INTERFERENCE MANAGEMENT WITHIN 3GPP LTE ADVANCED

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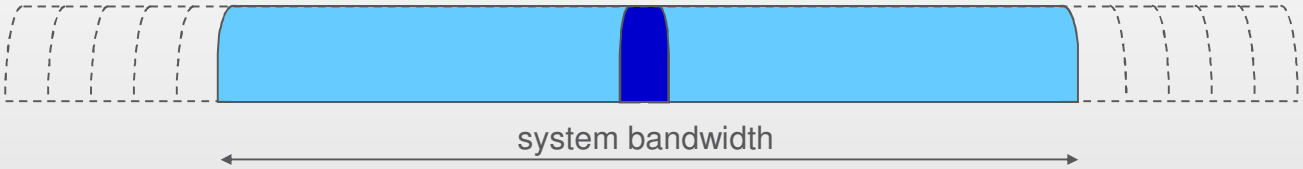
OUTLINE

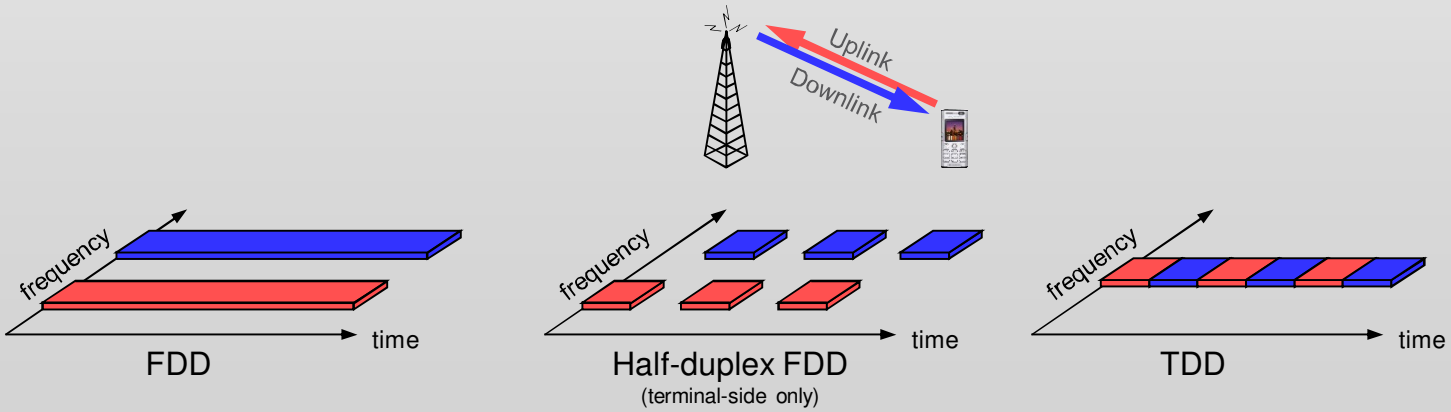
- Introduction to 3GPP LTE (Advanced)
  - Spectrum
  - Radio Frame Structure
  - OFDM, SC-FDMA
- Interference Management
  - Goal of interference management in cellular systems
  - Sources of interference within 3GPP LTE Advanced
    - Inter-system Interference
    - Intra-LTE Interference
      - Inter-Cell Interference
- Inter-Cell Interference Coordination (ICIC)

LTE – *SPECTRUM FLEXIBILITY*

- Operation in differently-sized spectrum allocations
  - From 1.4 MHz to 20 MHz (3GPP Release 8 & 9)



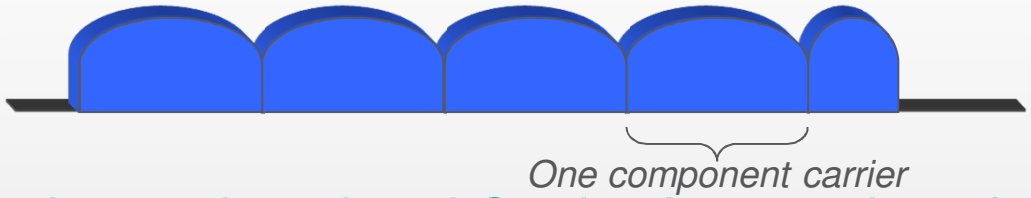
- Support for paired *and* unpaired spectrum allocations



