3GPP TSG RAN Meeting #76
West Palm Beach, U.S.A., 6th-8th of June, 2017
RP-171171
Document for: Discussion
Agenda Item: 9.1

Motivation for new Study Item on Multi Antenna Enhancements for NR

Nokia
Alcatel-Lucent Shanghai Bell

 © Nokia 2017

Current state of MIMO technology in LTE and NR

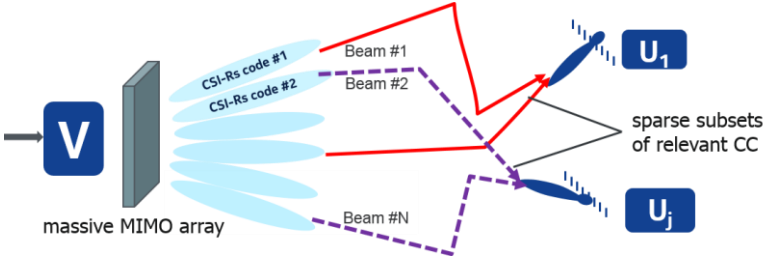
- Multi antenna techniques have been a capacity enhancer for multiple technologies such HSPA and LTE.
- Active antennas are a reality in low carrier frequencies, e.g., Release 14 FD-MIMO LTE is providing specification support for up to 32 DL antenna ports as well as DL advanced CSI feedback and UL enhancements.
- In high carrier frequencies, the form factor of the antenna arrays is enabling the utilization of a large number of antennas, while new antenna architectures, based on digital/analog and hybrid of the two, are also becoming possible.
- In new radio (NR), multi antenna techniques are becoming an integrant system component:
    - NR SI identified MIMO technology components in the form of reference symbols support, CSI feedback, multi-beam operation.
    - Clear technology differentiators are needed for multi antenna operation, in particular in low carriers were LTE FD-MIMO is providing a strong baseline.

 © Nokia 2017

NOKIA

Motivation and objectives: below 6 GHz

- A future proof NR system should provide more *accurate CSI* to inherently support advanced radio concepts like NOMA, non-linear precoding, JT CoMP, interference mitigation or other new upcoming proposals.
- Typical target for below 6 GHz MBB NR scenarios with inter site distances less than 500m provide high SNR and are *mainly interference limited.*
  → Interference Mitigation based on *intra- and inter site JT CoMP* promises significant performance gains over massive MIMO 'only' solutions (e.g., Fantstic5G deliverable D4.3)
- The combination of increased resolution CSI with JT CoMP requires
  - Support for high number of **(non-orthogonal) CSI RS sequences** (up to 288 sequences in a large cell JT-CoMP cluster),
  - **Explicit CSI feedback** for high resolution CSI
  - **Channel prediction** to overcome CSI aging and to relax backhaul,
  - Detailed study of **RF impairments** (e.g., freq. offsets)



© Nokia 2017
NOKIA

Motivation and Objectives: for higher frequencies

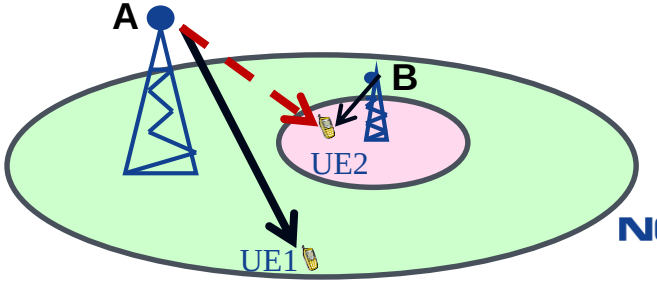
- NR is targeting both digital and analog/hybrid MIMO implementations, venturing into the **beam based operation** in high frequency carriers. The NR study has identified the basic mechanisms of beam based operation in high carriers (the so called '**beam management**') which is likely to evolve.
- While the Phase I NR specification will provide support for high speed operation and multi-point transmission, optimizations in the direction of **high speed train connectivity** as well as **ultra-reliable transmission** in high carriers requires further study and are parts of the currently proposed work.
- **Multi-panel/Multi-TRP transmission** provide the framework for multi-antenna operation in high carriers where 3GPP needs to investigate further system evolution for robust data and control transmission/reception.
- Investigating ways to increase the **multi-user scheduling** is of great importance for the system evolution, in particular when narrow beams are utilized. Support for **enhanced feedback**, **orthogonal/non-orthogonal reference symbols** for UL and DL, are necessary study items.

