3GPP TSG RAN Meeting #75
Dubrovnik, Croatia, March 6 - 9, 2017
RP-170365
Document for: Discussion
Agenda Item: 9.1

Motivation for new Study Item on Multi Antenna Enhancements for NR

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Current state of MIMO technology in LTE and NR

- Multi antenna techniques have been a capacity enhancer for multiple technologies such HSPA and LTE.

- 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 new radio (NR), multi antenna techniques are becoming an integrant system component
  - 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.

- NR SI identified MIMO technology components in the form of reference symbols support, CSI feedback, multi-beam operation.

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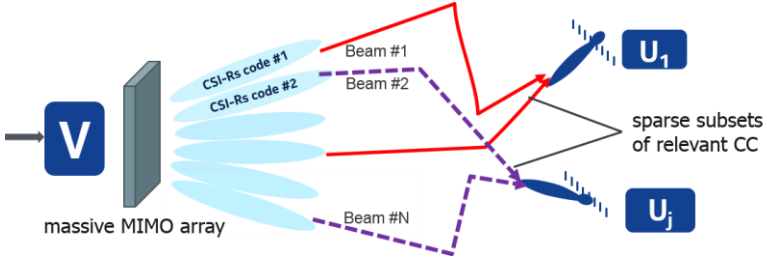
Motivation and objectives

- Clear technology differentiators are needed for multi antenna operation, in particular in low carriers were LTE FD-MIMO is providing a strong baseline.
- Active antennas are a reality in low carrier frequencies where high number of antenna ports are supported by LTE and NR Phase I (up to 32 ports).
- Extension of the number of ports, such as 64, requires further study, along with the CSI feedback operation and all the other supporting mechanisms such as reference signals and interference estimation.
- Advanced and increased resolution CSI feedback should target combining massive MIMO with JT CoMP over several cells and sites. Such goals require careful investigation of CSI feedback overhead, UE computation reliability and complexity.
- Considering per channel component feedback could be a solution for limiting the overall overhead, where a channel component is defined as the combination of one Tx- and one Rx-beam forming an effective radio channel (right figure).



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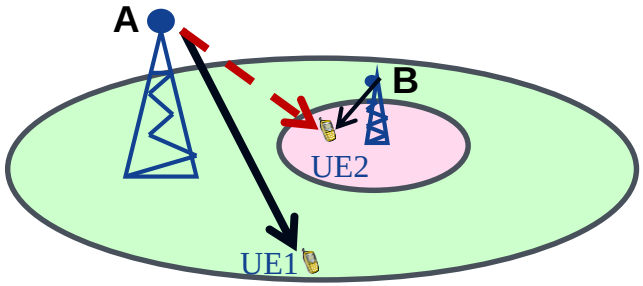
Motivation and objectives, cont.

- 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.
  - Tomlinson-Harashima precoding (THP) is a simplified and efficient version of DPC, which is less computationally demanding and thus more attractive for practical implementation.



- In above figure we illustrate a HetNet scenario where the transmission to UE1 from macro cell A interferers UE2’s transmission by small cell B.
- 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 same point.

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Motivation and objectives, cont.

- 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 investigates 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.

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

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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

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Objectives

- Study various application **scenarios**
  - **Single-TRP** case (MU-MIMO)
  - **Multi-TRP** case (HetNet, CoMP)
  - **Multi-Panel** case for higher frequencies
- Identify and evaluate **efficient non-linear precoding solutions** for mitigating transmitter side interference in various scenarios to enhance the system and UEs' performance
- Study the required **signaling**
  - between TRP and UEs in the single-TRP case
  - between TRPs in the multi-TRP case
  - In hybrid analog/digital beamforming procedure
- Study **advanced CSI acquisition** schemes to better assist linear and non-linear precoding

