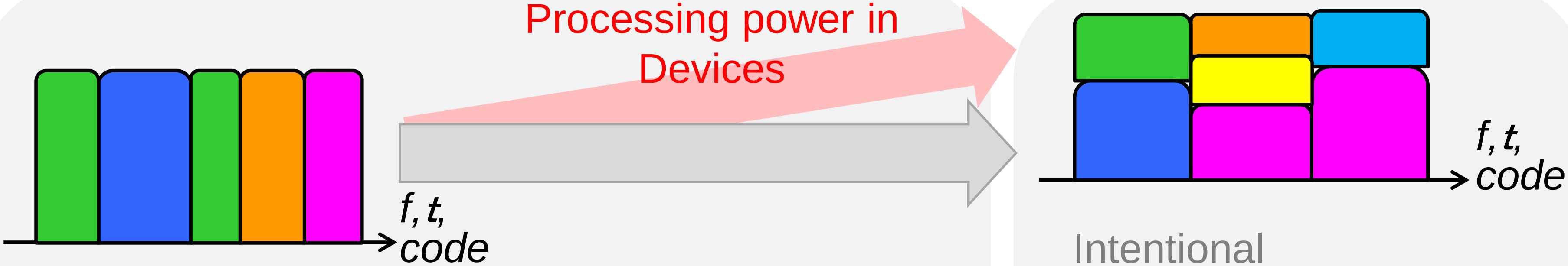
3GPP TSG RAN meeting #66
Maui, USA, Decmber 8 - 11, 2014

RP-141936

Justification for NOMA in New Study on Enhanced Multi-User Transmission and Network Assisted Interference Cancellation for LTE

NTT DOCOMO, INC.

Non-Orthogonal Multiple Access (NOMA)



Effort for Orthogonality

Effort for Interference Mitigation

Intentional Non-orthogonality

FDMA,TDMA, CDMA, OFDMA

Equalizer, Canceller

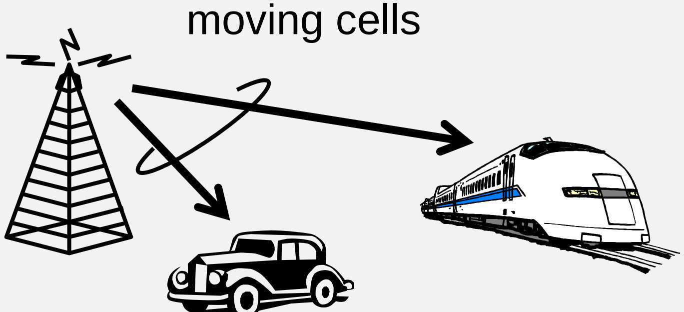
MIMO

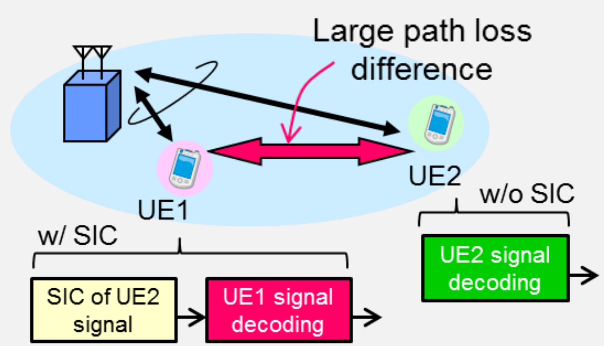
NOMA

Exploitation of **power-domain**, **path loss difference** among users, and UE processing power