© Nokia 2017
NOKIA

Motivation and Objectives: Non-linear precoding

- Non-linear precoding has been identified as a promising candidate of new radio.
  - With full CSI at the transmitter side, "Dirty-Paper" Coding (DPC) technique relies on a pre-subtraction of the non-causally known interference, and can achieve the maximum sum rate of the system and provide the maximum diversity order.
  - E.g., **Tomlinson-Harashima precoding (THP)** is a **simplified and efficient** version of DPC, which is less computationally demanding and thus more attractive for practical implementation.
  - Non-linear precoding can provide a significantly enhanced system performance as compared to linear precoding, especially for **highly correlated channels** [1]
- For future multiple antenna systems, how to take advantages of high-performance non-linear precoding in **single-TRP, multi-TRP,** and **multi-panel** application scenarios is a key issue and of prime interest for further discussions.

  - [2] E.g., **HetNet** scenario where the transmission to UE1 from macro cell A interferers UE2's
  - Non-linear precoding helps to mitigate interference suffered by UE2 from macro cell A



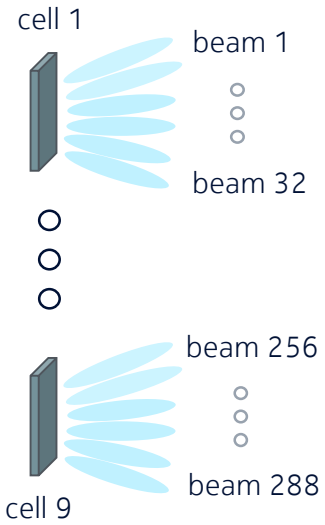
© Nokia 2017

Selected examples of multi antenna techniques to be considered in Phase II

© Nokia 2017

Study Proposal 1: Advanced CSI RS Solutions

- For FDD – as well as TDD - massive MIMO channel estimation of tens to hundreds of antenna elements is an essential challenge
- Channel estimation is the crucial first step to an accurate CSI information at the transmitter → estimation errors will eventually translate into limited system performance
- **Increasing the number of ports**, such as 64 to 288 per gNB or cooperation area, requires further study.



a) orthogonal CSI RS

- up to 288 RE per PRB
- Within time freqeuncy correlation window
- → extreme overhead or poor performance

b) Subset of APs

- UE specific subsets of APs
- Adapted to served user groups
- varying over frequency subbands
- → often reconfigurations of CSI RSs and scheduling limitations
- Performance so far unclear
- Overhead so far unclear

c) Non orthogonal CSI RS

- Limited length CSI RS sequences per AP or beam over N_{CSI} = e.g. 20 or 40 REs
- Non orthogonal per beam individual sequences
- allows CSI reconstruction of up to N_{CSI} relevant channel components
- → exploits sparsity of relevant channel components
- ***Accurate CSI with moderate overhead like 5 to 10%***

W. Zirwas, M. Sternad, A. Bilal, Coded CSI Reference Signals for 5G – Exploiting Sparsity of FDD Massive MIMO Radio Channels, 20 International ITG Workshop on Smart Antennas 2016, 9 – 11 March 2016, Munich, Germany

© Nokia 2017

Study Proposal 2: Explicit CSI Feedback Schemes

- Advanced precoding schemes (e.g., zero-forcing, non-linear precoding) for interference suppression rely on **explicit CSI knowledge**
- NR should support an explicit CSI reporting configuration where UEs report explicit CSI for each (relevant) CSI-RS antenna port (=beam/channel component)
- The explicit CSI reporting shall support beamformed and non-beamformed CSI-RS
- The **CSI feedback overhead** can be strongly reduced by reporting only
    - Selected/relevant antenna ports (beams); e.g., determined by a configurable received power threshold or determined by the available feedback payload
    - Relevant taps of channel impulse response; e.g., determined by a configurable received power threshold or determined by the available feedback payload

