

R1-060899



> BUSINESS MADE **SIMPLE**

On MIMO-OFDM Downlink Pilots and Pre-Coding Index Feedback

3GPP TSG-RAN Working Group 1 Meeting #44bis

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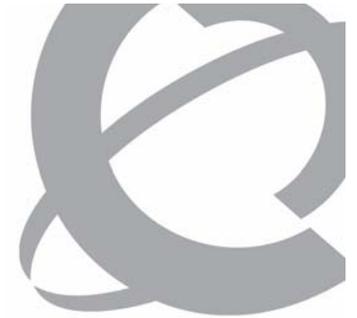
Document for: Discussion

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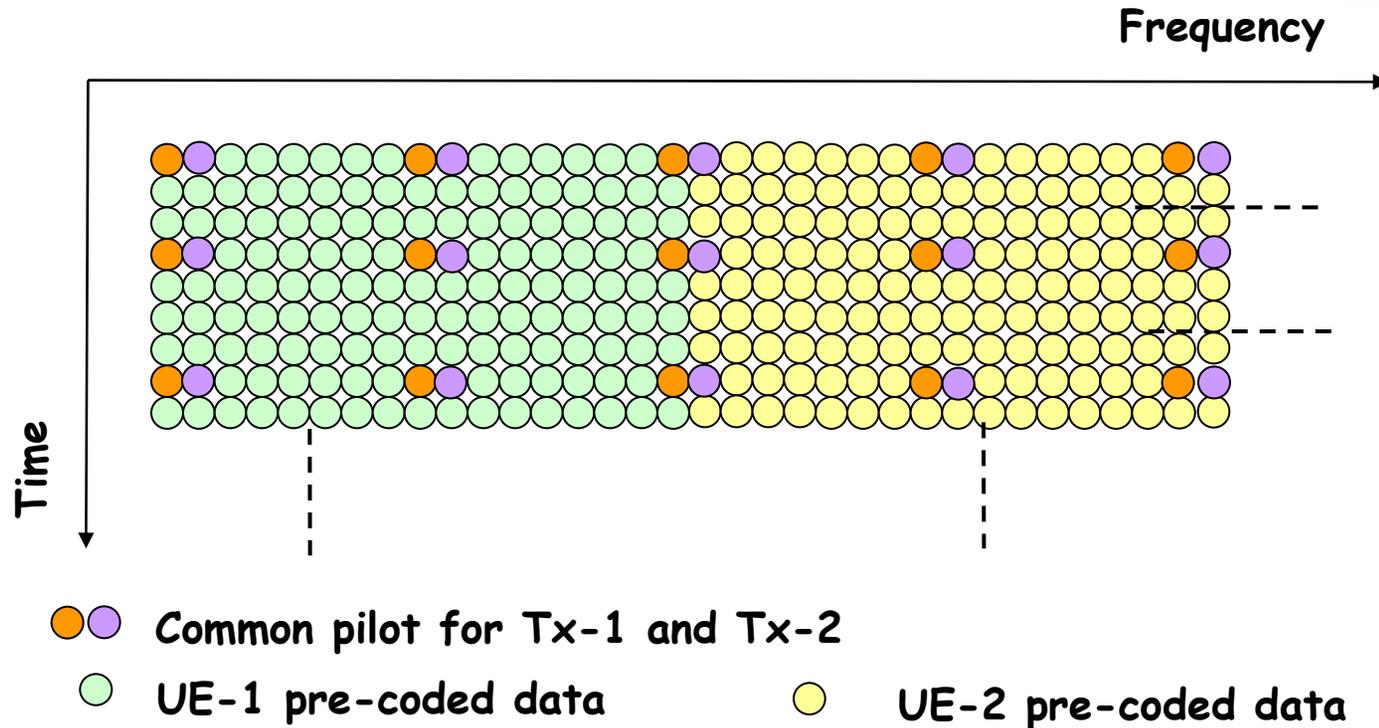
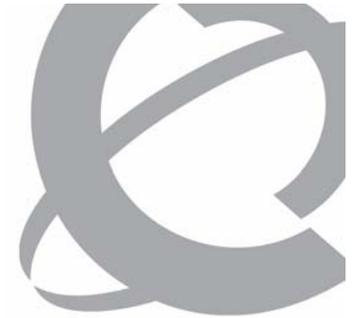
Introduction and Background

- > Closed-loop MIMO aims to significantly improve throughput and reliability of nomadic UEs.
- > For an FDD system the information of a pre-coding matrix is fed back through either channel sounding like approaches or codebook index like approaches.
- > Codebook index feedback like approaches are more feasible for higher order MIMO systems.