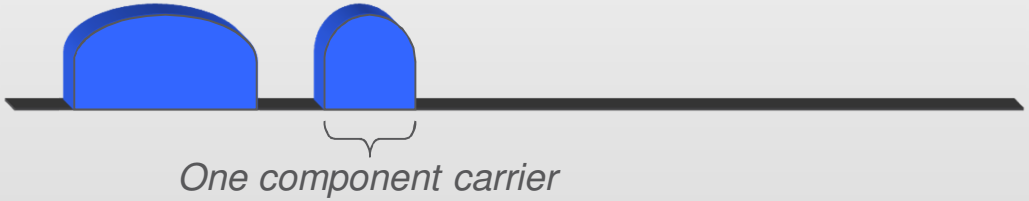
CARRIER AGGREGATION – RELEASE 10

INTRA- AND INTER-BAND CARRIER AGGREGATION

- Contiguous Carrier Aggregation of up to 5 component carriers in each direction



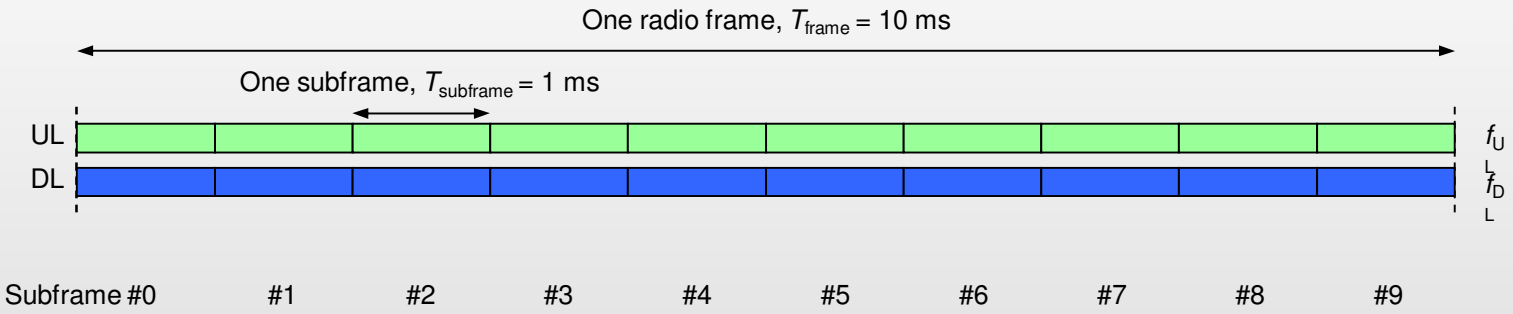
- Non-contiguous intra-band Carrier Aggregation of up to 5 component carriers in each direction



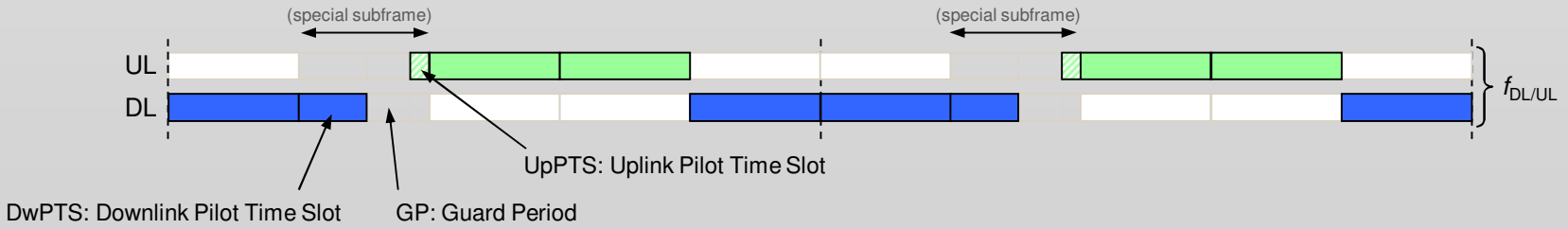
- Inter-band Carrier Aggregation (a.k.a. spectrum aggregation) of up to 5 component carriers in each direction

TIME-DOMAIN STRUCTURE

- FDD
  - Uplink and downlink separated in frequency domain



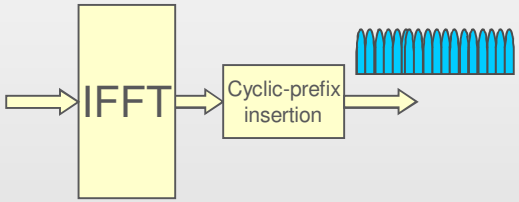
- TDD
  - Uplink and downlink separated in time domain ➡ "special subframe"
  - Same numerology etc as FDD ➡ economy of scale



TRANSMISSION SCHEME

Downlink – OFDM

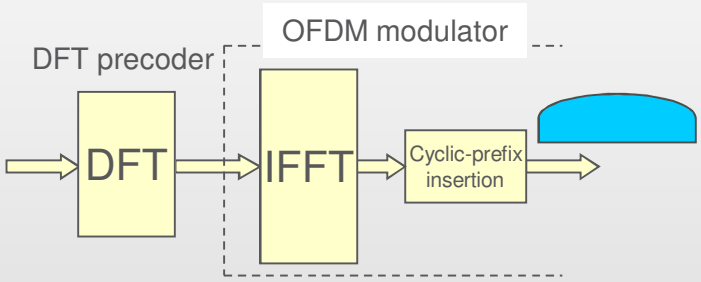
- Parallel transmission on large number of narrowband subcarriers



- Benefits:
  - Avoid own-cell interference
  - Robust to time dispersion
- Main drawback
  - Power-amplifier (PA) efficiency