Robust gain against user mobility

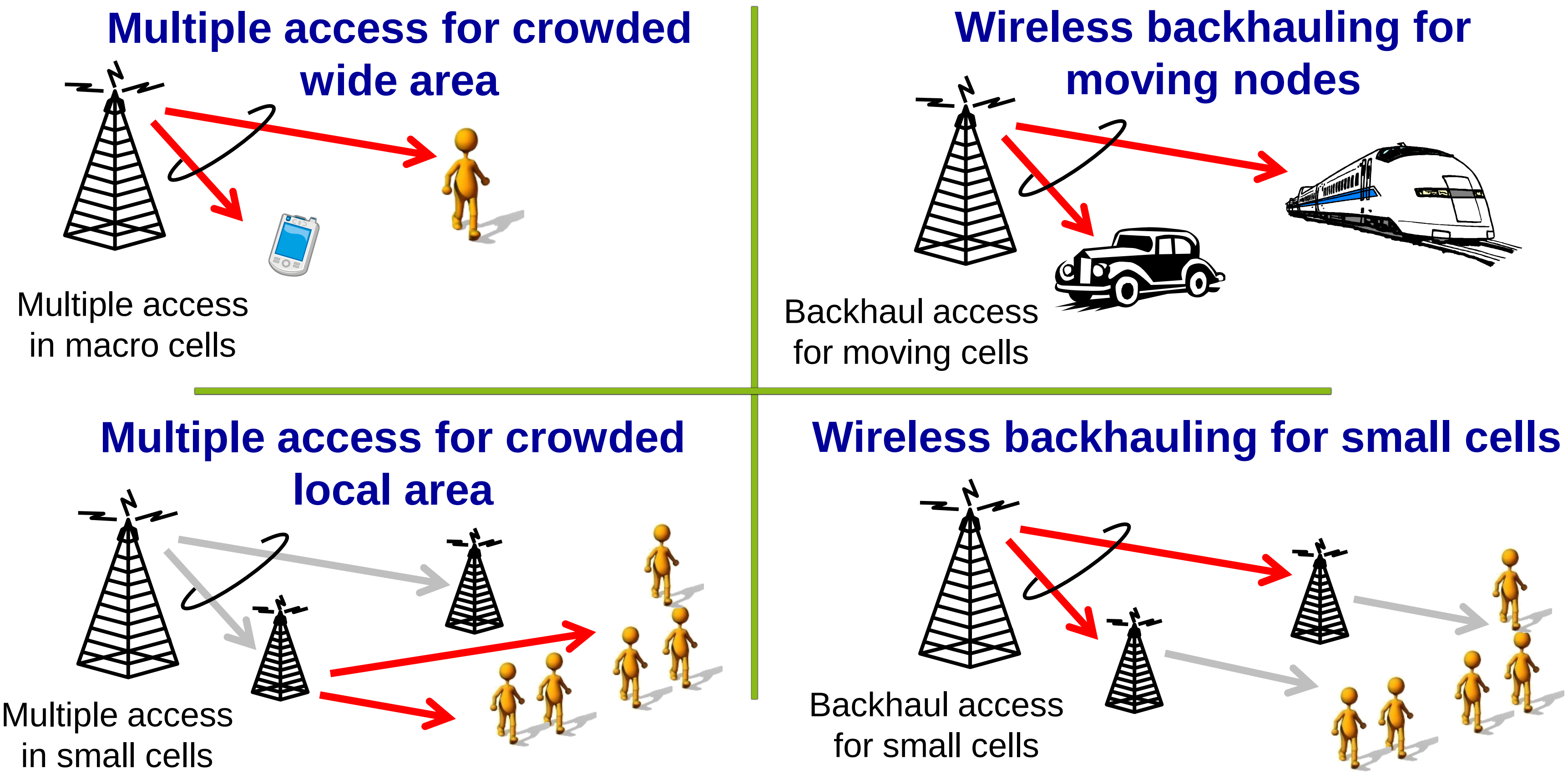
e.g., NOMA backhaul for moving cells





NOMA Scenarios

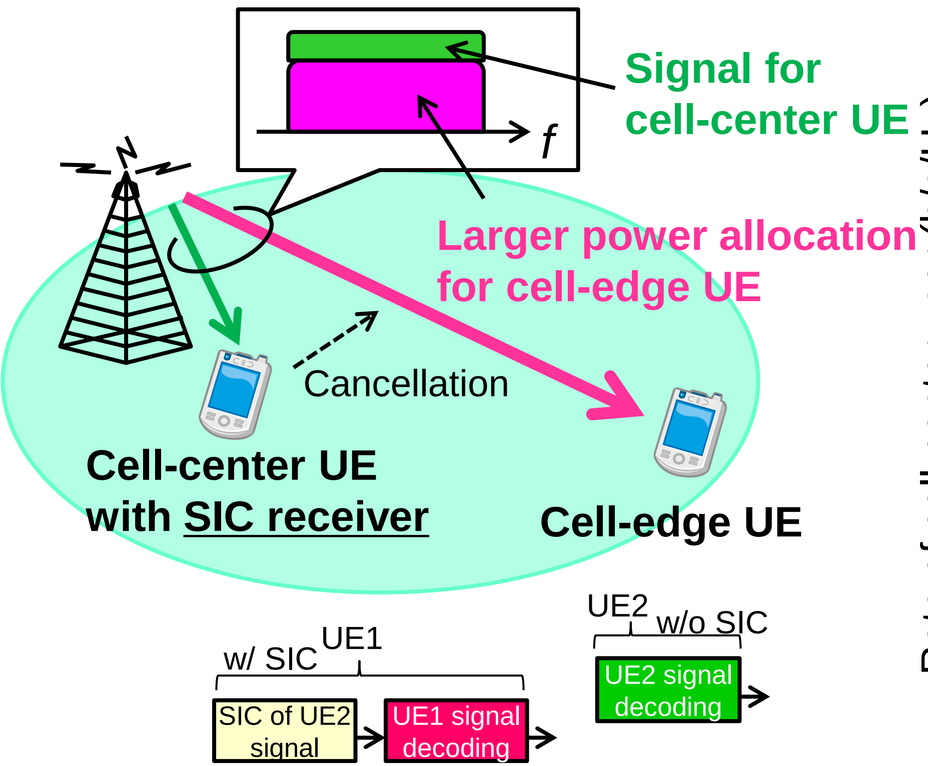
- NOMA exploits the power-domain for user multiplexing (users of different SNRs (PLs) are superposed in power-domain). Power-domain was not fully exploited so far.
- There are multiple scenarios in which NOMA can be applied.