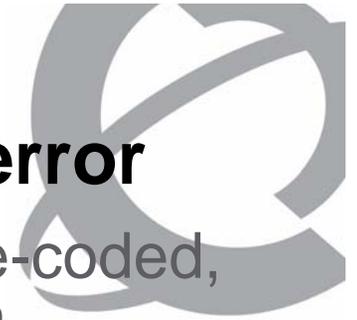
However, codebook index feedback uses up a large amount of uplink radio resources.

Common pilot based systems

— a two transmit antenna example



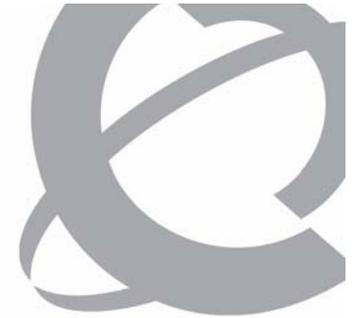
In a common pilot based system, pilots are not pre-coded, and hence have different channel matrixes from data.



The impact of codeword index feedback error

- > In a common pilot based system, pilots are not pre-coded, and hence have different channel matrix from data.
- > If the receiver knows the pre-coding matrixes used by the transmitter, it can reconstruct the channel matrix with pre-coding effects.
- > When data channel matrix can be correctly reconstructed, data can be correctly decoded.
- > If the receiver uses a different pre-coding matrix from the transmitter, constructed effective data channel matrix will be wrong.
 - Detected data will be useless due to incorrect channel references.
 - Detected data cannot be used for H-ARQ purpose.

The receiver needs to know when a codeword index feedback error occurs.



Differential codeword index feedback

- > Closed-loop MIMO is intended for nomadic UEs.
- > The channel will not change fast.
- > For each given currently used pre-coding matrix, a small subset of codewords is more likely to be used due to slow channel variation.
- > This subset of codewords can be determined in several ways, such as spatial correlation and matrix correlation.
- > If we only feed back the index associated with this subset, fewer bits are needed.
- > The problem: If a feedback error occurs, the transmitter will keep using wrong subsets for consequent pre-coding updates.

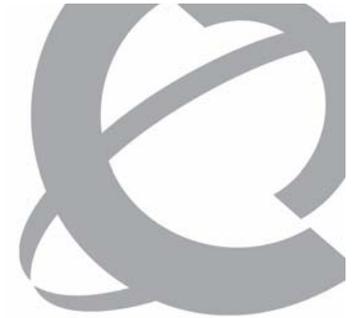
Feedback error propagates in differential codeword index feedback.

Periodic resetting in differential codeword index feedback



- > To address this error propagation problem, it was proposed to periodically transmit whole codeword index to correct possible feedback errors.
- > However, this raises more problems than it solves:
 - The whole codeword can be wrong, and hence error propagates.
 - The resetting is a random process: the system can be resetting when no error occurs, and not resetting when an error does occur.
 - To make the probability of error propagation low, a system must make a large amount of unnecessary resetting, which quickly diminishes the benefit of differential codeword index feedback.
 - To completely eliminate error propagation, a system has to reset every time, i.e. not use the differential index feedback approach.

Periodic resetting does not solve the error propagation problem.