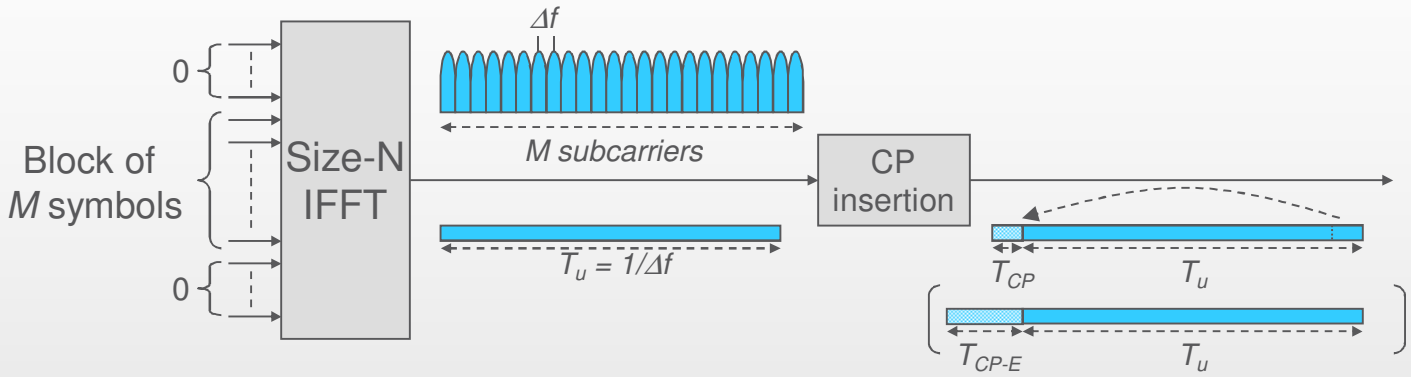
Uplink – DFTS-OFDM

- DFT-precoded OFDM



- Tx signal has single-carrier properties
  ⇨ *Improved power-amplifier efficiency*
  - Improved battery life
  - Reduced PA cost
- **Critical for uplink**
- Equalizer needed ⇨ Rx Complexity
  - **Not critical for uplink**

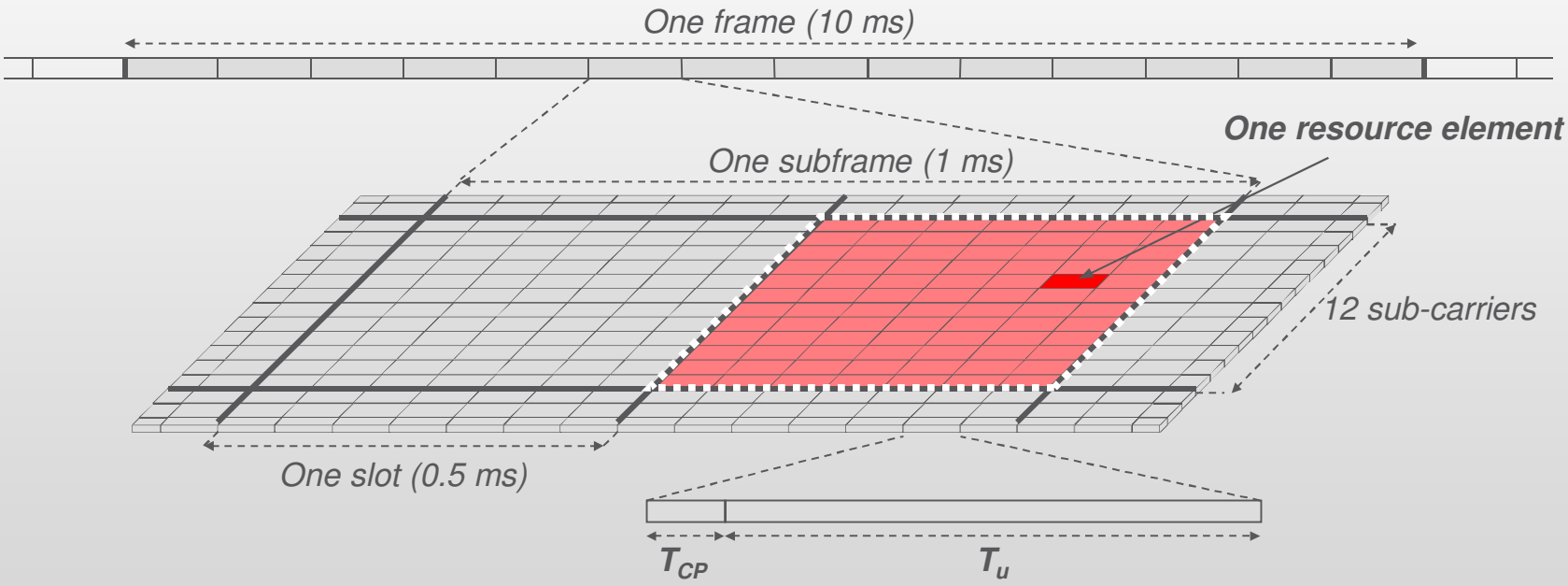
DOWNLINK – OFDM



- Parallel transmission using a large number of narrowband "sub-carriers"
- "Multi-carrier" transmission
  - Typically implemented with FFT
- Insertion of cyclic prefix prior to transmission
  - Improved robustness in time-dispersive channels – *requires CP > delay spread*
  - Spectral efficiency loss

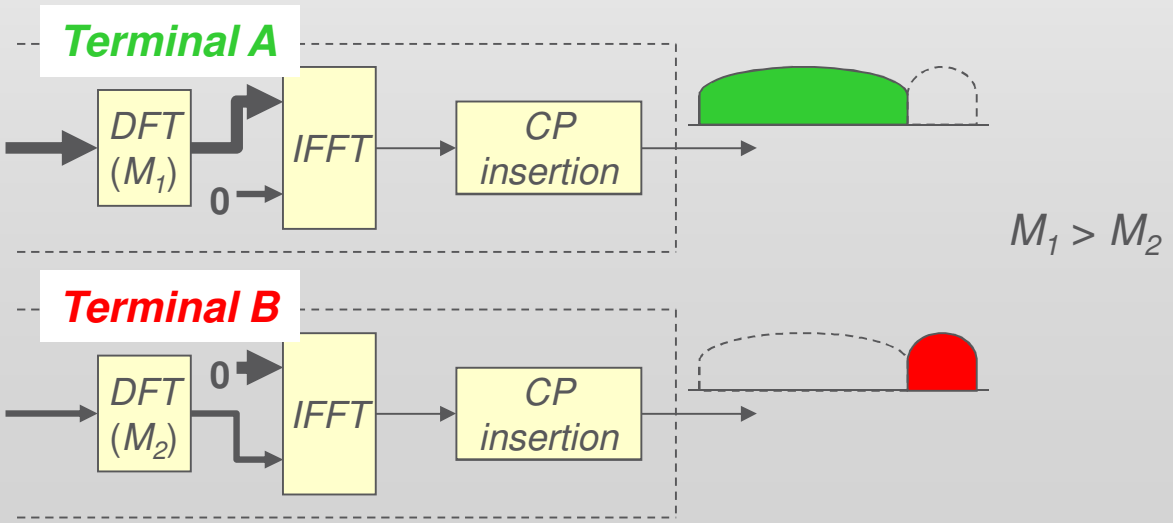
Configuration, Δf		CP length	Symbols per slot
Normal	15 kHz	≈4.7 µs	7
Extended	15 kHz	≈16.7 µs	6
	7.5 kHz	≈33.3 µs	3