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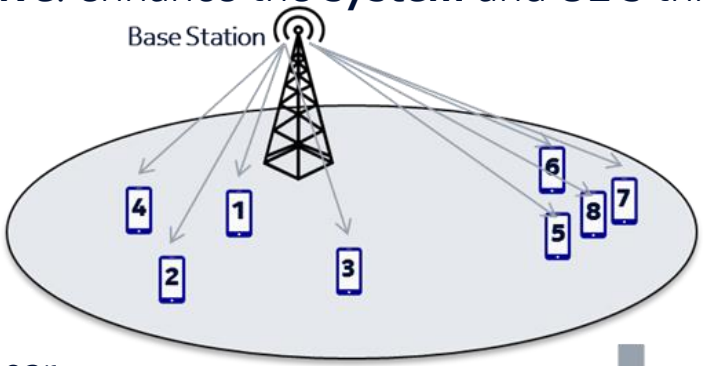
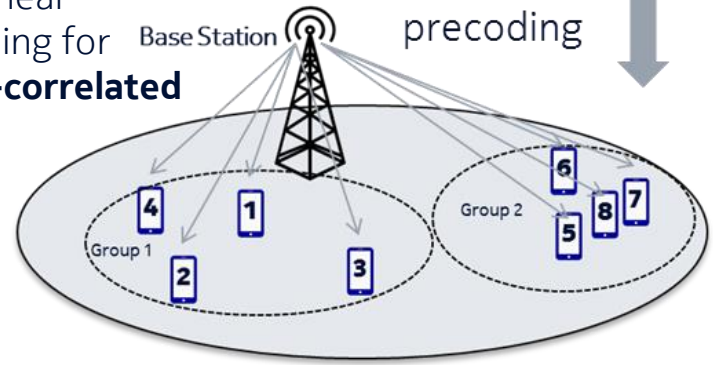
Single-TRP Scenario (MU-MIMO)

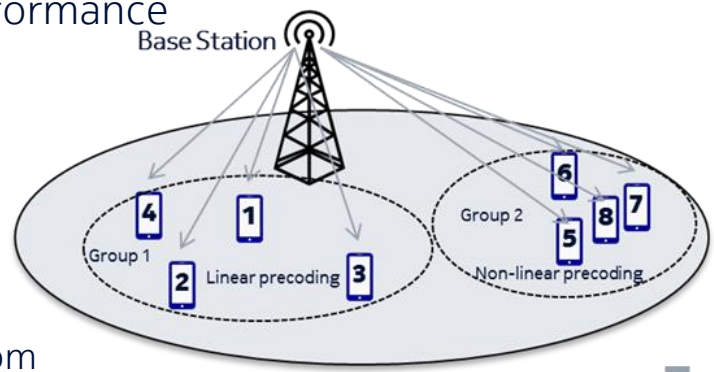
- **Objective**: enhance the **system** and **UE's** throughput performance