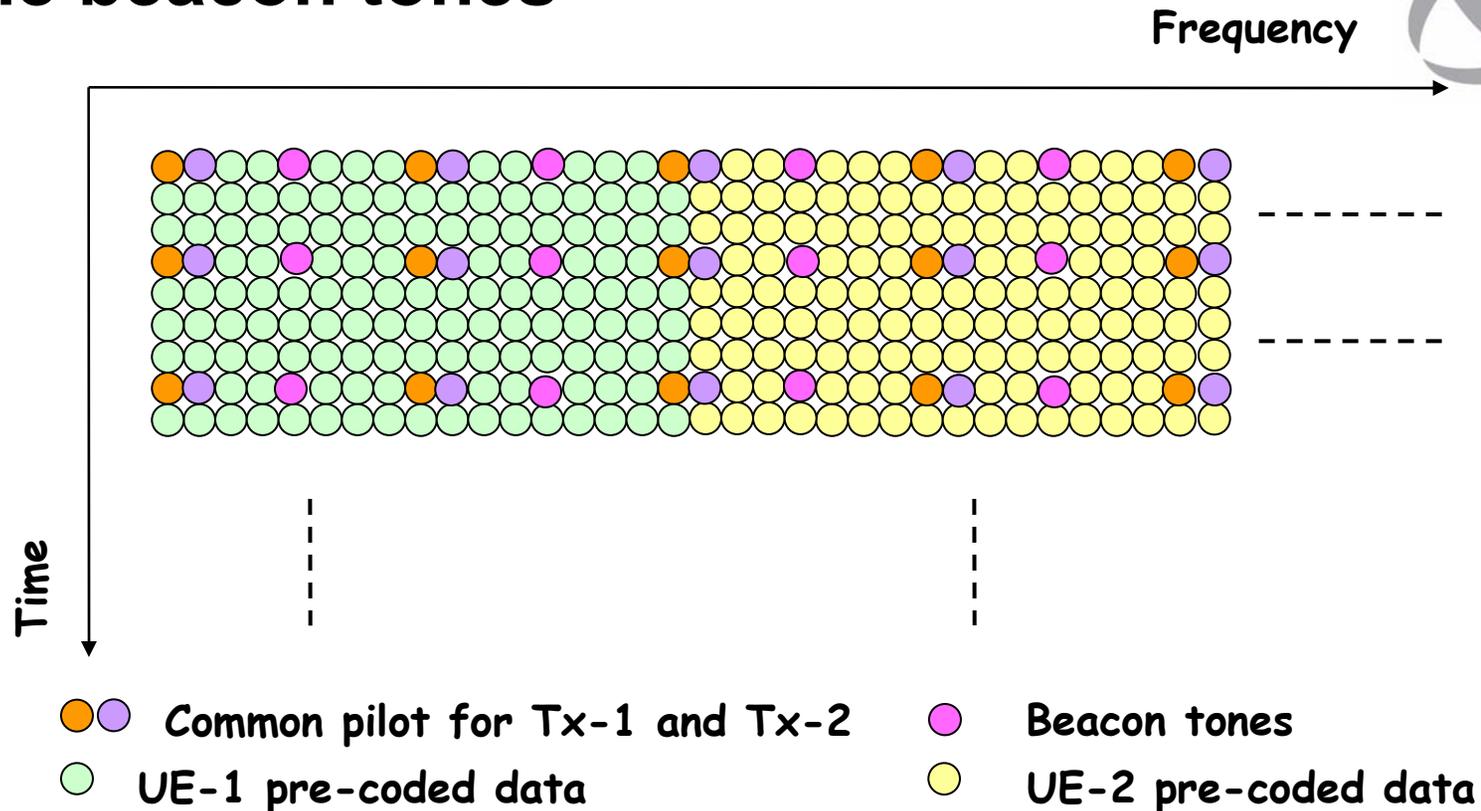


The motivation of the proposal

- > To detect feedback errors instantly
 - If a packet data error is not caused by pre-coding codeword feedback error, the received data can be used for H-ARQ purpose.
 - Otherwise, it needs to be discarded.
- > To detect which codeword is used by the transmitter
 - The subsequent differential codeword index feedback is based on the codeword being currently used by the transmitter.
 - Eliminate the error propagation instantly.

The proposal makes H-ARQ and reliable differential codeword index feedback feasible.

The beacon tones



Beacon tones are introduced to provide instant pre-coding codeword check.