PHYSICAL RESOURCE



UPLINK – DFT-SPREAD OFDM ('SC-FDMA')

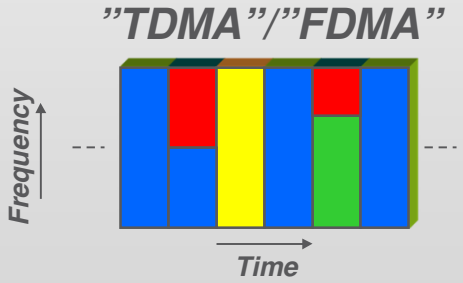
- Single-carrier uplink transmission ➡ efficient power-amplifier operation ➡ improved coverage
  - OFDM requires larger back-off than single-carrier
  - DFT-spread OFDM – OFDM with DFT precoder to reduce PAR
- Uplink numerology aligned with downlink numerology



UPLINK – DFT-SPREAD OFDM ('SC-FDMA')

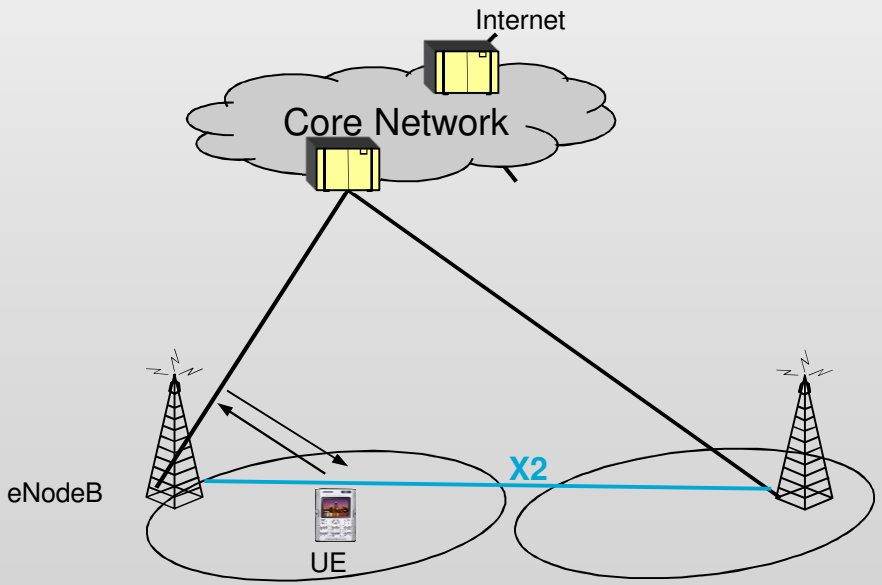
- Combined TDMA/FDMA ➡ intra-cell orthogonality
  - Scheduled uplink – NodeB scheduler controls resource allocation
  - Orthogonal uplink ➡ no intra-cell interference
  - Orthogonal uplink ➡ relaxed need for fast closed-loop power control

- Why FDMA component?
  - To support small payloads
  - To handle the case of power limitations

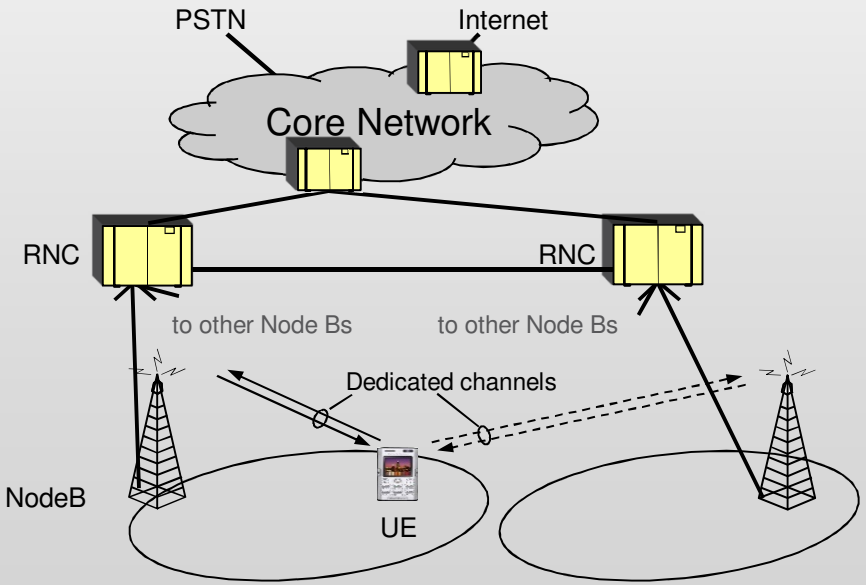


ARCHITECTURE

- Core network evolved in parallel to LTE
  - EPC – *Evolved Packet Core*
- Flat architecture, single RAN node, the *eNodeB*
  - Compare HSPA, which has an RNC