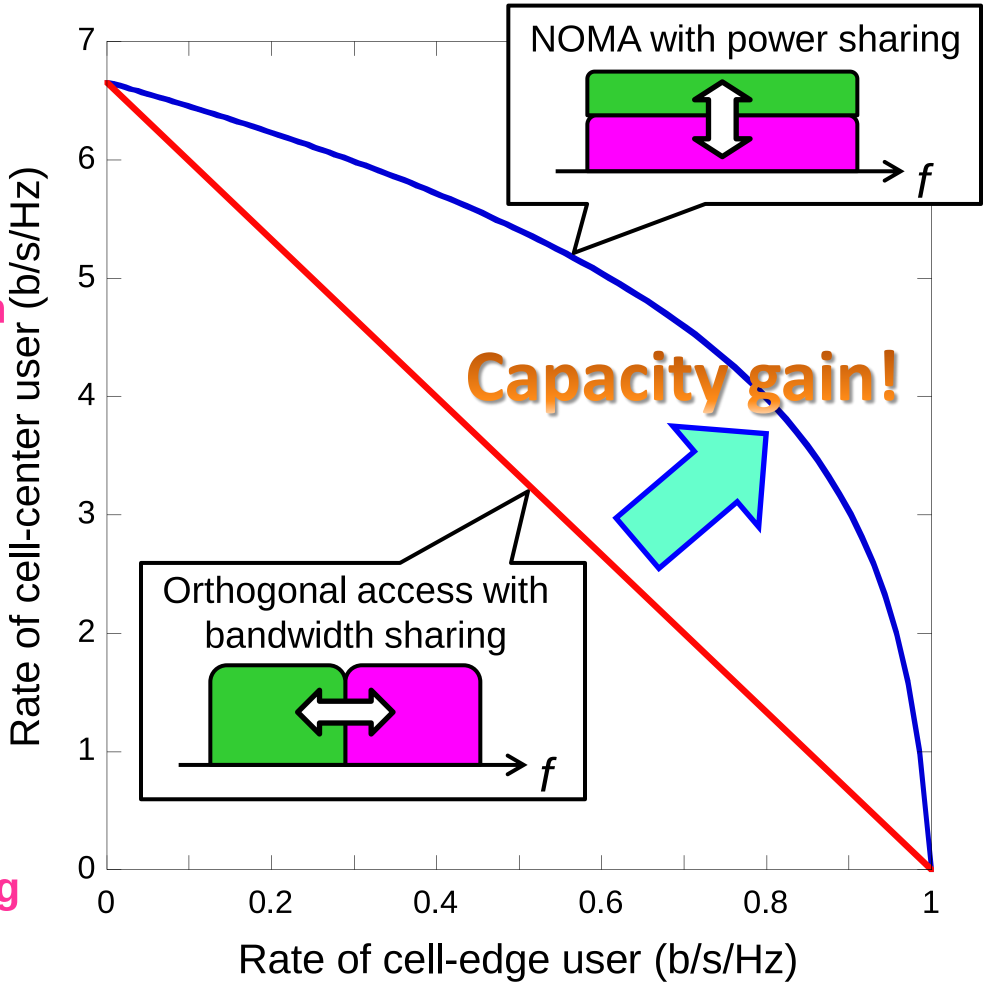


LTE NOMA – Concept

- LTE non-orthogonal multiple access (NOMA)

= NAICS extension into intra-cell user multiplexing





NOMA with SIC as capacity-region achieving in degraded broadcast channels

NOMA & e-MUMIMO

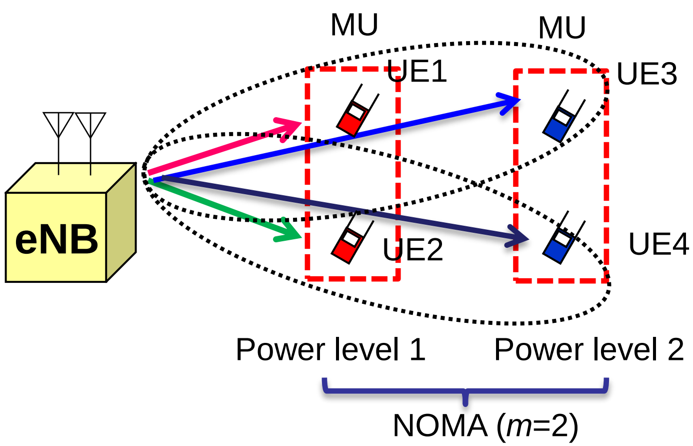
- **Commonalities**
  - Both exploit **advanced receiver** to provide better spectrum efficiency
- **Differences**
  - **e-MUMIMO** = **Enhanced** multi-user transmission with **orthogonal or quasi-orthogonal** beams, **equal** multi-user power allocation
  - **NOMA** = **Overloaded** multi-user transmission with **non-orthogonal** beams (complete or partial overlapping among beams), **non-equal** multi-user power allocation
- **Drivers for gains**
  - **e-MUIMO**: Spatial domain separation by exploitation of larger number of eNB transmit antennas than UE receive antennas
  - **NOMA**: Power domain separation made possible by exploitation of larger path loss difference and non-equal multi-user power allocation