The pre-coding codeword validation

$$\vec{r}_{pilot} = H_c V_p \vec{s}_{pilot} + \vec{n}$$

$$\hat{V}_p = \arg \min_{k=1, \dots, L} \left\| \vec{r}_{pilot} - H_c V_k \vec{s}_{pilot} \right\|^2$$

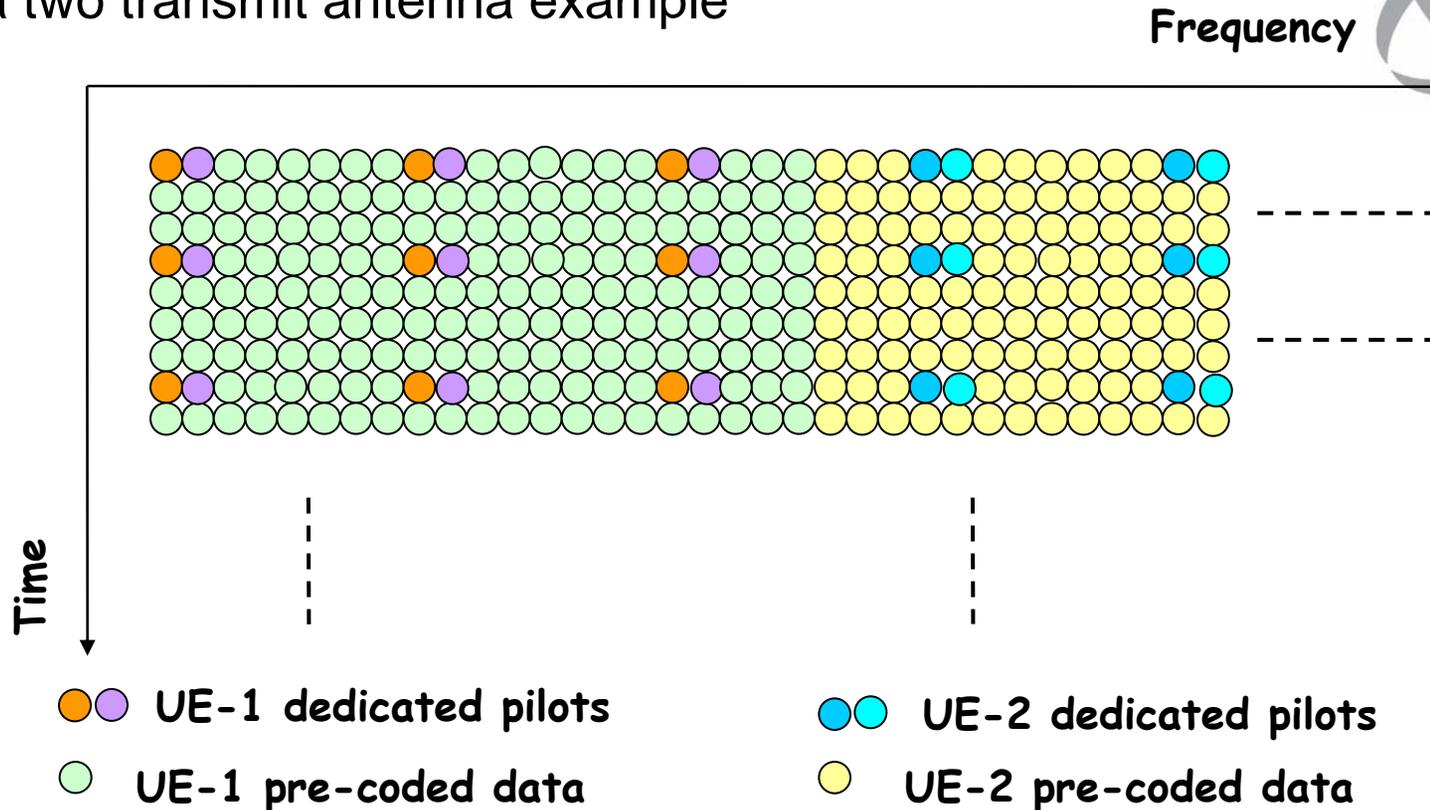
> Where

- V_p is the pre-coding matrix based on the “previous” feedback, which is unitary.
- \vec{s}_{pilot} is the pilot vector transmitted on a “beacon tone”.
- H_c is the “current” channel matrix without pre-coding.
- \vec{r}_{pilot} is the received signal vector on the corresponding “beacon tone”.
- \vec{n} is the noise vector at the receiver.
- L is the codebook size
- \hat{V}_p is the estimated pre-coding matrix at the receiver.
- $\|\cdot\|^2$ is the square of the norm.

