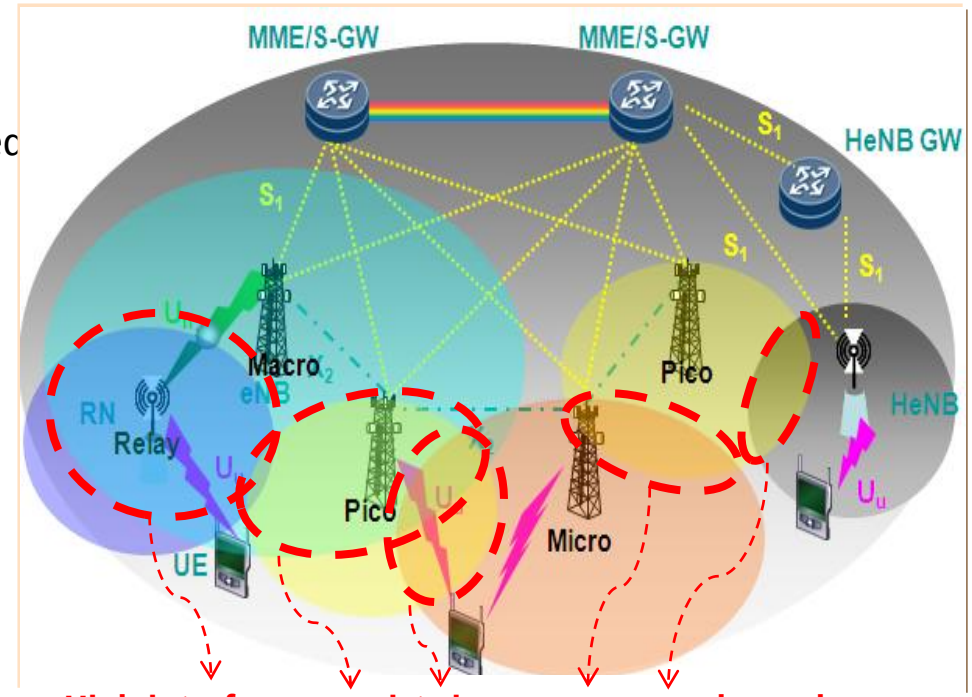
- **Concept**
  - Relay node is wirelessly connected to radio-access network via a donor cell
- **Benefit**
  - Relaying is considered for LTE-A to improve:
    - Cell-edge throughput
    - Coverage extension
    - Temporary network deployment
    - Coverage of high data rates
- **Feature**
  - Abundant application scenarios





Enhanced ICIC

- **Concept**
  - Enhanced ICIC for non-CA based deployments of heterogeneous networks for LTE
    - To reduce high inter-cell-interference (ICI) in coverage overlapped areas
- **Benefit**
  - Support highly variable traffic load
  - Support increasingly complexity and network deployments with unbalanced transmit power nodes sharing same frequency
- **Feature**
  - Low power nodes include
    - Remote radio head (RRH)
    - Pico eNB
    - Home eNB (HeNB)
    - Relay nodes



High interference exists in coverage overlapped areas

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Thank you

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