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Title: Clarification on explicit feedback *vs.* implicit feedback

Document for: Discussion / Decision

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1 Introduction

The feedback mechanism to support DL MIMO in LTE-A has been discussed extensively in recent RAN1 meetings. Based on definitions in TR 36.814 for CoMP, it has generally been attempted to consider MIMO feedback mechanisms for release 10 in two categories (plus SRS): implicit and explicit channel state/statistical information feedback:

- Explicit channel state/statistical information feedback
  - Channel as observed by the receiver, without assuming any transmission or receiver processing
- Implicit channel state/statistical information feedback
  - feedback mechanisms that use hypotheses of different transmission and/or reception processing, e.g., CQI/PMI/RI

In this contribution we review this categorisation of feedback in the light of recent proposals and discussion.

2 Views on implicit and explicit feedback

In the Release 8 kind of implicit feedback, assuming a certain receiver processing, each UE feeds back its desired precoding vector in the form of PMI. The eNB can either use this PMI or choose another precoder for the downlink transmission. In release 8, only codebook based precoding is supported, so any such other precoder is constrained to being selected from the specified codebook.

The introduction of precoded demodulation RS makes non-codebook based precoding possible in release 10. The eNB can determine arbitrary precoding vectors for scheduled users based on the feedback information. Therefore the codebook definition becomes relevant only for the purpose of feedback quantisation, not for the precoding scheme itself. As the precoders are no longer limited to code-words in the pre-defined codebook, MU interference could be mitigated significantly.

With explicit feedback, channel information observed by each UE is quantised and fed back in the form of a codebook index. The eNB interprets the feedback as an estimate of the UE's channel and performs precoding based on this information.

This is actually closely related to implicit feedback, where each UE selects the desired PMI from the codebook according to a certain criterion. Different PMI selection criteria for implicit feedback could for example be maximum likelihood, minimum singular value, mean squared error, and capacity. Literature shows that all these criteria are in fact equivalent and the selected precoding vector is the conjugate transpose of the principle eigen mode of the physical channel [8]. This makes the explicit and implicit feedback equivalent as long as the baseline codebook has conjugate pairs of codewords, which is true for the Rel-8 codebook. In other words, the precoder that maximizes the post-processing capacity is actually a conjugate transpose of the eigenmode of the physical channel. This blurs the line between implicit and explicit feedback.

Additionally, in both the "implicit" and "explicit" feedback cases, spatial correlation information could be used to improve the usefulness of the channel state information at the eNB. In the case of so-called explicit feedback, spatial correlation information could be used to fine-tune the channel quantisation to reduce the quantization error and consequent multi-user interference. In the case of so-called implicit feedback, the correlation properties could be used as

a long term metric of the channel to provide a finer spatial quantization of the desired precoder. Moreover, the spatial correlation information can be vector-quantized and fed back in the form of additional PMI. It has been shown that the use of spatial correlation information can enable a codebook to be adapted to specific antenna configurations and deployment scenarios [2-4]. This can help to avoid the accuracy limitations of the feedback becoming a bottleneck to the MU-MIMO performance, especially as with a practical feedback budget an all-purpose codebook that performs well for every antenna configuration and deployment scenarios is impossible.

Therefore we propose that the feedback discussion should not be focused with such polarity on implicit versus explicit feedback, but rather on the specific types and methods of feedback that it is useful to support in Release 10, following the prioritisation agreed in RAN1#59bis:

- *Feedback requirements for SU/MU-MIMO shall be agreed on the basis of single-cell operation (i.e. without CoMP).*
    - *Additional feedback requirements for CoMP shall be consistent with feedback framework for SU/MU-MIMO.*

The discussion should therefore focus on deciding whether the release 10 specifications should support specific types of feedback, examples of which include multiple PMI reports, quantised spatial correlation/covariance information, and amplitude/phase differential feedback for CoMP.

3 Conclusions

In this contribution, we show that the distinction is not necessarily clear between implicit and explicit feedback as currently defined in TR36.814.

Further, feedback types and methods such as spatial correlation information [2-4] and multiple PMI [5-7], and amplitude and phase differential feedback for CoMP can be equally considered under the "implicit" and "explicit" feedback categories.

We therefore propose that the feedback discussion should focus on the specific types of feedback to be supported rather than on the broad categories of so-called "implicit" and "explicit.

4 References

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[3] R1-100719, "Correlation-based explicit feedback", Alcatel-Lucent Shanghai Bell, Alcatel-Lucent

[4] R1-100190, "Low-Overhead Feedback of Spatial Covariance Matrix", Motorola

[5] R1-100051, "A Flexible Feedback Concept", Ericsson

[6] R1-100527, "Consideration on Enhancement of MU-MIMO Feedback Schemes", ZTE

[7] R1-100418, "Summary of enhanced UE PMI feedback signalling for intra-cell and inter-cell interference avoidance", Alcatel-Lucent, Alcatel-Lucent Shanghai Bell

[8] D. J. Love, R. W. Heath, Jr., Limited feedback Unitary Precodings for Spatial Multiplexing Systems, *IEEE Transactions on Information Theory.* Vol. 51, No. 8, 2005, pp.2967-2976