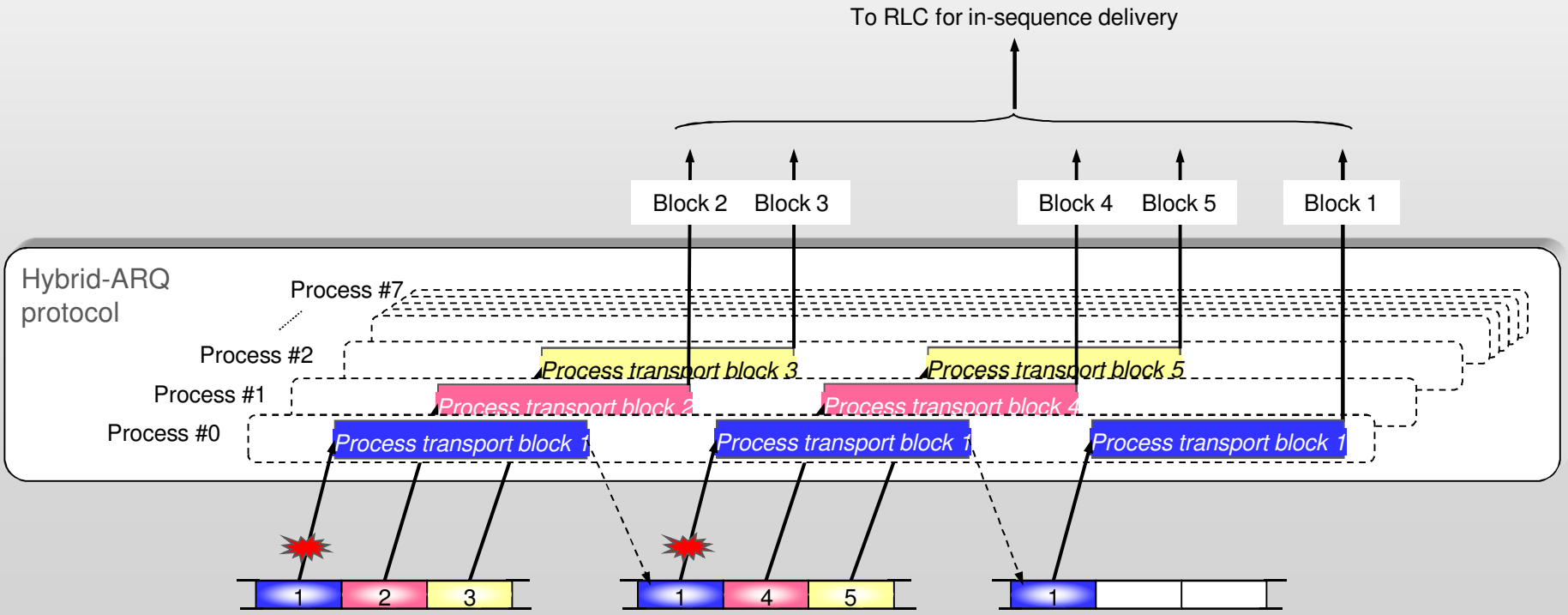
LTE



HSPA

HYBRID-ARQ WITH SOFT COMBINING

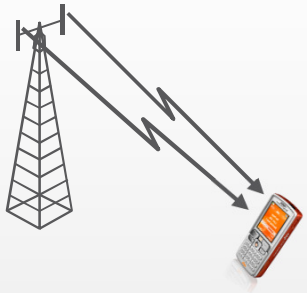
- Same basic structure as HSPA
  - Parallel stop-and-wait processes
  - 8 processes ➡ 8 ms roundtrip time



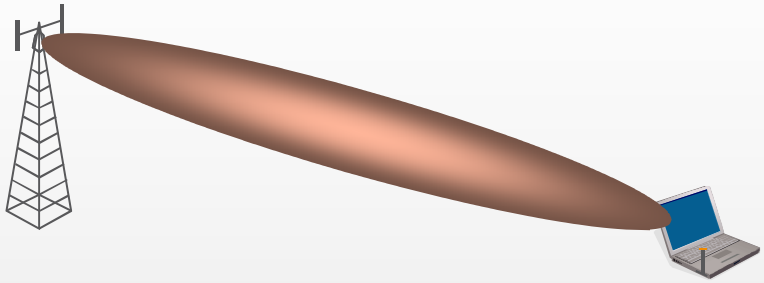
INTERACTION WITH RLC

- Why *two* transmission mechanisms, RLC and hybrid-ARQ?
  - Retransmission protocols need feedback
- Hybrid ARQ [**with soft combining**]
  - Fast retransmission, feedback every 1 ms interval
  - Frequent feedback ➡ need low overhead, single bit
  - Single, uncoded bit ➡ errors in feedback (~10^{-3})
- RLC
  - Reliable feedback (sent in same manner as data)
  - Multi-bit feedback ➡ less frequent
- Hybrid-ARQ and RLC *complement* each other