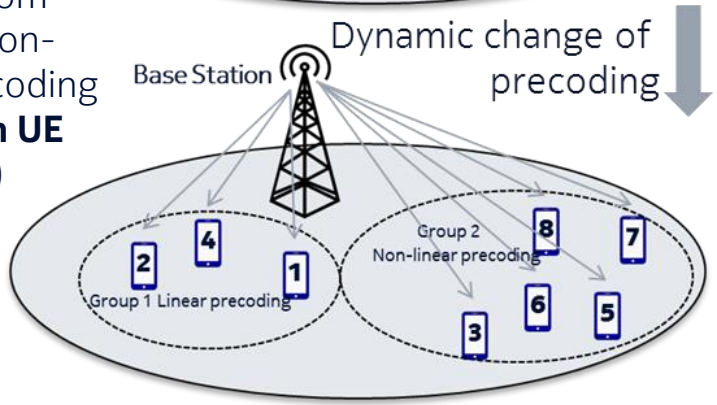


① Non-linear precoding for **highly-correlated UEs**



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

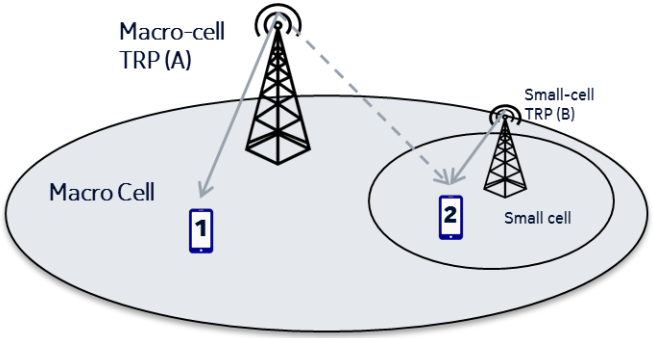




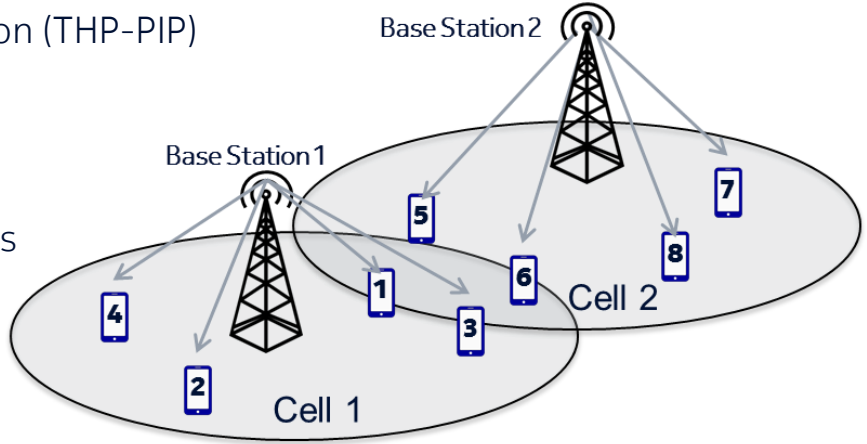
Proposal: Multi-antenna performance enhancement schemes using non-linear precoding should be studied for single-TRP scenarios.

Multi-TRP Scenario (HetNet, CoMP)

- **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)



- **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 multi-TRP scenarios.

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Multi-Panel Scenario at Higher Frequencies

- **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.

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Backup

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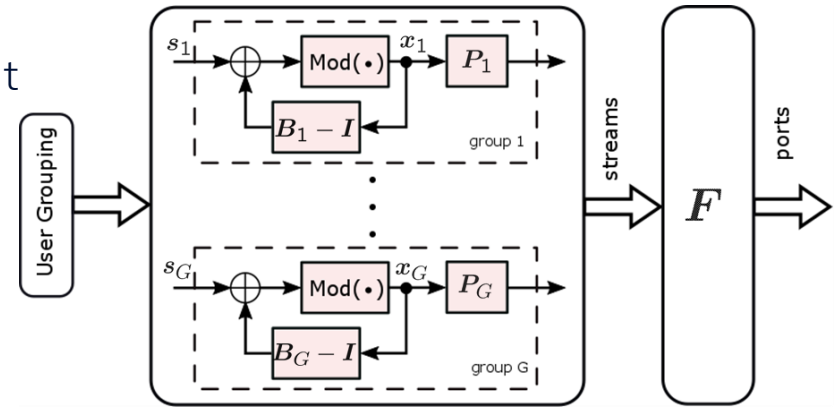
Single-TRP Scenario (MU-MIMO): Proposal 1

- **Proposal**: hybrid linear and non-linear precoding scheme to enhance the system and UE's throughput performance [1]
  - **UE grouping**
  - The **1st -stage linear** precoding acts like a low-rank transformation and aims at mitigating inter-group interference, which can be designed based on the long-term CSI, e.g., using BD algorithm.
  - The **2nd -stage precoding** is carried out in a reduced dimension in parallel for groups, where the non-linear precoding method is performed within each group to effectively suppress the inter-user interference in the group



[1] 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

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Single-TRP Scenario (MU-MIMO): Proposal 2

- **Proposal**: a UE-centric and BS-assisted precoding procedure with the support of specific UL/DL indications to dynamically accommodate non-linear precoding to improve the UE's performance
  - UL indication on the UE's choice of the precoding type and on the change of precoding types for certain UEs,
  - DL indication implying the BS's suggestion of the precoding type via a comparison index with respect to the UL indication, and
  - The dynamic SRS configuration information adapted to the dynamic change of the precoding type.
- **Example:** one BS serves 8 UEs simultaneously
  - At time t, UEs 1 - 4 form the group 1 are linearly precoded and UEs 5 – 8 in group 2 are non-linearly precoded
  - At time t+Δt, UE 3 requests to improve its performance by non-linear precoding.