© Nokia 2017
NOKIA

Performance of Precoder with Explicit CSI Feedback vs. LC Codebook

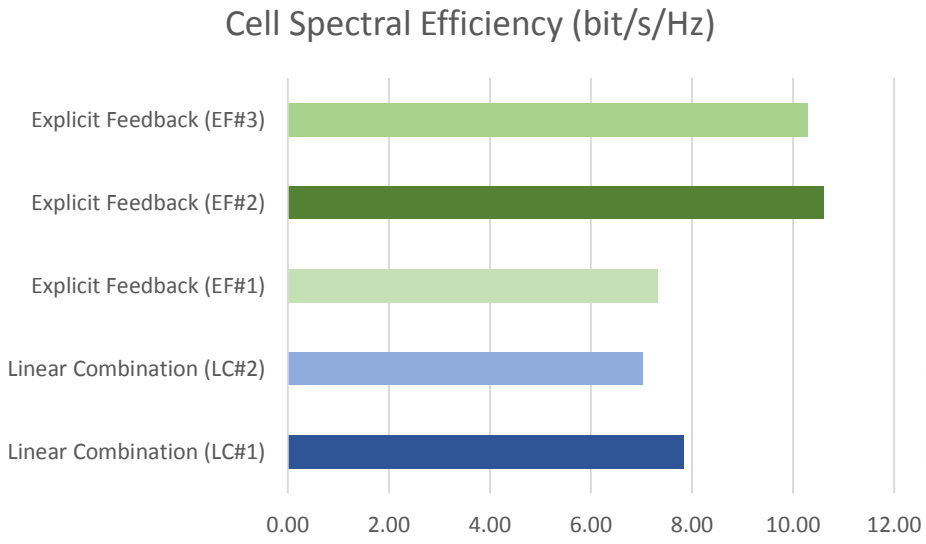
Simulation Settings

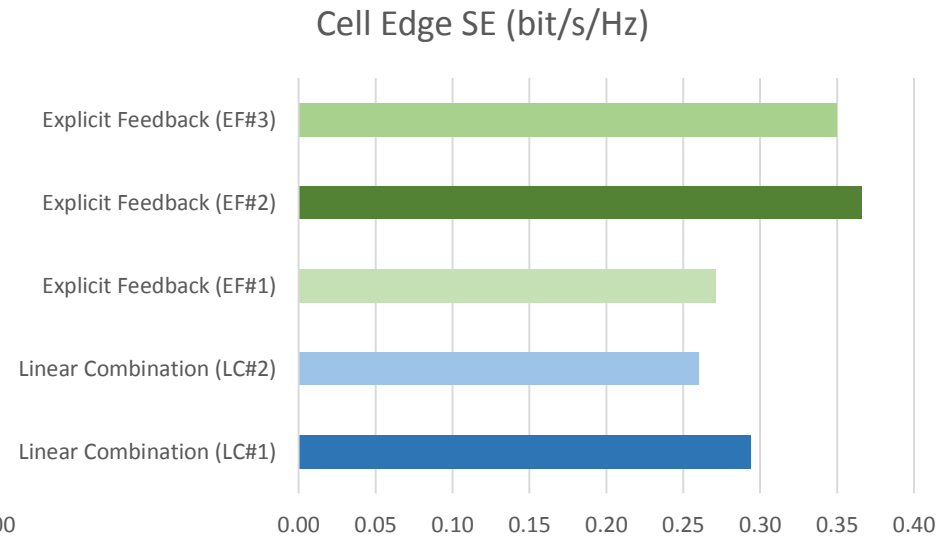
- Scenario:
  - 3D Umi/ISD = 200m
  - BW=10MHz/fc=2GHz
  - DL MIMO config: RANK-1, MU-MIMO with Greedy pairing
  - Non-ideal per-UE MMSE receiver
- gNB Antenna Config:
  - Azimuth: Four Xpols, (+45^0/-45^0), $d = 0.5\lambda$
  - Elevation: 8-elements, $d = 0.8\lambda$
- UE Feedback Configuration:
  - Feedback period: 10ms
  - LC Codebook:
    - Max-SLNR Tx weight calculation
    - WB W1 $L = 2,4$ beams per polarization
    - Subband W2 feedback
  - Explicit CSI Feedback (time domain):
    - Max-SINR Tx weight calculation
    - $N_{taps} = 20,80$ channel taps
    - $N_{phaseBits} = 4,6,8$ per channel tap, $N_{ampBits} = 2,3,4$ per channel tap