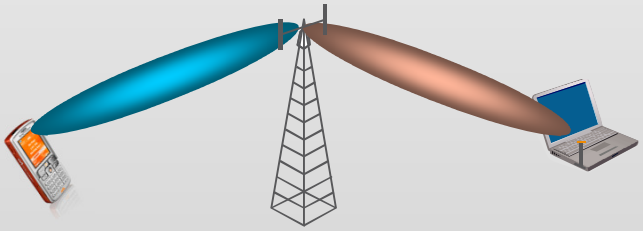
MULTI-ANTENNA TRANSMISSION TECHNIQUES



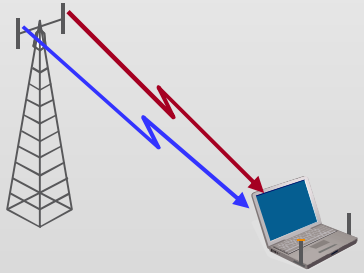
Diversity for improved system peformance



Beam-forming for improved coverage (less cells to cover a given area)



SDMA (or "Multi User MIMO") for improved capacity (more users per cell)

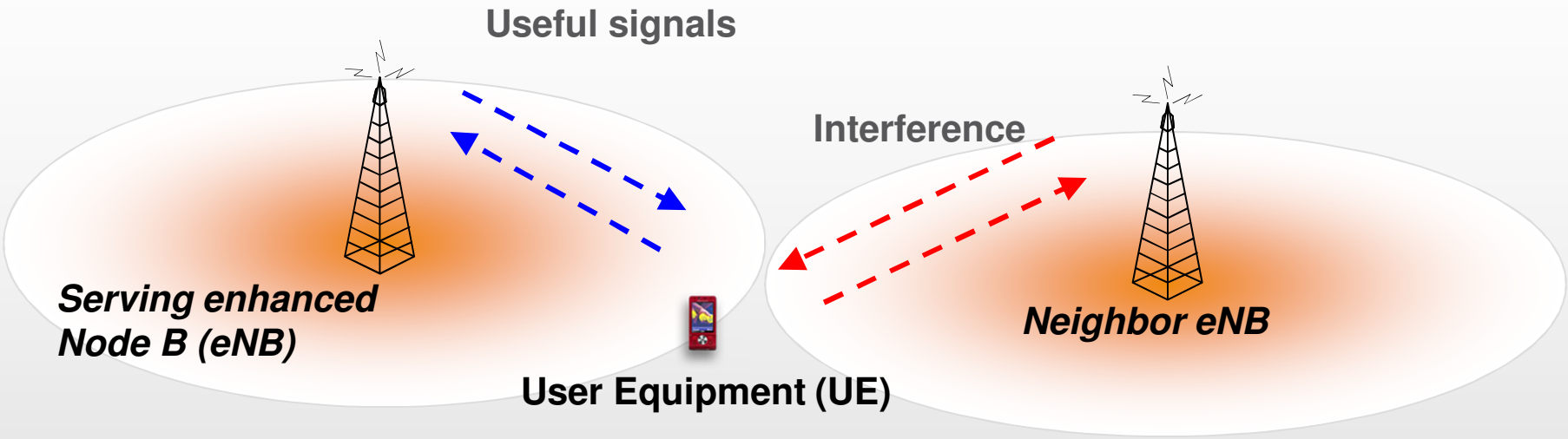


Multi-layer transmission (”MIMO”) for higher data rates in a given bandwidth

The multi-antenna technique to use depends on what to achieve

GOAL OF INTERFERENCE MANAGEMENT

INTERFERENCE WITHIN CELLULAR SYSTEMS



$$SINR = \frac{S}{I + N}$$

Useful Signal

Noise

Interference

Downlink

› Interference @ the UE

Uplink

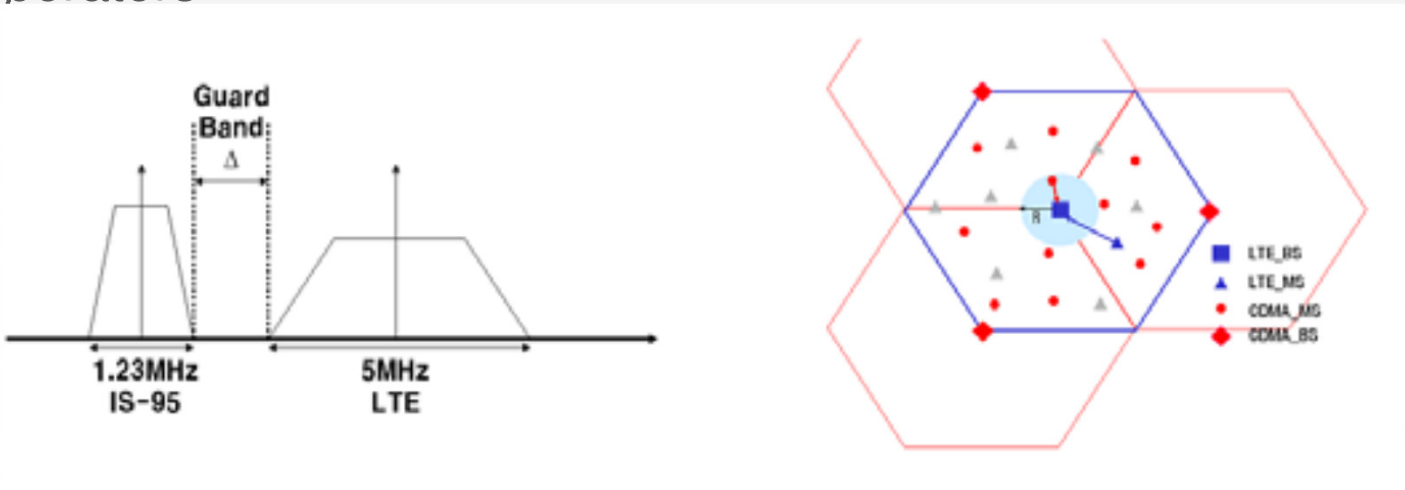
› Interference @ the eNB

Reduce interference so as to increase SINR

TYPES OF INTERFERENCE

TYPES OF INTERFERENCE

- Inter-system interference
  - From other cellular systems
    - E.g. from WCDMA, IS-95 or from bands belonging to other LTE operators