All the beacon tones within a feedback period can be used jointly for the pre-coding codeword check purpose, but the minimum required number of beacon tones in a feedback period is one.

Dedicated pilot based systems

— a two transmit antenna example



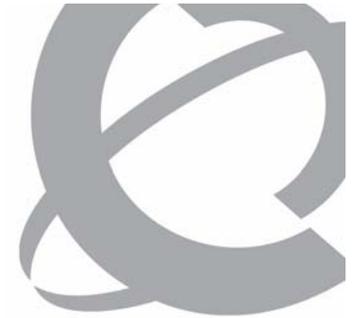
In a dedicated pilot based system, pilots are pre-coded, and hence have the same channel matrixes as data.



The issues in a dedicated pilot system

- > Since other UEs in the system do not know what pre-coding matrix is being used by the BTS, they are unable to monitor the channel.
 - Do not know which pre-coding matrix to use.
 - Do not know the rank of the current channel.
 - Cannot estimate per-layer based SINR.
 - Unable to do channel dependent scheduling.

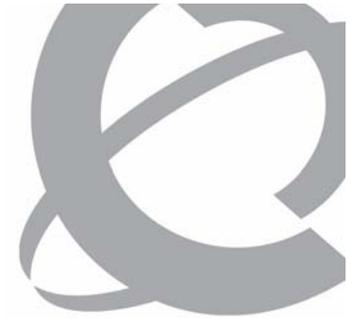
- > Since both pilot and data go through the same channel, the system is more resilient to codeword index feedback error.
 - One feedback error will propagate over two feedback periods.
 - Feedback causes performance degradation, but the decoded data can still be used for H-ARQ.



Differential codeword index feedback

- > Differential feedback error propagates, but the consequences are less severe than in the common pilot case for the UE of interest.
- > Lose the benefit of pre-coding with all the uplink feedback.
 - When the pre-coding matrix becomes random, the system behaves like an open loop system.
 - Wrong per-layer based power allocation can further hamper system performance.

Feedback error still propagates, but with less severe consequence than in the common pilot case.