Configuration	Settings	#Short term Channel feedback overhead bits
LC#1	$L = 4$	420 bits
LC#2	$L = 2$	180 bits
EF#1	$N_{taps} = 80$, $N_{phaseBits}$ =4, $N_{ampBits}$ =2	480 bits
EF#2	$N_{taps} = 40$, $N_{phaseBits}$ =8, $N_{ampBits}$ =4	480 bits
EF#3	$N_{taps} = 20$, $N_{phaseBits}$ =6, $N_{ampBits}$ =3	180 bits

© Nokia 2017
NOKIA

Performance of Precoder with Explicit CSI Feedback vs. LC Codebook
Simulation Results





 © Nokia 2017

Study Proposal 3: Channel Prediction Schemes

- A NR system should ideally provide significant performance gains over LTE
- Channel Prediction has been identified as one main enabler to more advanced concepts like, massive MIMO, JT CoMP, non-linear precoding etc. as it:
  - Overcomes channel aging for moving objects → maintains large part of ideal JT CoMP performance
  - Relaxes backhaul, scheduling and precoding latency requirements
  - Relaxes frequency synchronization requirements between cooperating TRPs
- Different options for channel prediction should be considered:
  - Channel prediction at UE side plus reporting of predicted CSI
  - Channel prediction at gNB based on multiple UE CSI reports
  - CSI reporting framework with specific support for channel prediction, and low-rate-low-latency feedback for compensating hardware impairments (e.g. freq. offsets etc)

 © Nokia 2017

NOKIA

Considering practical impairments

- Advanced concepts like massive MU MIMO, JT CoMP, non-linear precoding, NOMA might provide interesting performance gains, but are more sensitive to practical impairments like:
  - Frequency offsets between RF units or TRPs
  - LO phase noise
  - Calibration errors
  - gNB with limited EVM for Tx-signals
  - CSI outdating or aging

- The proposed studies would consider:
  - Specific frequency offset estimation, reporting and control
  - Specific low rate low latency feedback for fast error correction

 © Nokia 2017

NOKIA

Study Proposal 4: Non-Linear Precoding Schemes

- Consider non-linear precoding in NR Phase II as one of the transmitter side interference cancellation techniques [2,3], including
  - **Efficient** non-linear precoding based solutions in MU MIMO **single-TRP, multi-TRP,** and **multi-panel** scenarios
    - Purely non-linear precoding schemes, e.g., THP , vector perturbation
    - Linear and non-linear hybrid precoding techniques
  - **Advanced CSI acquisition** schemes in support of non-linear precoding operating for the above mentioned scenarios
    - High resolution/explicit CSI feedback
    - Fast CSI acquisition
  - **Reference signal** design (e.g., DMRS, CSI-RS, etc.)
  - Specific **signalling** schemes to support non-linear precoding
  - Potential **backhaul** and **fronthaul** impacts
  - Impacts from **channel imperfections** such as channel estimation error , TDD reciprocity error, etc.

 © Nokia 2017

NOKIA

Precoding for MIMO performance enhancement

	Linear Precoding	Non-Linear Precoding
Examples	• Zero-Forcing (ZF) for single-antenna UEs • Block Diagonalization (BD) for multiple-antenna UEs	• Efficient DPC such as THP • Vector Perturbation (VP)
Performance	• Large performance loss compared to DPC especially for **correlated channels** • Robust again CSI error	• Approach DPC performance • Significant **performance gain** than **linear precoding** • Sensitive to CSI error
CSI requirements	• instantaneous CSI or long-term CSI	• instantaneous CSI with high quality
Implementation Complexity	• Reasonable, much lower than DPC	• Relatively high, more efficient than DPC