  - From other types of systems
    - E.g. TV or other broadcasting systems, satelite communications, radars
- Intra-LTE Interference
  - Inter-cell Interference

INTER-SYSTEM INTERFERENCE

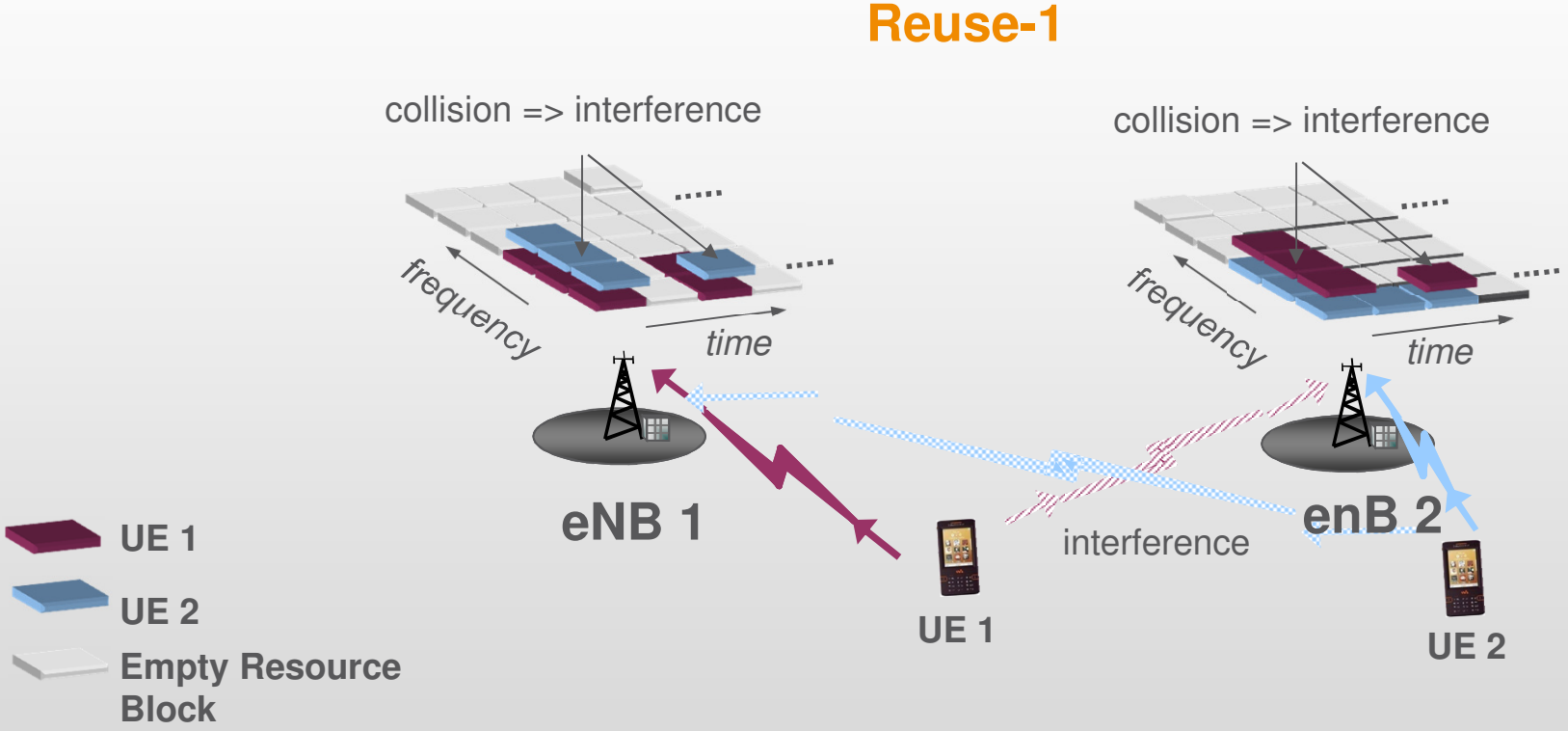
- Typically of steady nature
  - Exception: interference created by radars transmiting pulses/signals on certain time instants
- Either on the same frequency
  - "Co-channel interference" or
- On adjacent frequencies
  - "Adjacent channel interference"
    - Created by
    - hardware imperfections at the transmitter resulting in:
      - Out of Band/Spurious emissions
      - Adjacent Channel Leakage
    - Non-perfect filter at the receiver

SOLUTIONS TO INTER-SYSTEM INTERFERENCE

- Adjacent channel interference
  - Receiver blocking
    - Filtering
  - Guard bands
- Co-channel interference
  - Receiver Desensitization
  - Network Planning
  - Inter-system coordination

INTRA LTE INTERFERENCE

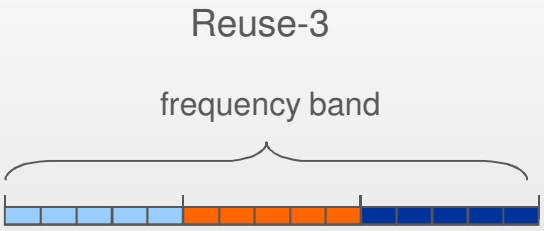
- Other-cell interference



- Independent scheduler operation may result in collisions
- For data: A collision typically leads to some SINR degradation; it does not necessarily mean information loss
  - Collisions more harmful to cell edge users

HOW CAN A COLLISION BE AVOIDED?

