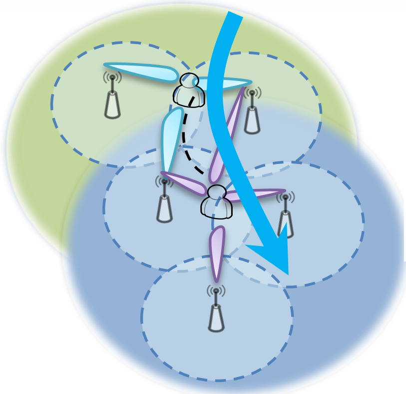
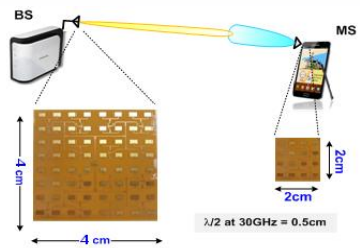
An Efficient CDI Acquisition Scheme Facilitating Large Scale Antenna Systems

LSAS promising but challenging: problem to be tackled

1. @ mmW band with massive antennas to form pencil beam





Narrow beam alignment in mmW cells:

- increase signal strength for coverage
- reduce interference

Problem (Fast beam tracking)

- CDI acquisition by multi-stage due to large propagation loss

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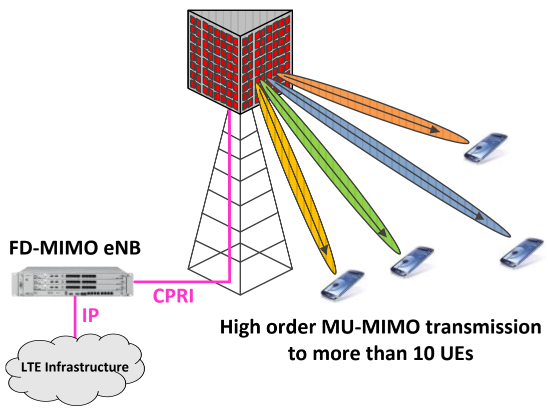
2. Support of higher-order MU-MIMO by Massive MIMO operation



Problem

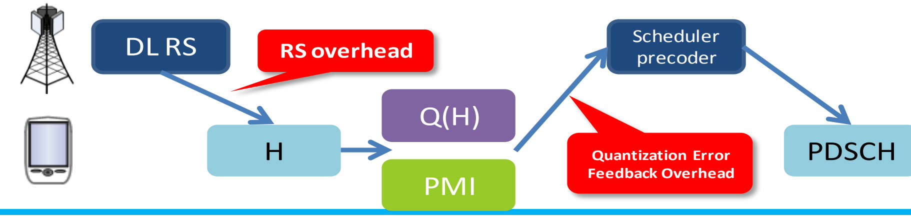
- RS & feedback overhead due to large number of antennas and higher-order MU-MIMO;
- Or pilot contamination due to limitation of UL SRS capacity

Efficient & accurate CSI acquisition Mechanism: MUST get around the hurdles by practical design

Differential Channel Direction Probing (DCDP)

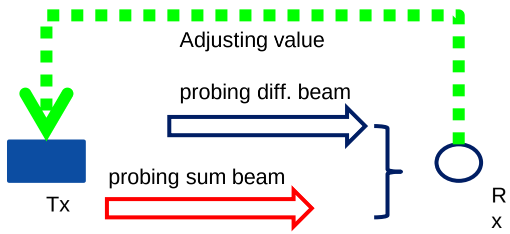
Why DCDP? Motivated by

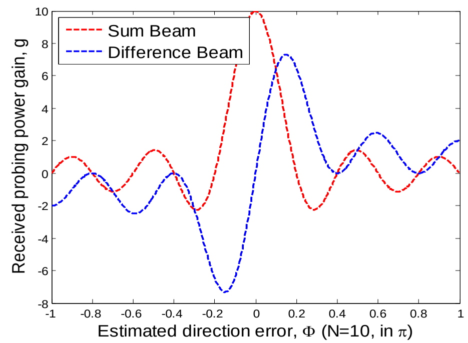
- Overhead issue of CE RS and feedback in FDD mode;
- Conventional beamformed RS may save overhead, but
  - ✓ Slow convergence for beam-tracking @ mmW band
  - ✓ Performance loss along with the reduction of overhead.