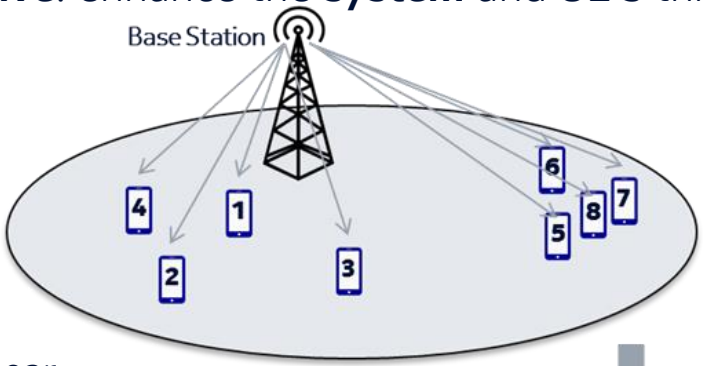
Non-linear precoding as one transmitter side interference cancellation technique is able to provide a significant performance enhancement than standard precoding schemes

 © Nokia 2017

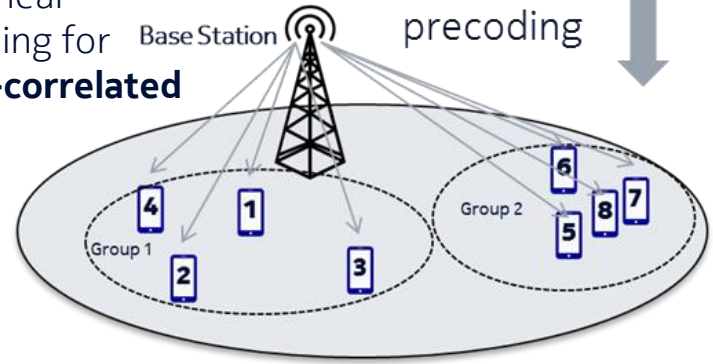
NOKIA

Single-TRP Scenario (MU-MIMO) [3]

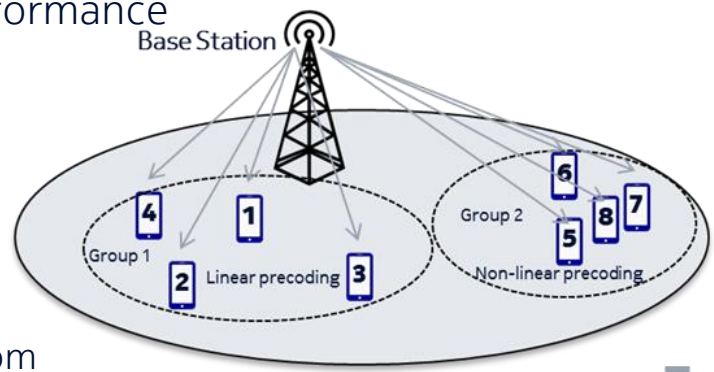
- **Objective**: enhance the **system** and **UE's** throughput performance

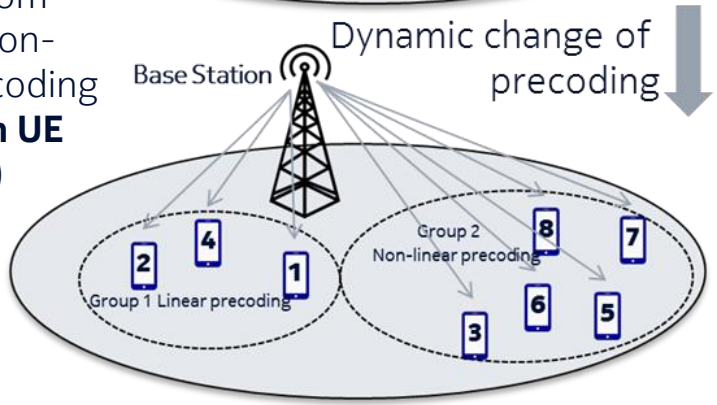


① Non-linear precoding for **highly-correlated UEs**



② **Change** from linear to non-linear precoding for **certain UE** (e.g., UE 3)