- Radio Resource Management (RRM)
  - Frequency Reuse (FR)



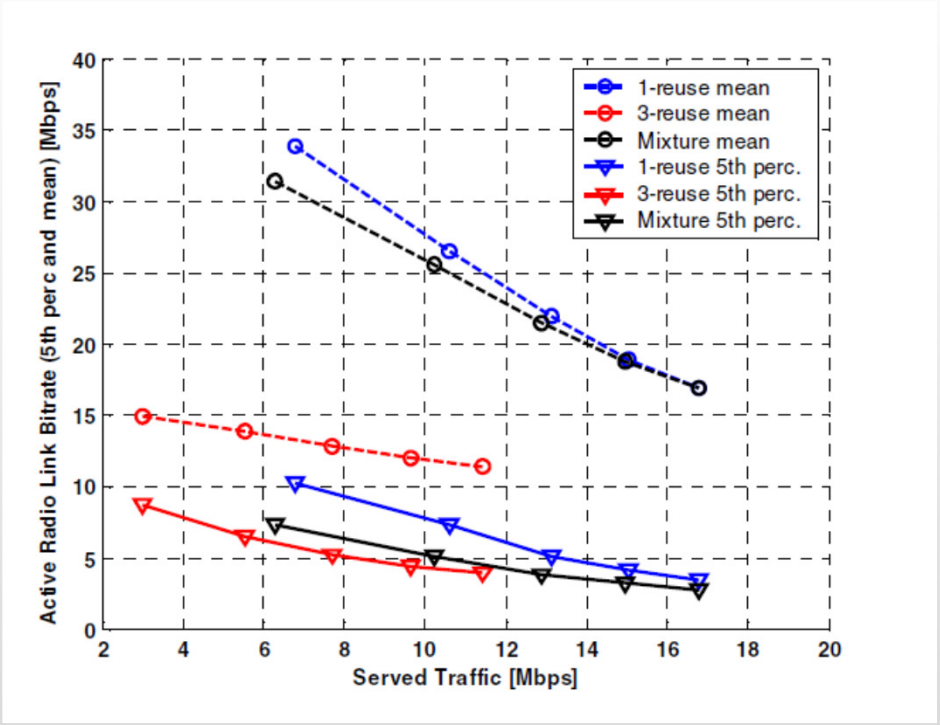
- Coordinated RRM
  - Joint scheduling

ICIC FOR DATA CHANNELS "COST" TRADE-OFF ANALYSIS

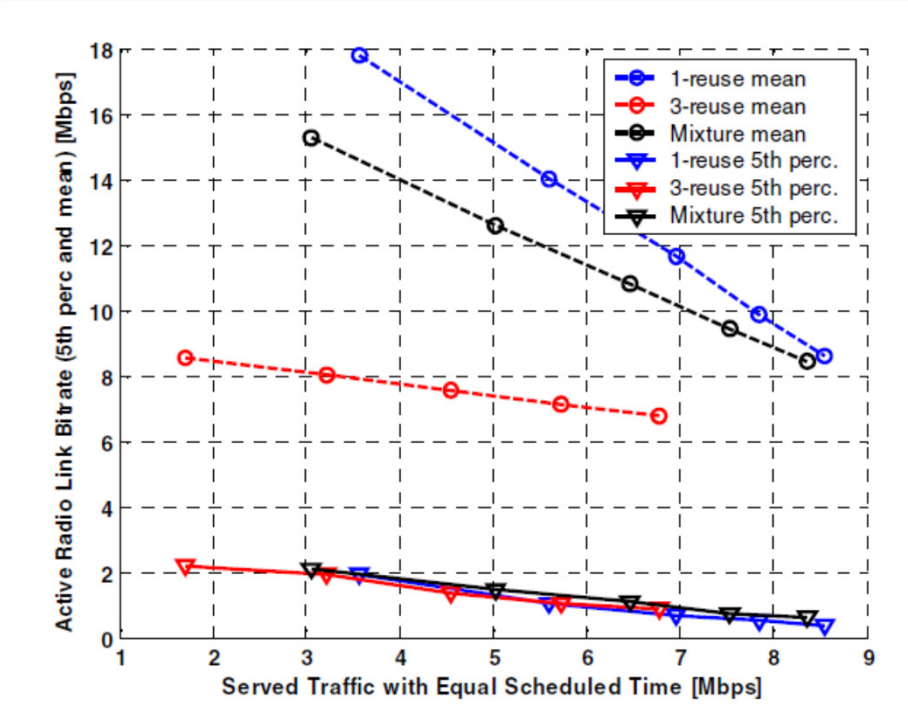
- "Cost" of a "collision"
  - Fewer user data bits can be carried in one PRB, as the link adaptation needs to select lower modulation order and/or lower coding rate to compensate the lower SINR
  - More HARQ retransmissions may be needed for successful data delivery (due to BER degradation)

- "Cost" of avoiding a collision
  - Bandwidth restriction: colliding PRBs may need to be banned from use in the neighbor cell or may be used only with restrictions (e.g., with lower power)
  - Delayed scheduling: the scheduling of some UEs (interfering or interfered UEs) may need to be postponed.

WHAT IS THIS RESULT OF THIS TRADE-OFF?



Downlink: 2X2, Maximum Ratio Combining (MRC)



Uplink: 1X1, Single Input Single Output (SISO)

Avoiding a collision results in higher loss in radio resource usage than the gain in interference reduction

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