2D-DCDP Rationale & general procedure

1) 3-steps CDI probing procedure :





$$g = \vec{h}^H(\sin(\theta_{true}))\,\vec{w} + n$$

Fig a): power differentiation

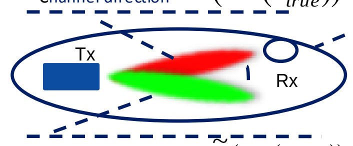
2) Differential beam pair:

$$\vec{w}_{Sum} = \tilde{\vec{h}}(\sin(\theta_{\text{prob}}))$$

$$= \left[1, e^{j2\pi\sin(\theta_{\text{prob}})d/\lambda}, \cdots, e^{j2\pi\left(\frac{N}{2}-1\right)\sin(\theta_{\text{prob}})d/\lambda}, e^{j2\pi\left(\frac{N}{2}\right)\sin(\theta_{\text{prob}})d/\lambda} \cdots, e^{j2\pi\frac{d}{\lambda}(N-1)\sin(\theta_{\text{prob}})d/\lambda}\right]^T$$

$$\vec{w}_{Diff} = \left[1, e^{j2\pi\frac{d}{\lambda}\sin(\theta_{\text{prob}})}, \cdots, e^{j2\pi\left(\frac{N}{2}-1\right)\sin(\theta_{\text{prob}})d/\lambda}, -e^{j2\pi\left(\frac{N}{2}\right)\sin(\theta_{\text{prob}})d/\lambda} \cdots, -e^{j2\pi(N-1)\sin(\theta_{\text{prob}})d/\lambda}\right]^T$$

3) Constructed mapping relationship:



Channel direction $\vec{h}(\sin(\theta_{true}))$

Estimated direction $\tilde{\vec{h}}(\sin(\theta_{prob}))$

Estimated direction error

$$\Phi = 2\pi\frac{d}{\lambda}(\sin(\theta_{\text{prob}}) - \sin(\theta_{\text{true}}))$$

Modified to differential detection

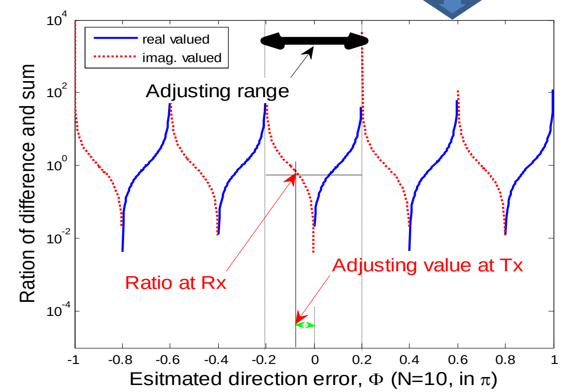
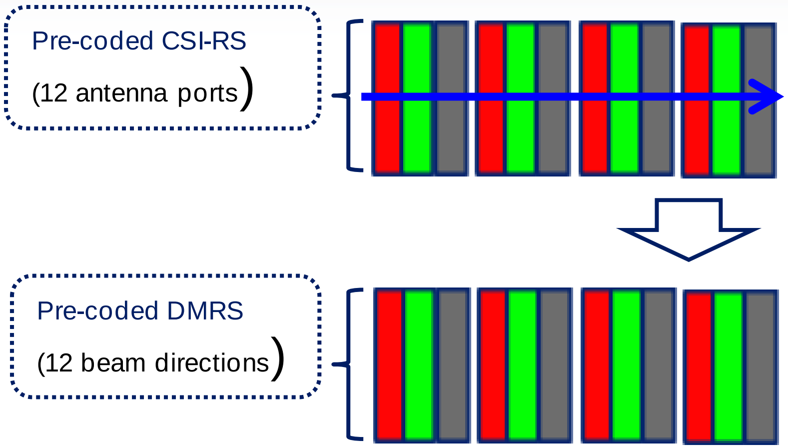


Fig b): relation mapping between gain ratio and CDI

DCDP is a simple solution to accelerate the convergence for multi-stage CSI acquisition and/or further limit the RS overhead.
Can suit for both of mmW beam tracking and higher-order MU-MIMO pre-coding!

