CWC Oulu CENTRE FOR WIRELESS COMMUNICATIONS
University of Oulu

www.cwc.oulu.fi

Creating Wireless World

Subchannel Allocation in Relay-Enhanced OFDMA Downlink With Imperfect Feedback

Jouko Leinonen[1], **Taneli Riihonen[2]**, Jyri Hämäläinen[2], and Markku Juntti[1]
[1]University of Oulu, Centre for Wireless Communications
[2]Helsinki University of Technology, SMARAD CoE

GLOBECOM 2009

HELSINKI UNIVERSITY OF TECHNOLOGY
SMARAD Centre of Excellence

UNIVERSITY of OULU
OULUN YLIOPISTO

Content

- Introduction
- System model
- RB-wise one bit feedback
- Capacity analysis: RB-wise one bit feedback
- Best-*M* feedback
- Capacity analysis: Best-*M* feedback
- Example results
- Conclusion

Introduction

- Key technologies in future wireless systems
  - Opportunistic resource allocation in OFDMA
  - MIMO methods
  - Relaying
- Feedback design is a crucial problem

Introduction

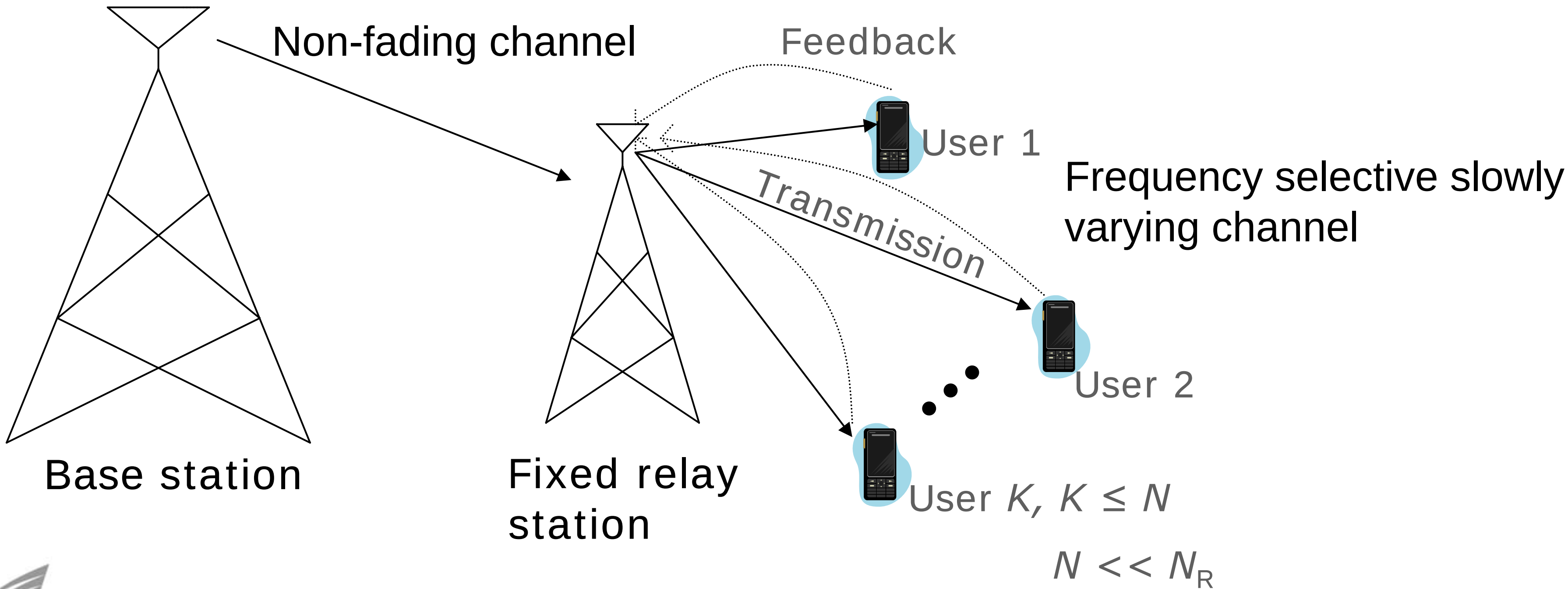
- Analytical performance evaluation of relay enhanced OFDMA systems with limited feedback has received less attention in literature