→ The proposed precoding technique allows the BS to dynamically update its precoding by re-decoupling of UE groups and to perform precoding for each group

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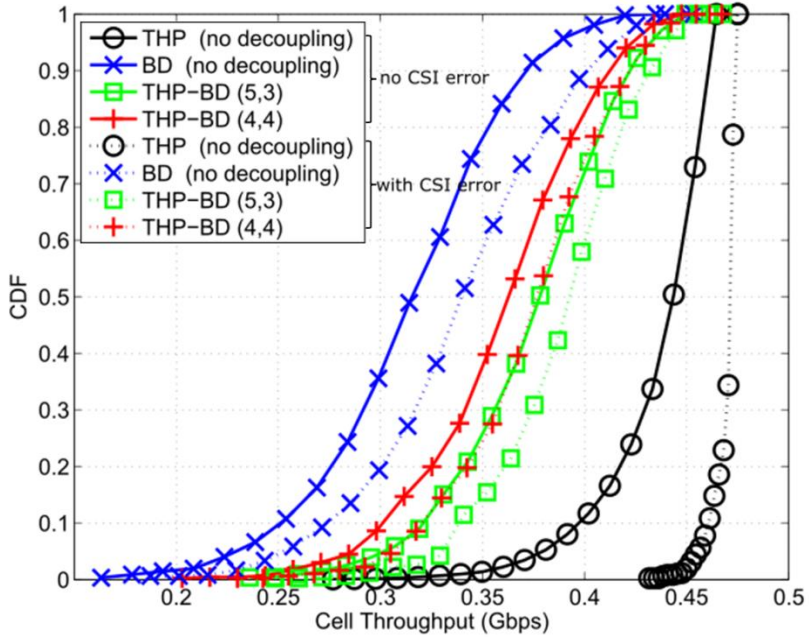
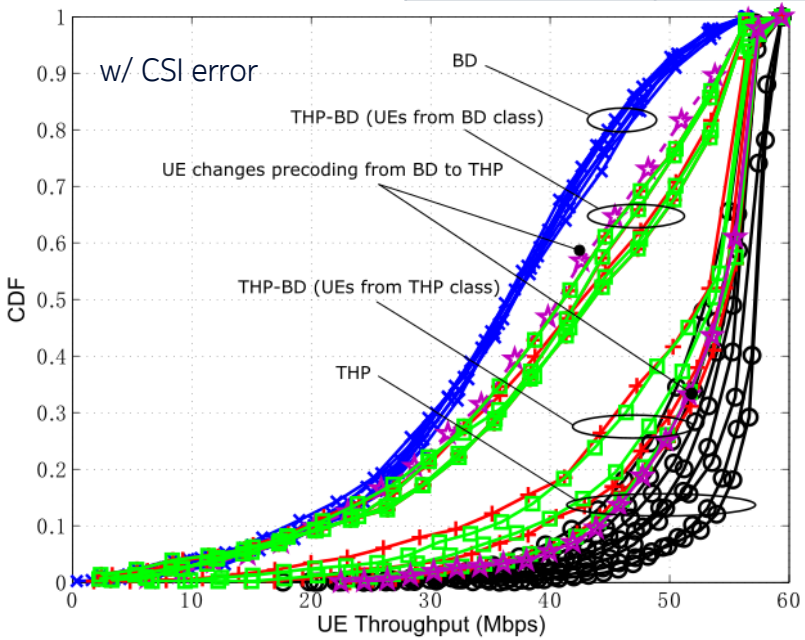
Single-TRP Scenario (MU-MIMO): Results for proposal 1&2

Hybrid linear and non-linear precoding scheme

Simulation Parameters (WINNER II)	
Scenario	Local area small office
Antenna array @ BS	16 (ULA)
Antenna array @ UE	2 (ULA)
Number of UEs	8
UE groups	(4,4) & (5,3)





Observation 1: THP has a higher sensitivity to CSI errors compared to the linear BD precoding scheme; the hybrid linear and non-linear precoding scheme is less sensitive to CSI error than the full THP scheme.