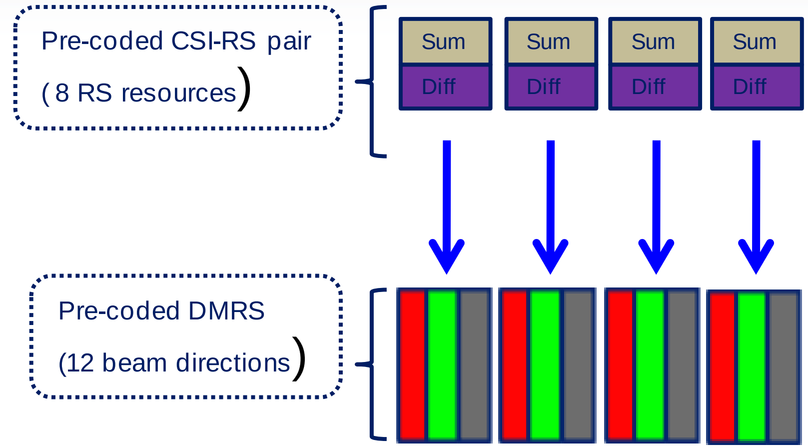
Illustration of DCDP practical usage

- **Clear benefit : CSI-RS overhead further reduction for LSAS operation @ low band**



CSI-RS Antenna port feedback map to DMRS antenna port

(a) GoB for overhead reduction



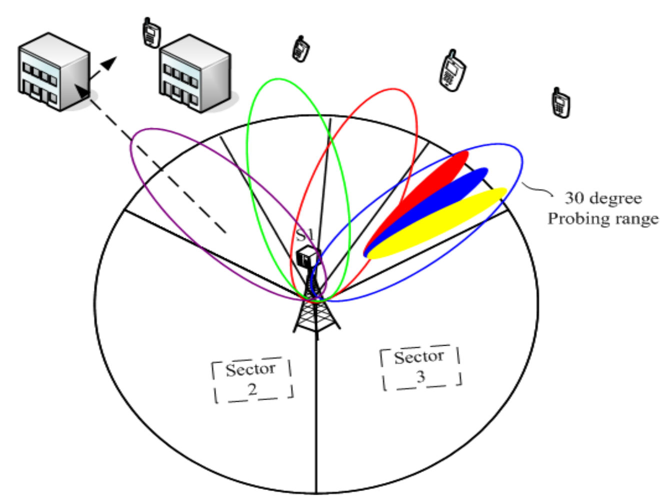
One Feedback of ratio (diff/sum) can help Tx to select one among 3 DMRS port

(b) DCDP for overhead reduction

- In the above example, DCDP (b) can further save the overhead of CSI-RS by 1/3 compared to the straightforward overhead reduction method (a). And based on each CSI-RS pair, a 10 ° beam among 30 ° range can be identified.
- The amount of overhead saving depends on the accuracy of DCDP design. E.g if the beam resolution can be 10 °among 60 ° degree range, the number of precoded CSI-RS pair can be further reduced to 2.

Note: GoB (grid of beam) represents the conventional beamformed RS scheme;

Note: pencil beam formed by LSAS can be < 10 °in reality.