Contribution

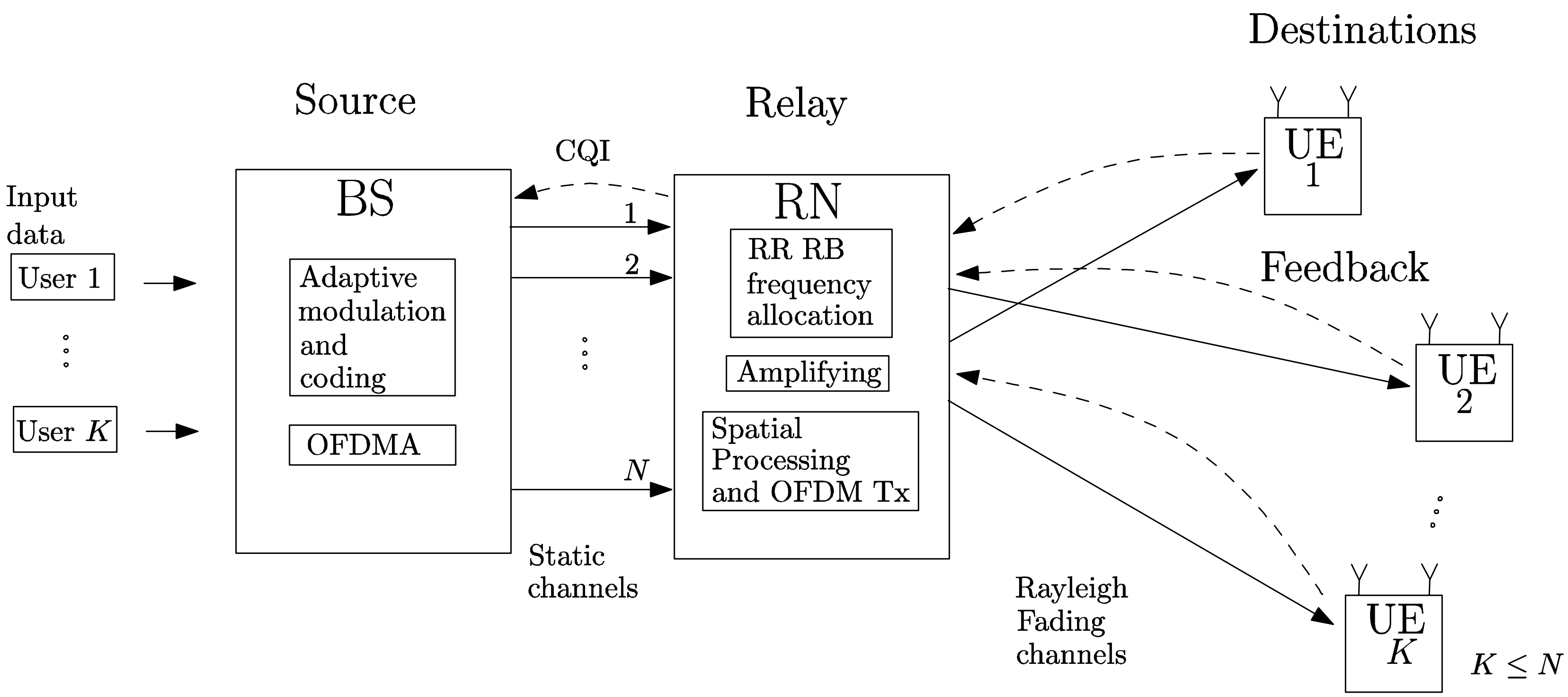
- Analytical performance expressions
  - Imperfect and limited feedback
  - Practical frequency allocation
  - AF relay
  - Multiantenna transmission

