**3GPP TSG-RAN WG4 Meeting #112 R4-2414299**

**Maastricht, Netherlands, 19th – 23rd August, 2024**

**Title:** WF on other issues (MIMO)

**Agenda Item:** 8.2.5

**Source:** Nokia, Spark

**Document for:** Approval

**Background**

System-level simulation results relating to implementation of IMT BS multiuser spatial beamforming techniques, such as zero-forcing (ZF) or minimum mean-square error (MMSE) based schemes, have been provided to RAN4#111.

There are different views on the assumptions, parameters and methodologies which should be used for such study, especially considering the various aspects on MIMO implementation. In order to simulate the impact of MU MIMO via ZF/MMSE on over the horizon emissions, the MU MIMO algorithm used must be appropriate that reflects what is commercially used. Simulation results presented to this meeting show that MU MIMO via ZF/MMSE have similar answers for over the horizon emissions to the baseline case of using AAS beamforming – currently used by the ITU-R. Some of the assumptions used to obtain the results are not clearly stated. Especially, if the assumptions discussed in points 1-11 below are varied the answers will be different. However, it would be difficult to agree on the assumptions, parameters and methodologies due to the following considerations.

1. A model for the channel impulse response, i.e., whether the UEs are lying in LOS or NLOS conditions, the value of Ricean K factor if both LOS and NLOS conditions exist. If pure LOS conditions exist, the channel impulse response should still be modified by the phase of the geometric azimuth and elevation angles.
2. A model to calculate the AAS beam array factor (**FR**F) specific to each UE in the ZF set (co-scheduled UEs).
3. A model to calculate the ZF/MMSE precoding matrix – pseudo inverse, whether the pseudo inverse is on the concatenated channel of the channel propagation information for each UE, or the concatenated channel of an equivalent channel (h1 FRF1, ... hK FRFK) based on channel propagation and AAS RF beamforming for each UE (commercial systems have AAS RF beamforming and ZF/MMSE is done on the equivalent channel).
4. System equations and dimensions of the constituent vectors/matrices in (3).
5. A method to choose UEs in the ZF/MMSE set by azimuth separation, azimuth and elevation separation or by a correlation calculation.
6. A way to modify the array factor in (2) when ZF/MMSE beamforming is also used.
7. A way to plot (16 and the corresponding azimuth and elevation responses.
8. A definition of array gain above the horizon, from the elevation responses in (7) and a method to compute a CDF.
9. A method to determine a CDF in (8 when no ZF/MMSE BF is used and only AAS RF beamforming is employed.
10. All the above issues will vary the answers showing ZF/MMSE based MU MIMO is similar to AAS beamforming or very different when considering the impact of array gain in elevation.
11. In case of MMSE we must also chose a value of **β** that is a coefficient of the identity matrix in the corresponding precoding matrix.

Moreover, there are practical issues in implementing MU MIMO that need to be considered in evaluating the co-existence conditions with ZF/MMSE based MU MIMO. These are:

1. MU MIMO is only invoked for users lying in high SNR conditions whether AAS beamforming is used or ZF beamforming is used. The threshold SNR to invoke MU MIMO is a vendor feature.
2. The pseudo inverse calculation (W**)** is based on the estimated channel and errors in CSI will not make the multiplication of **H** and **W** as diagonal and will in turn result in inter-user interference even for the zero forced users- thereby reducing their SNR further.
3. In 3GPP standards, beamforming is dependent on the quality and accuracy of the acquired CSI at the base station. This is in turn based on the information provided by the UE. Here there are long term CSI (frequency independent) and short-term CSI based in sub-bands. CSI accuracy is also dependent upon the speed with which the UEs are moving. The simulation of the CSI for co-existence simulations therefore requires the availability of link and system level simulation parameters which are not generally available and are also vendor dependent. Noting that in AAS beamforming the AoD to form the beam needs to be correctly known.
4. Given a threshold SNR for invoking MU MIMO, the selection of UEs in a MU MIMO set is a scheduler feature that is not standardised in 3GPP standards and is vendor proprietary.
5. Users seldom lie in pure LOS conditions, there will be some NLOS present, a Ricean K factor will need to be defined and a composite impulse response will need to be determined as is the case for base stations performing MU MIMO.
6. One could agree on a solution for all of the above (for example, perfect CSI can be assumed, users in MU MIMO set are agnostic of SNR reductions due to power sharing, agree on pure LOS, etc) and then look at a range of answers.

**Agreements**

In the RAN4 LS reply to WP5D on “guidance on the process of deriving the necessary beamforming weights for the IMT AAS BS to compute its radiation pattern,”

1. RAN4 can recommend to WP5D the formulas for the beamforming weights, but as far as the conclusions of the simulation study are concerned, RAN4 would need to continue to look at the impacts of different assumptions as outlined above and appropriately confirm any simulation conclusions.
2. RAN4 can point out to WP5D the complexities arising from practical issues in simulating ZF/MMSE based MU MIMO for co-existence and with this view RAN4 can recommend to WP5D the use of current AAS beamforming model seems more appropriate whilst noting that even for M 2101 some practical issues exist.

In the TR 38.922, system-level simulation results provided to RAN4#112 and any further simulation study can be put into an annex for information.