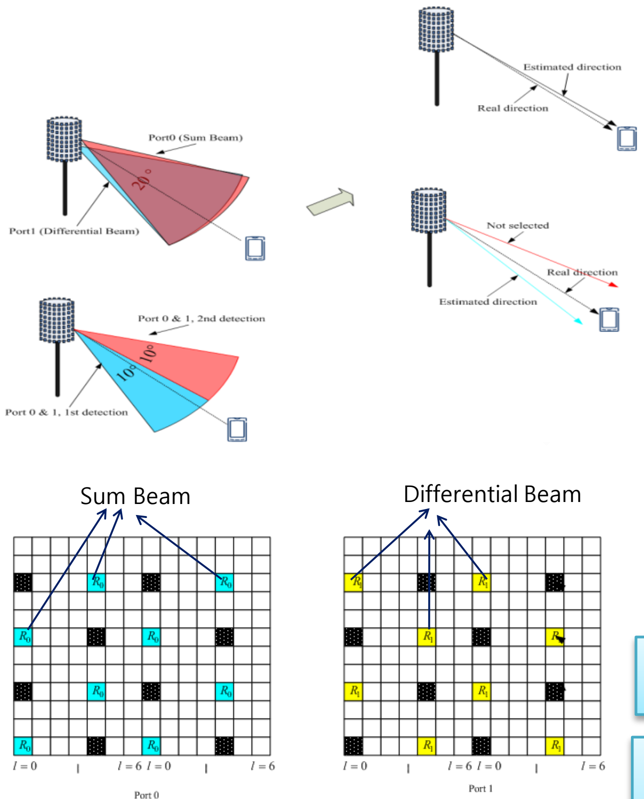


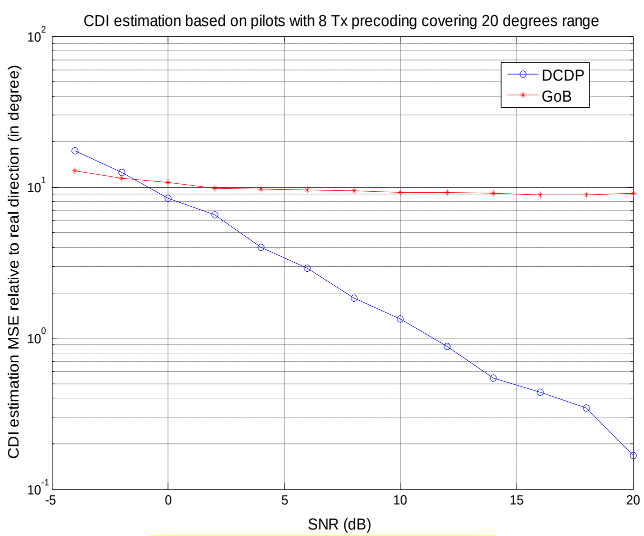
CDI estimation accuracy

8 Tx antenna is used for beamforming CDI detection MSE in degree

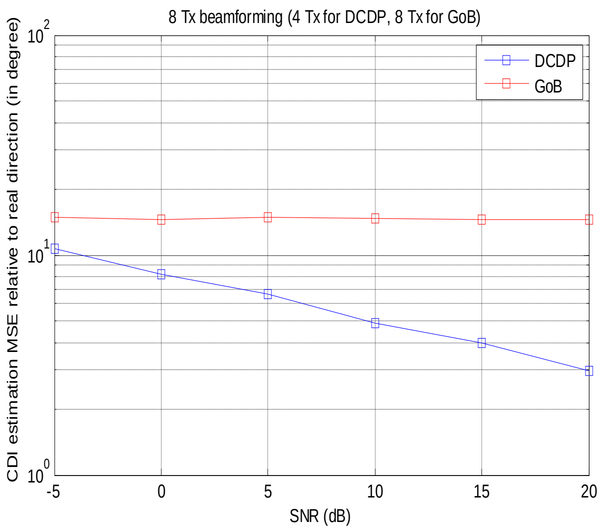
- ✓ **CDCP scheme, provides refined spatial resolution within probing range.**
  - ✓ 20° detection region, CRS port 0 for sum beam, port 1 for differential beam
  - ✓ 1PRB used, one detection performed
- ✓ **Conventional precoded RS scheme, provides fixed** 10° **resolution**.
  - ✓ 20 ° detection region is divided into 2 * 10° detection region, two detections performed.