System model

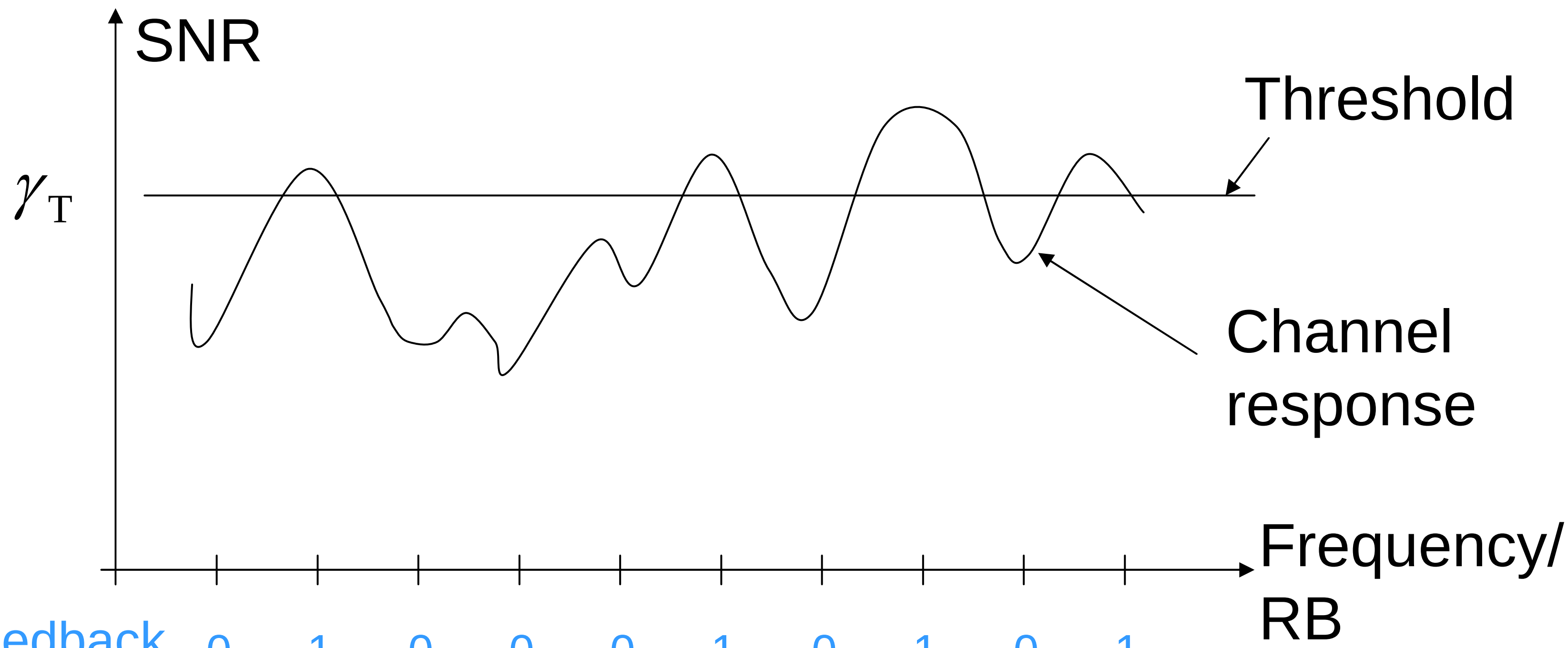
- Single cell environment
- Downlink
- Amplify-and-forward relay
- Round Robin allocation
- MIMO
  - AS, STBC
- Erroneous feedback p_b



System model



RB-wise one bit feedback



Feedback word 0 1 0 0 0 1 0 1 0 1

Capacity analysis, RB-wise one bit feedback & STBC

$$C(k) = \frac{q_1(k, p_b)}{2 p_1^Q} \int_{\gamma_T}^{\infty} f_{\mathrm{STBC}}(\gamma) \log_2(1+\gamma) d\gamma + \frac{q_0(k, p_b)}{2 p_0^Q} \int_{0}^{\gamma_T} f_{\mathrm{STBC}}(\gamma) \log_2(1+\gamma) d\gamma$$

$q_1(k, p_b)$ Probability: the SNR of allocated RB exceeds γ_T

User Feedback BEP

$$q_0(k, p_b) = 1 - q_1(k, p_b)$$

$$p_1^Q = \int_{\gamma_T}^{\infty} f_{\mathrm{STBC}}(\gamma, \bar{\gamma}) d\gamma, \quad p_0^Q = 1 - p_1^Q$$