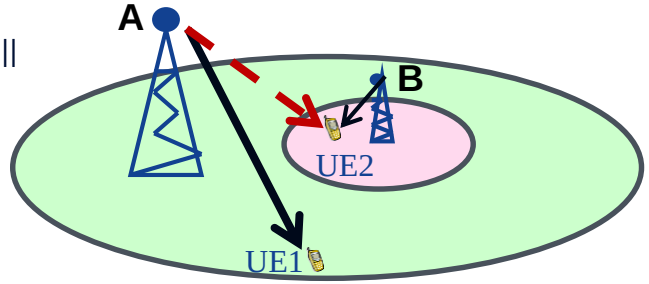




Proposal: Multi-antenna performance enhancement schemes using non-linear precoding should be studied for single-TRP scenarios.

Multi-TRP Scenario (HetNet) [2]

- **HetNet**
  - **Scenario**: Interference from macro cells limits the coverage of small cells, severely limiting the benefits of small cells
  - **Objective**: to **mitigate the interfering signal from macro cell** & to enhance the UE's performance in the small cell
  - **Method**: THP with Partial Interference Presubtraction (THP-PIP)

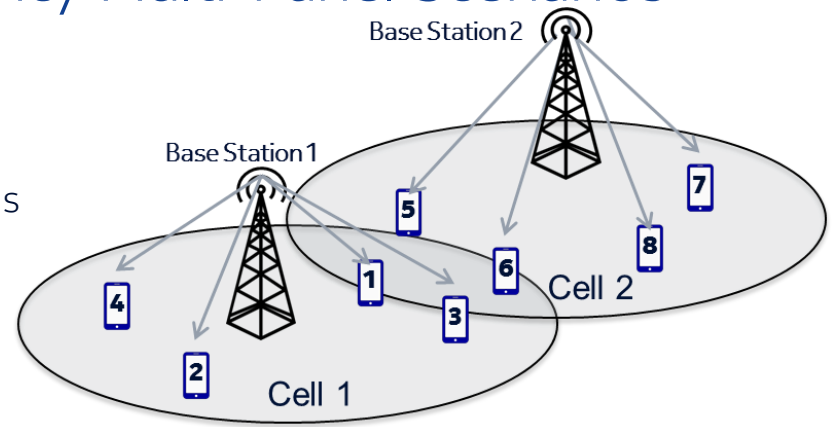


- Scheduling information from cell A, can be used by cell B in order to mitigate interference at the transmitter.
- This may involve a prescheduling stage where macro cell A forwards a copy of the symbol sequence which will be used for UE1's transmission. Such communication happens over the backhaul link.
- The problem becomes easier in MU MIMO of same TRP as transmission to UE1 and UE2 is from the same point.

Proposal: Coordinated transmitter side interference cancellation schemes using non-linear precoding should be studied for HetNets.

 © Nokia 2017

Multi-TRP (CoMP) & Higher-Frequency Multi-Panel Scenarios



- **CoMP**
  - **Scenario:** multiple cells with MU-MIMO configurations
  - **Objective:** to improve **cell-edge UEs**' performance

Proposal: Coordinated transmitter side interference cancellation schemes using non-linear precoding should be studied for the CoMP scenario.

- **Multi-Panel**
  - **Scenario:** multi-panel array supporting MU and multi-stream transmissions
  - **Objective:** to further enhance the MIMO performance for multi-panel based hybrid analog/digital beamforming at higher frequencies

Proposal: Hybrid analog/digital beamforming techniques with non-linear precoding capabilities should be considered for multi-panel scenarios at higher frequencies.

 © Nokia 2017

References

[1] WINNER, “Assessment of Advanced Beamforming and MIMO Technologies”, IST-2003-507581 WINNER, D2.7 v1.00, Feb. 28, 2005

[2] R1-1703186, “Nonlinear Precoding for Interference Mitigation in HetNets”, Nokia, Alcatel-Lucent Shanghai Bell, 3GPP TSG-RAN WG1 #88, Athens, Greece, 13th - 17th February, 2017

[3] R1-1703187, “On MU MIMO non-linear precoding in NR”, Nokia, Alcatel-Lucent Shanghai Bell, 3GPP TSG-RAN WG1 #88, Athens, Greece, 13th - 17th February, 2017

 © Nokia 2017

NOKIA