- A LTE like system is used to perform the simulation
  - Number of subcarriers: Ns=256
  - Number of PRB used: nPRB=1
  - Reference signal used: CRS
  - Number of Tx antennas: 8, 16, 32
  - Channel model: one-ring channel with 2 degree variance or SCM





one ring channel

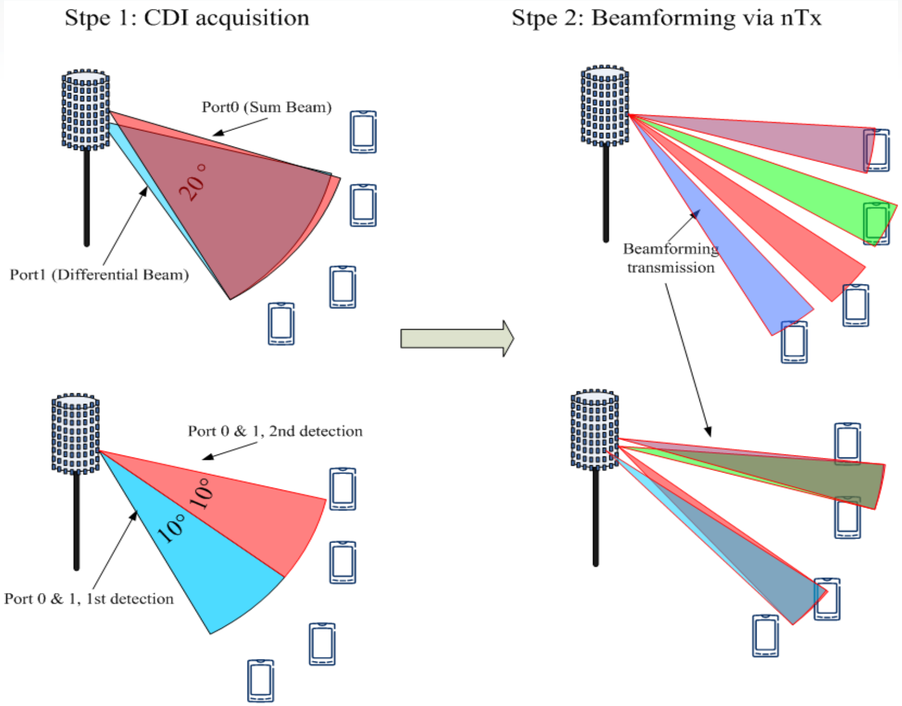


SCM channel

Therefore:

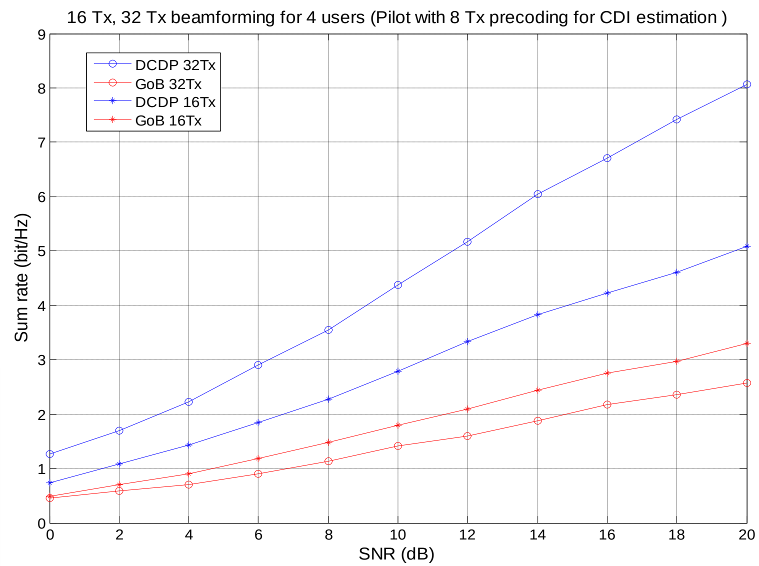
- DCDP scheme provides more accurate CDI information close to the real channel direction.