Capacity analysis, RB-wise one bit feedback & AS

$$C = q_1^Q(k, p_b)\Big(\big(1 - p_{\mathrm{ASE}}\big)C_{\mathrm{AS}_1}(\gamma_{\mathrm{T}}) + p_{\mathrm{ASE}}C_{\mathrm{ASE}_1}(\gamma_{\mathrm{T}})\Big)\Big/2$$
$$+ q_0^Q(k, p_b)\Big(\big(1 - p_{\mathrm{ASE}}\big)C_{\mathrm{AS}_0}(\gamma_{\mathrm{T}}) + p_{\mathrm{ASE}}C_{\mathrm{ASE}_0}(\gamma_{\mathrm{T}})\Big)\Big/2$$

p_{ASE} Probability of antenna selection error

$$C_{\mathrm{AS}_1}(\gamma_{\mathrm{T}}) = \int_{\gamma_{\mathrm{T}}}^{\infty} f_{\mathrm{AS}}(\gamma)\big/p_1^Q \log_2(1+\gamma)d\gamma$$

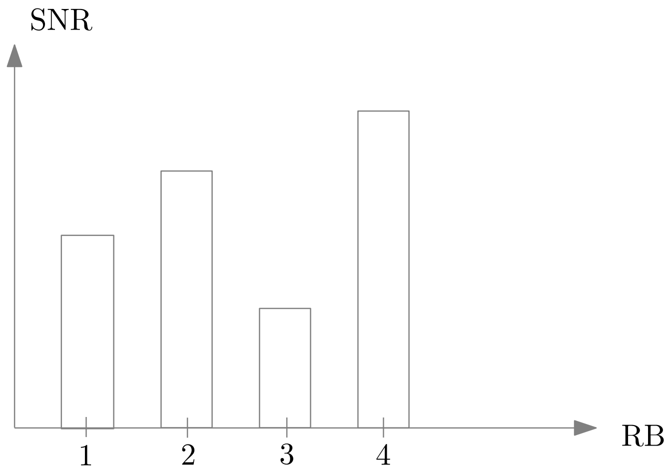
$$C_{\mathrm{ASE}_1}(\gamma_{\mathrm{T}}) = \int_0^{\infty} f_{\mathrm{ASE}_1}(\gamma \mid \gamma_{\mathrm{AS}} > \gamma_{\mathrm{T}})\log_2(1+\gamma)d\gamma$$

$$C_{\mathrm{AS}_0}(\gamma_{\mathrm{T}}) = \int_0^{\gamma_{\mathrm{T}}} f_{\mathrm{AS}}(\gamma)\big/p_0^Q \log_2(1+\gamma)d\gamma$$

$$C_{\mathrm{ASE}_0}(\gamma_{\mathrm{T}}) = \int_0^{\gamma_{\mathrm{T}}} f_{\mathrm{ASE}_0}(\gamma \mid \gamma_{\mathrm{AS}} < \gamma_{\mathrm{T}})\log_2(1+\gamma)d\gamma$$

Best-*M* feedback

- Indices of *M* best RBs are fed back from UE to RN
- Conventional best-*M* and sub-block best-*M* (SBB-*M*) methods are considered



(a) Channel condition

Index of RB combination	Index of RB combination in bits
12	000
13	001
14	010
23	100
24	101
34	110

Feedback word: 101

(b) Best-M feedback case

	RB index	RB index in bits
sub-band 1	1	0
	2	1
sub-band 2	3	0
	4	1

Feedback word: 11

(c) SBB-1 feedback case with two sub-blocks

Capacity analysis, Best-M feedback & STBC

$$C(k,\bar{\gamma}) = \frac{Nq(k,p_b) - M}{M(N-M)} \sum_{n=1}^{M} C_n^{\mathrm{STBC}}(\bar{\gamma}) + \frac{N(1-q(k,p_b))}{N-M} C_{\mathrm{STBC}}(\bar{\gamma})$$