➔ **Note that NOMA can be used together with e-MU-MIMO**

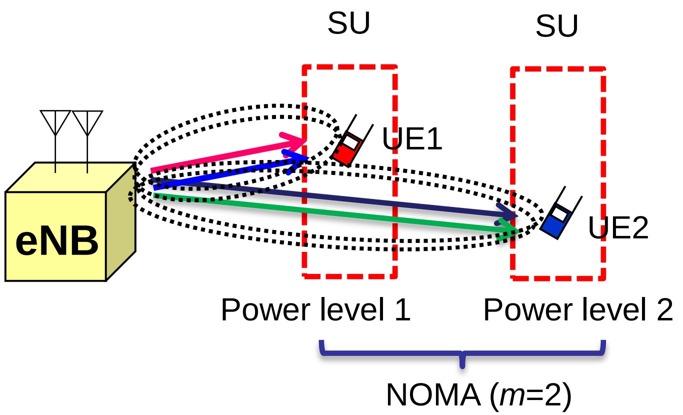
NOMA with MIMO (2x2)

4-layer transmission using 2 Transmit antennas

NOMA + MU-MIMO



NOMA + SU-MIMO



- **NOMA + MU-MIMO: Non-orthogonal user multiplexing**
  - **Inter-user:** Orthogonal multiplexing among beams
    - MU-MIMO (spatial domain)
  - **Inter-user:** Non-orthogonal user multiplexing within a beam
    - NOMA (power-domain)
- **NOMA + SU-MIMO: Non-orthogonal beam multiplexing**
  - **Intra-user:** Orthogonal beam multiplexing within a user
    - SU-MIMO (spatial domain)
  - **Inter-user:** Non-orthogonal multiplexing among user beams
    - NOMA (power-domain)

Enablers for NOMA with MIMO

UE

- **Receiver**
  - Codeword-level SIC and Reduced ML (or symbol-level SIC)
- **CSI (PMI, CQI, RI) feedback**
  - The same procedures as SU-MIMO (except CQI)

eNB

- **SIC ordering for NOMA scheduling**
  - Based on SU-MIMO throughput derived from SU-MIMO CQI
- **Multi-user scheduling and power allocation for NOMA**
  - Multi-user proportional fairness maximization with dynamic switching between NOMA and OMA (orthogonal multiple access)
  - Multi-user power allocation: Full search (non-equal) power allocation (FSPA) among users and equal power allocation (EQPA) among layers
- **CQI estimation for NOMA scheduling**
  - To decide on user pairing and select MCS at eNB side, NOMA CQI needs to be computed for each candidate user set
  - The case when eNB knows the SINR at UE after NOMA pairing provides an upperbound (genie-aided CQI)

NOMA with SU-MIMO Evaluations

3GPP case 1, 2x2, *m*=2, 10UEs/sector, FSPA (10 power sets)

Genie-Aided CQI estimation

	2x2 MIMO, TM3			2x2 MIMO, TM4		
	OMA	NOMA	Gain	OMA	NOMA	Gain
Case 1: Subband scheduling and subband MCS selection						
Cell (Mbps)	21.375	27.053	26.56%	21.97	27.866	24.73%
Cell-edge (Mbps)	0.472	0.633	34.11%	0.544	0.777	40.77%
Case 2: Subband scheduling and wideband MCS selection						
Cell (Mbps)	21.59	26.29	21.77%	22.291	27.499	23.36%
Cell-edge (Mbps)	0.476	0.62	30.25%	0.552	0.769	39.31%
Case 3: Wideband scheduling and MCS selection						
Cell (Mbps)	19.068	24.894	30.55%	19.577	25.515	30.33%
Cell-edge (Mbps)	0.401	0.538	34.16%	0.451	0.649	43.90%

- With genie-aided CQI estimation and 10 power sets:

For case 2 (3GPP compliant MCS selection), around 20% cell throughput gains and 30% to 40% for cell edge user throughput gains are achieved

Summary

- **Proposal: Investigate the potential gain of multi-user transmission schemes using NOMA and its combination with MIMO in the context of "study on enhanced multiuser transmissions and network assisted interference cancellation for LTE" [1].**