Sum Rate in multi-user MIMO case



Settings:

- 4 users randomly distributed within 20° space
- CDI is acquired through 8Tx
- MRT precoding based on the estimated CDI
- Sum rate calculated via SINR analysis



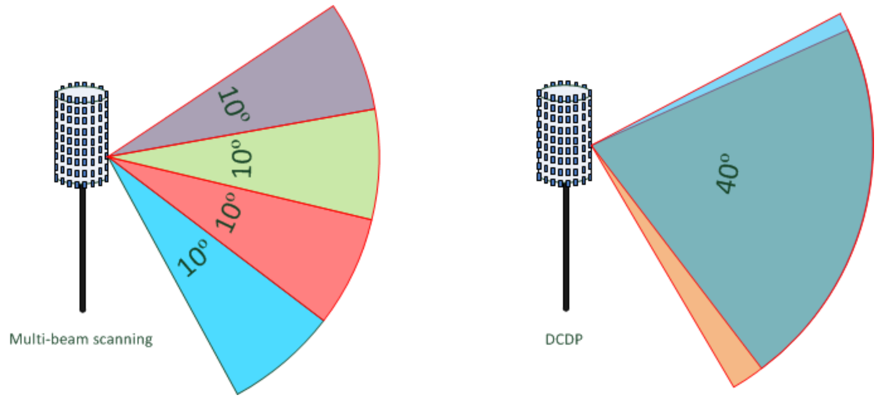
one ring channel

Conclusion:

- The DCDP enables more accurate CDI, which suppresses the MU-interference in a MU scenario, given same RS overhead for channel estimation.
- In the other way around, DCDP can reduce the overhead given same performance requirement.

single user MIMO case

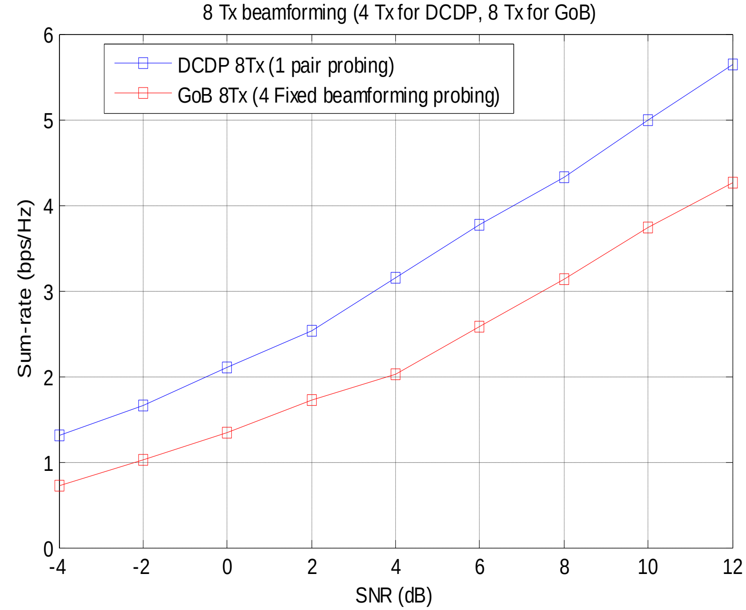
DCDP provides higher SNR for receiver due to the high resolution CDI, accordingly higher achievable sum-rate, even though the pilot overhead is reduced by ½.



Settings:

- Overhead is halved by DCDP
- Scanning range is the same
- DCDP uses less antennas to achieve a wider beam
- Multi-beam scanning has resolution of 10 degree
- Assume no feedback quantization loss

Shannon rate



SCM channel

Conclusion:

- DCDP's benefit is still sustained in practical multi-path MIMO channel

謝！

Thanks