$q(k, p_b)$ Probability that the allocated RB is among the *M* best RBs

User index

Feedback bit error probability

$$C_n^{\mathrm{RB}} = \int_0^\infty f_n^{\mathrm{STBC}}(\gamma)\log_2(1+\gamma)d\gamma$$ The average capacity of the *n*th best RB

$$C_{\mathrm{STBC}} = \int_0^\infty f_{\mathrm{STBC}}(\gamma)\log_2(1+\gamma)d\gamma$$ The average capacity of a RB

- Mathematical tool: Order statistics

Capacity analysis, Best-M feedback & AS

$$C(k,\bar{\gamma}) = (1-p_{\text{ASE}})\left(\frac{Nq(k,p_b)-M}{M(N-M)}\sum_{n=1}^{M} C_n^{\text{AS}}(\bar{\gamma}) + \frac{N(1-q(k,p_b))}{N-M} C_{\text{AS}}(\bar{\gamma})\right)$$

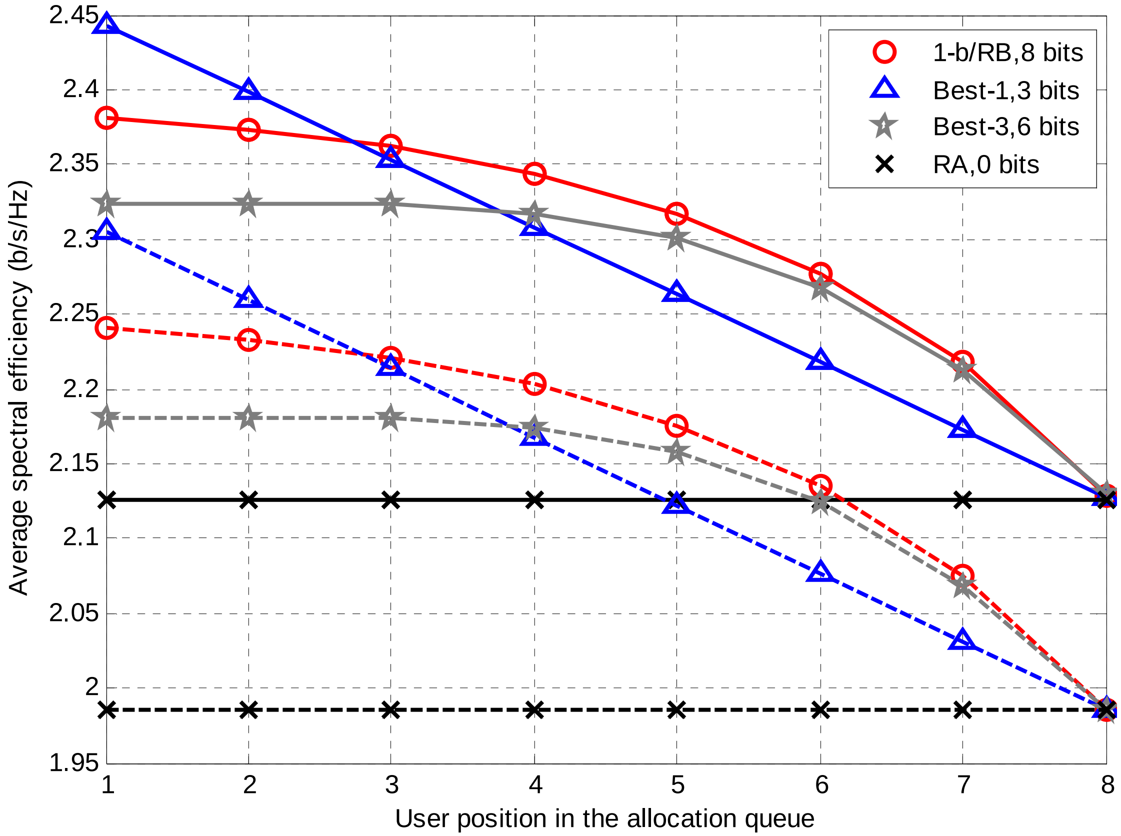
$$+\, p_{\text{ASE}}\left(\frac{q(k,p_b)}{M}\sum_{l=1}^{M} C_{l+}^{\text{MRC}}(\bar{\gamma}) + (1-q(k,p_b))C_{\text{ASE}}(\bar{\gamma})\right)$$