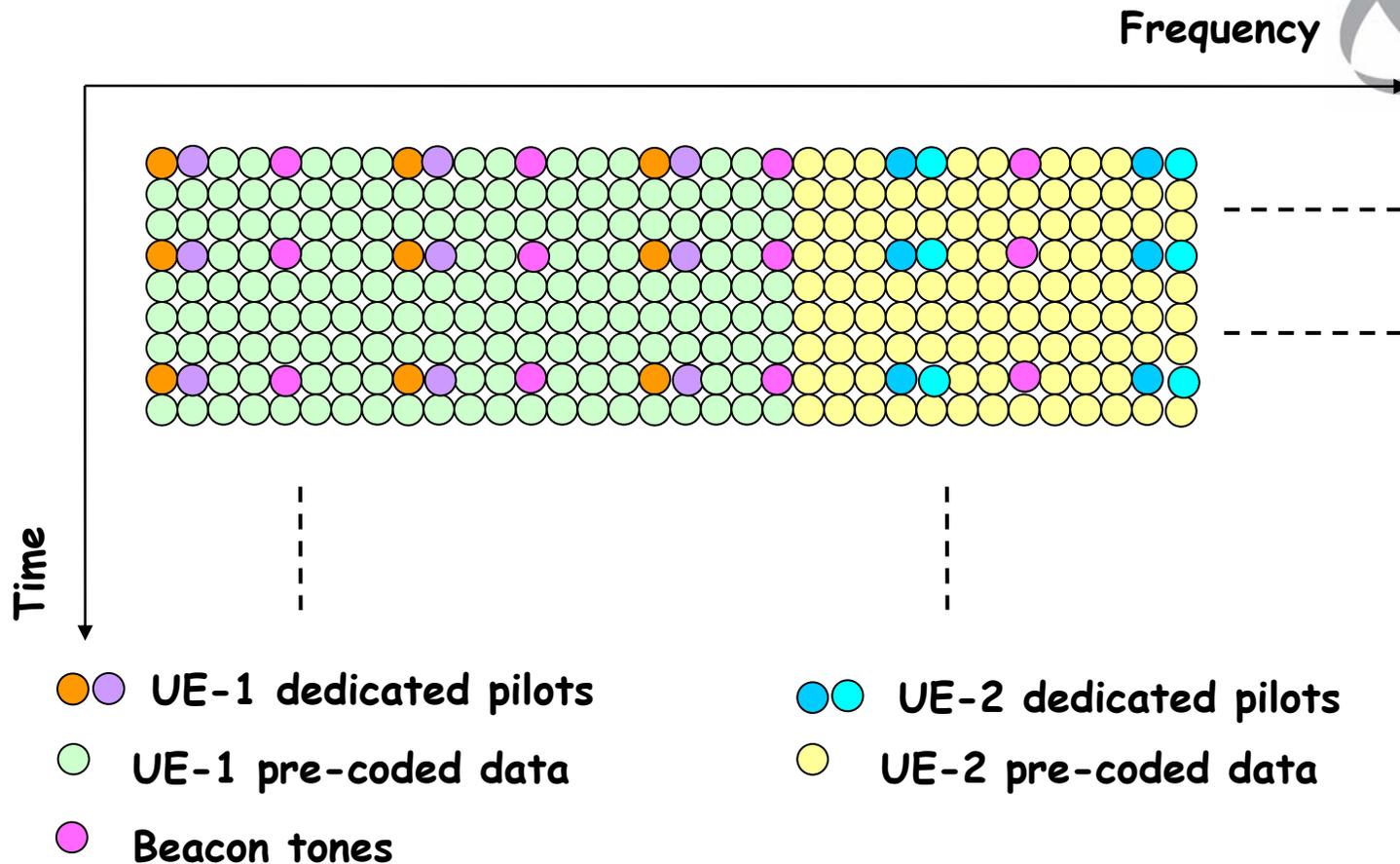


The motivation of the proposal

- > To allow other UEs in the system to track the channel, so that they can use proper closed-loop schemes and be scheduled properly.
- > To detect feedback errors instantly, so as to stop the error propagation effect and make sure that a pre-coding system function properly.

The proposal makes channel tracking and reliable differential codeword index feedback possible.

The beacon tones



Beacon tones are introduced to provide instant pre-coding codeword check.



The pre-coding codeword validation

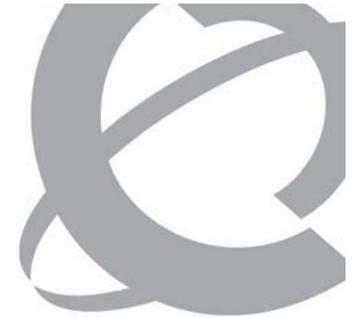
$$\vec{r}_{pilot} = H_c \vec{s}_{pilot} + \vec{n}$$

$$G = H_c V_p$$

$$\hat{V}_p = \arg \min_{k=1, \dots, L} \left\| \vec{r}_{pilot} - G V_k' \vec{s}_{pilot} \right\|^2$$

$$H_c = G V_p'$$

All the beacon tones within a feedback period can be used jointly for the pre-coding codeword check purpose, but the minimum required number of beacon tones in a feedback period is one.



The estimation error issue

- > When estimation noise power is larger than the codeword quantization distances, an estimation error could occur.
- > The larger is the distances among codebook entries, the smaller is the probability of error.
- > Several approaches can be employed to make detection more reliable:
 - Use more than one beacon tone for each sub-band.
 - Track the codeword error — if the same wrong codeword is detected twice, then it is safe to assume that this specific codeword was used as an earlier pre-coding codeword.



Summary

- > A beacon tone based approach is able to instantly detect pre-coding feedback errors.
- > It is able to verify and detect currently used pre-coding matrixes, and consequently eliminate error propagation effects in a differential codeword index feedback based pre-coding system.
 - Significantly reduces the overhead in a pre-coding based closed-loop MIMO system.
 - Makes pre-coding practical.
- > It is able to detect packet data usability for H-ARQ in a common pilot based system.
- > It makes monitoring and tracking channels possible for all the UEs in a dedicated pilot based MIMO-OFDM system.