- Our initial evaluation results for NOMA with 2x2 SU-MIMO show the followings
  - **Up to 4-layer transmission using 2 transmit antennas (up to 2 beams/user, up to 2 users) is enabled through NOMA**
  - NOMA gains are confirmed for both open-loop (TM3) and closed-loop MIMO (TM4)
- Spec impact is expected to be limited and has high similarity with enhanced MU-MIMO
  - **MCS signaling & CQI enhancement**
  - **Codeword-level or symbol-level SIC**
  - Power allocation signaling, etc.

[1] 3GPP RP-141896, MediaTek, Alcatel-Lucent, "New study item proposal: study on enhanced multiuser transmissions and network assisted interference cancellation for LTE," Dec. 2014.

Simulation Parameters

Cell layout	**Hexagonal grid, 19 cell sites, 3 cells per site, wrap-around**
Inter-site distance	**500 m (Urban）**
Minimum distance between UE and cell site	**35 m**
Distance dependent path loss	**$128.1 + 37.6\log_{10}(r)$ dB**
Shadowing standard deviation	**8 dB**
Shadowing correlation	**0.5 (inter site) / 1.0 (intra site)**
Channel model	**SCM, Urban Marco, low angle spread**
UE speed (Maximum Doppler frequency)	**3 km/h (5.55 Hz)**
Penetration loss	**20 dB**
Node-B antenna pattern	**3D antenna**
Total transmission power	**46 dBm**
Transmitter antenna gain plus cable loss	**14 dBi**
UE antenna gain	**0 dBi**
UE noise figure	**9 dB**
Thermal noise density	**-174 dBm /Hz**
Number of transmitter antennas	**2**
Number of receiver antennas	**2**

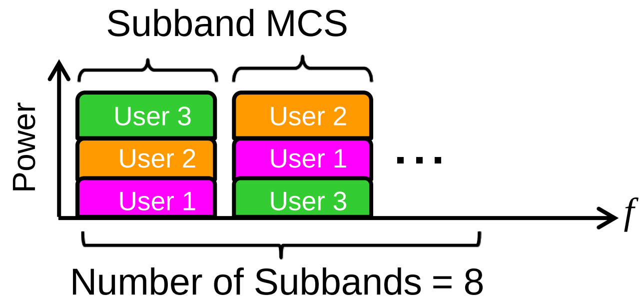
Simulation Parameters

Carrier frequency	2 GHz
System bandwidth	10 MHz
RB bandwidth	180 kHz
Sub-frame length	1.0 msec
MCS selection	Targeted BLER ≤ 0.1
Traffic model	Full buffer model
Granularity for CQI feedback and scheduling	Case 1/2: Subband CQI of 6 RBs (8 subbands) Case 3: Wideband CQI (1 subband)
CQI quantization	Yes
Control delay in Scheduling and AMC	6.0 msec
CQI/PMI/RI reporting interval	10 msec (CQI/PMI) and 100 msec for RI
Modulation scheme and Channel coding rate (MCS)	QPSK (R = 0.11 -0.53) TBS index #0 - 8 16QAM (R = 0.31 -0.54) TBS index #9 - 14 64QAM (R = 0.39 -0.93) TBS index #15 - 26
Channel estimation	ideal

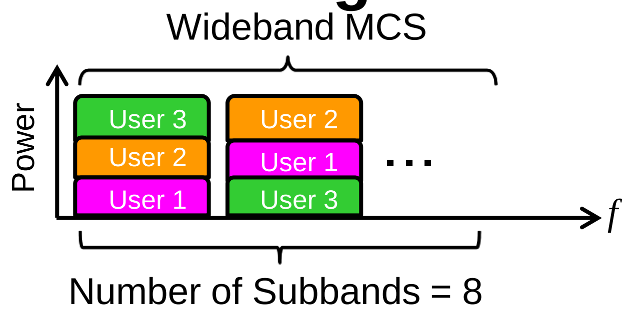
NOMA Multi-User Scheduling

- **Case 1: Subband MCS+ Subband scheduling**
  - Independent scheduling in each subband
  - A UE may have multiple TB/MCS in one TTI