Observation 2: UE changes from linear to non-linear precoding improves both its own throughput and the cell performance

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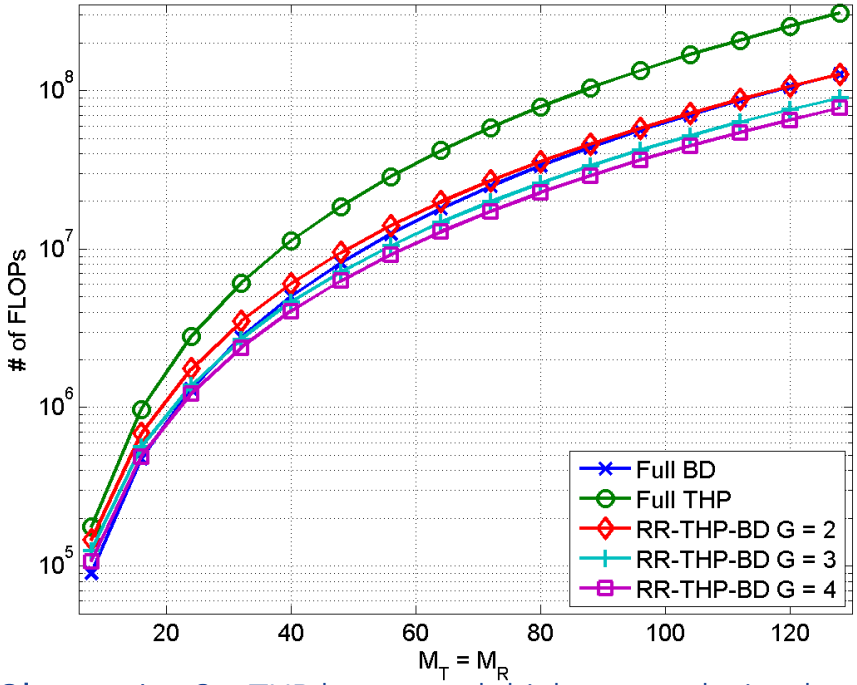
Single-TRP Scenario (MU-MIMO): Complexity Analysis [1]

Hybrid linear and non-linear precoding scheme



- Proposed: “RR-THP-BD”, compared with “Full BD” and “Full THP”
- *G*: number of groups

Observation 3: THP has a much higher complexity than BD precoding and the proposed mixed linear and non-linear precoding scheme shows a low complexity.

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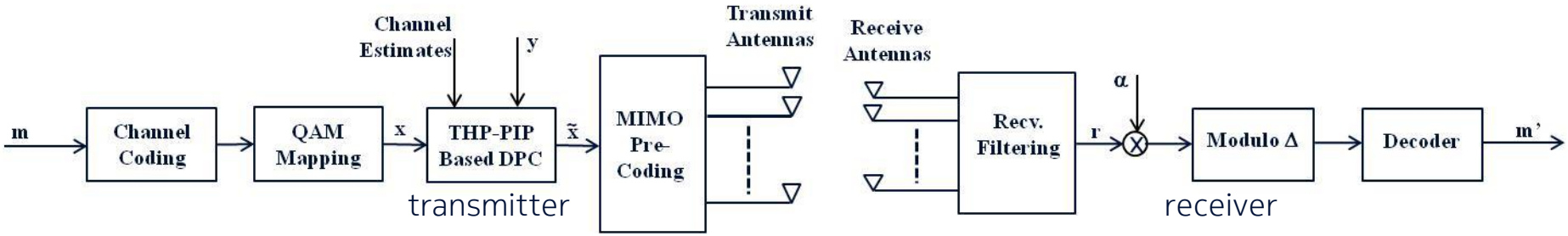
Multi-TRP Scenario (HetNet) 1: [2]

- **Scenario**: Macro and small cells share the same time-frequency resources, small-cell UE 2 receives data from TRP B, but suffers from the interference, i.e., the co-channel data that TRP A transmits to marco-cell UE 1.
- **Proposal**: THP with Partial Interference Presubtraction (THP-PIP) to mitigate the interfering signal from macro cell .