Probability of antenna selection error (ASE)

$$\frac{1}{NN_t-1}\sum_{n=l+1}^{NN_t} C_n^{\text{MRC}}(\bar{\gamma})$$

Capacity on the case of ASE and that the indicated channel is allocated

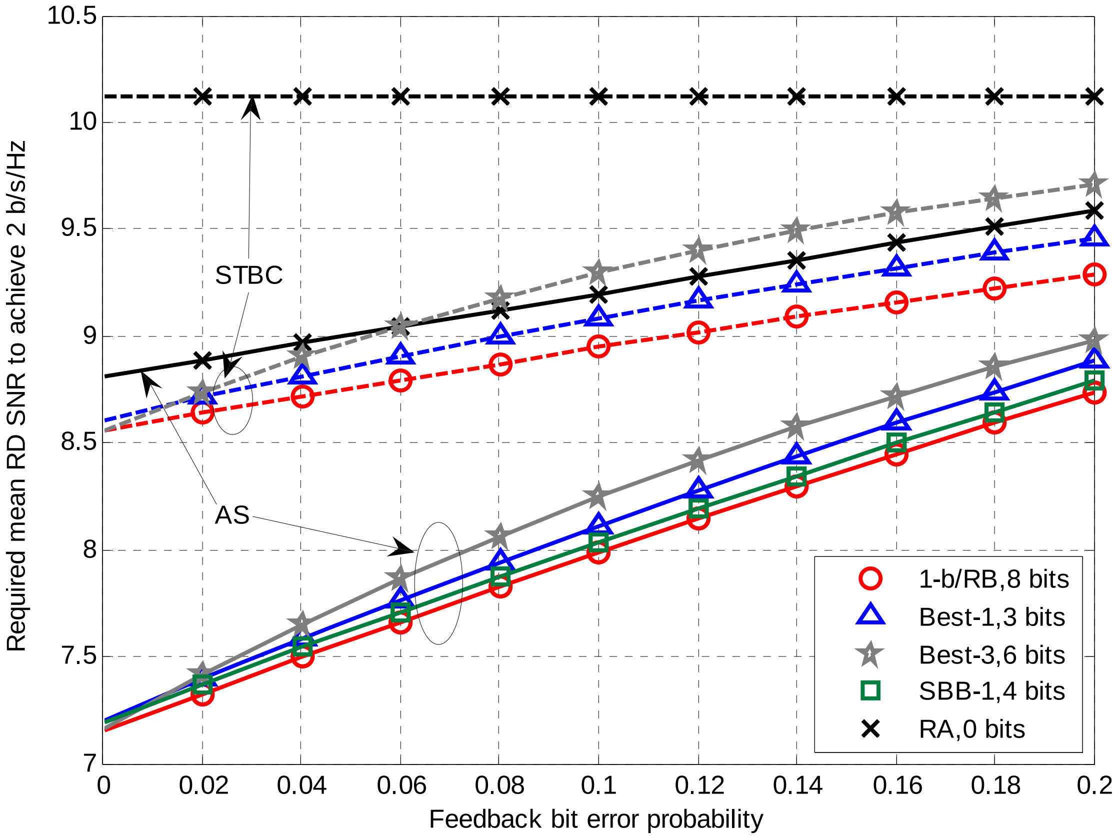
Example results
capacity vs. user position in the allocation queue



- Feedback BEP is 0.05
- AS outperforms STBC at the cost of increased feedback overhead
- RB-wise AS requires N = 8 bits

- Solid curve: AS
- Dashed curve: STBC

Example results
required mean RD SNR to achieve 2 b/s/Hz vs. FB BEP



- $N = K = 8$
- Best-M is sensitive for feedback bit errors
- SBB-1 reduces overhead and provides robustness against feedback errors
- SBB-1 with AS provides promising trade off between performance, overhead and performance

- Solid curve: AS
- Dashed curve: STBC

Conclusion

- Average capacity results for relay enhanced OFDMA are contributed
  - MIMO, two feedback methods, RR RB allocation and imperfect feedback channels are considered
- Analytical expressions are useful tools to compare the performance of the different feedback based methods