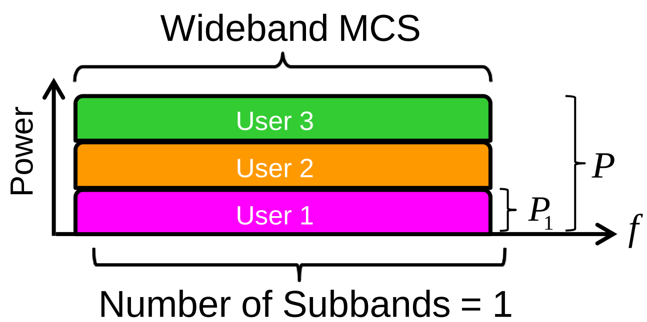
  (TTI: Transmission time interval, TB: Transport Block)



- **Case 2: Wideband MCS+ Subband scheduling**
  - Independent scheduling in each subband
  - A UE has and only has one TB/MCS in one TTI



- **Case 3: Wideband scheduling**
  - Only 1 UE is scheduled in whole bandwidth in one TTI
  - The UE has and only has one TB/MCS



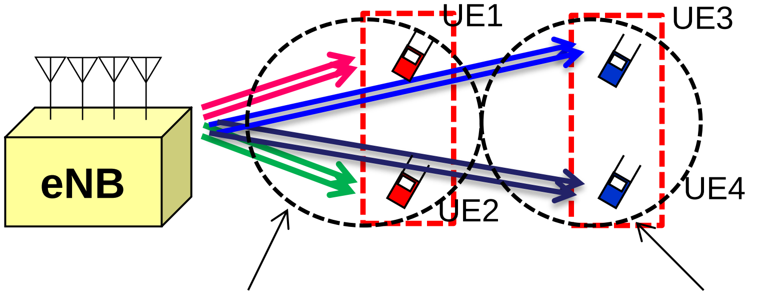
Simulation Parameters

Antenna configuration	• **Cross-polarized antenna(CPA)** **eNB:** **2Tx: X (+45, -45)** **UE: 0.5 wave lengths** **2Rx: X (+90, 0)**
Maximum multiplexing order (*m*)	**2 (Dynamic switching between NOMA + SU-MIMO (2-user multiplexing) and OMA + SU-MIMO)**
Codebook	**LTE codebook for MIMO TM3 and TM4**
UE receiver	**MRC for MIMO TM4 fixed Rank (RI=1)** **MMSE for MIMO TM3, TM4 rank adaptation (RA)**
Scheduler	**Proportional fairness (PF):** **Exhaustive search based user pairing** **Maximize PF metrics of all multiplexed users**
Number of power sets **(FSPA)**	**10 sets**: (β_1, β_2)=(0.88, 0.12); (0.85, 0.15); (0.83, 0.17); (0.81, 0.19); (0.78, 0.22); (0.75, 0.25); (0.73, 0.27); (0.71, 0.29); (0.68, 0.32); (0.65, 0.35)
OLLA	**No**
HARQ scheme	**Yes**

NOMA with MIMO (4x2)

Up to 8-layer transmission using 4 Transmit antennas

NOMA + SU/MU-MIMO



User Group 1: UE1, UE2

User Group 2: UE3, UE4

Orthogonal spatial multiplexing SU/MU-MIMO within user groups of users with similar SNRs:

User Group1: UE1 ⊥ UE2
User Group 2: UE3 ⊥ UE4

Non-orthogonal power-domain multiplexing among user groups of different SNRs:
User Group 1 (UE1 ⊥UE2)
&
User Group 2 (UE3 ⊥ UE4)