[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

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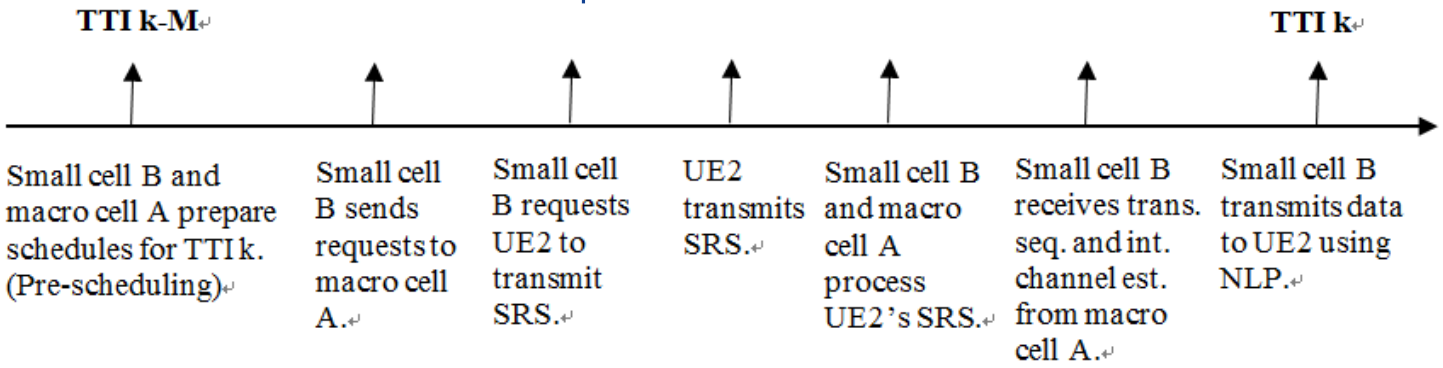
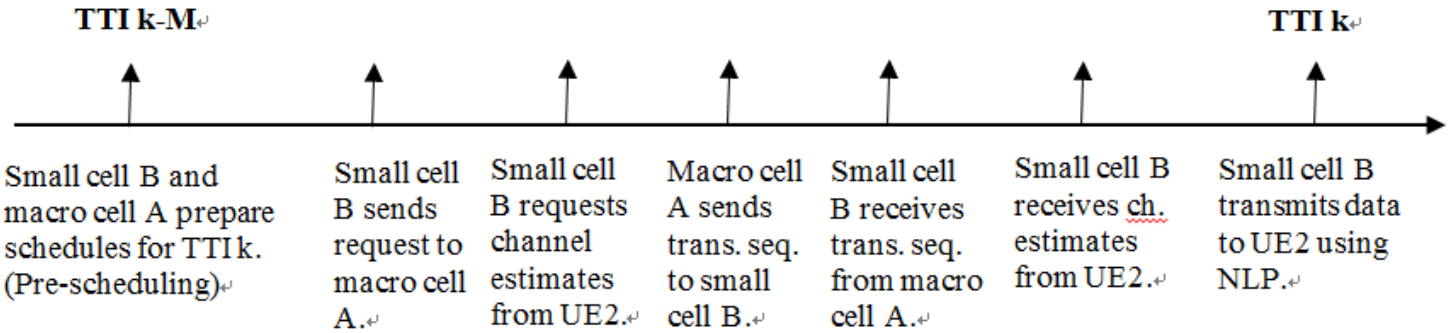
Multi-TRP Scenario (HetNet) 2: Implementation [2]

- **TDD**



- **FDD**:



Proposal : Pre-scheduling and its performance impact should be studied in the context of NLP schemes.
Proposal : Methods to reduce the downlink channel estimation and reporting delays in an FDD system should be studied.
Proposal : Methods to implement downlink channel estimation based on channel reciprocity in TDD systems should be studied with a view to applying them to the THP-PIP-based DPC scheme.

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