Investigation over NOMA with SIC in single antenna scheme

PHYSICAL LAYER SIMULATION

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Outline

- Introduction
  - NOMA with SIC (successive interference cancellation)
- SIC Model
  - Multiuser capacity
  - Signal multiplexing
  - Performance gain metrics
- Simulation
  - Tools (IT++)
  - System architecture, scenario and settings
  - Simulation results
- Reference

Recap of our previous works

- In the previous works, we surveyed and introduced literature on the physical and MAC layer techniques for non-orthogonal multiple access (NOMA)

[1] Y. Saito, Y. Kishiyama, A. Benjebbour, T. Nakamura, A. Li, and K. Higuchi, “Non-Orthogonal Multiple Access (NOMA) for Cellular Future Radio Access,” VTC Spring 2013.

[2] S. Tomida and K. Higuchi, “Non-orthogonal Access with SIC in Cellular Downlink for User Fairness Enhancement,” ISPACS), 2011.

[3] J. Umehara, Y. Kishiyama, and K. Higuchi, “Enhancing User Fairness in Non-orthogonal Access with Successive Interference Cancellation for Cellular Downlink,” ICCS 2012

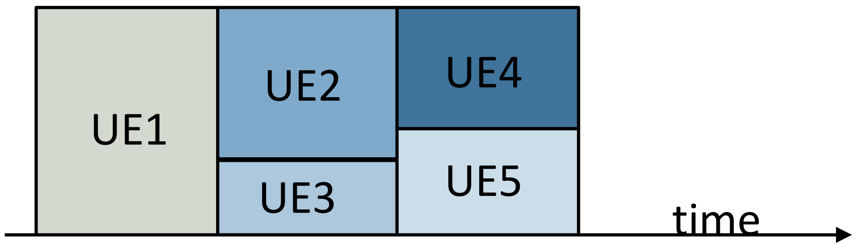
[4] J. Schaepperle and A. Regg, “Enhancement of Throughput and Fairness in 4G Wireless Access Systems by Non-orthogonal Signaling,” Bell Labs Technical Journal, 2009

[5] A. Ruegg and A. Tarable, “Iterative SIC Receiver Scheme For Nonorthogonally Superimposed Signals on Top of OFDMA,” PIMRC, 2010

- Based on previous works, we investigate theoretic and simulation models for NOMA to lay a more solid ground for the resource allocation and scheduling to be studied in this project

NOMA with SIC

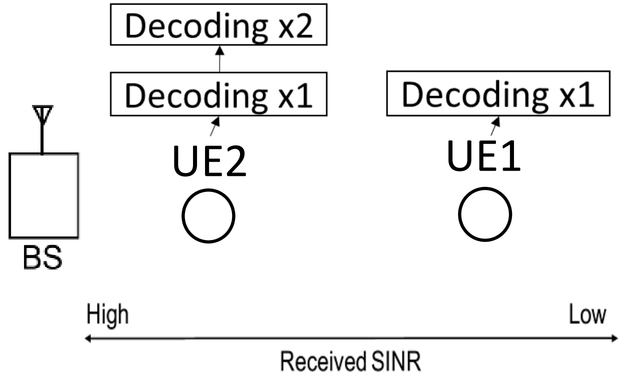
- Allocate more than one user at a single resource block, which achieves performance gain and improve user fairness.
- Simulations investigate SIC in SISO in downlink cases, and the BS is capable of supporting two users.

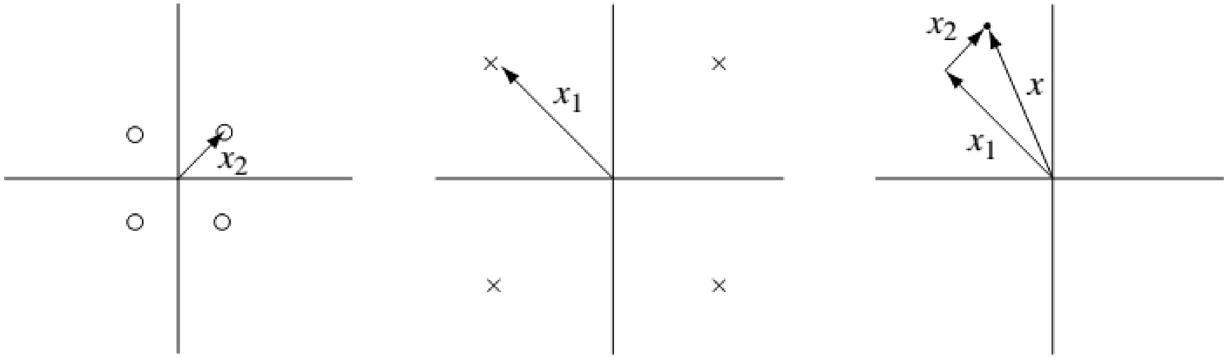


[1] Y. Saito, Y. Kishiyama, A. Benjebbour, T. Nakamura, A. Li, and K. Higuchi, "Non-Orthogonal Multiple Access (NOMA) for Cellular Future Radio Access," VTC Spring 2013.
[2] J. Schaepperle and A. Regg, "Enhancement of Throughput and Fairness in 4G Wireless Access Systems by Non-orthogonal Signaling," Bell Labs Technical Journal, 2009

NOMA with SIC

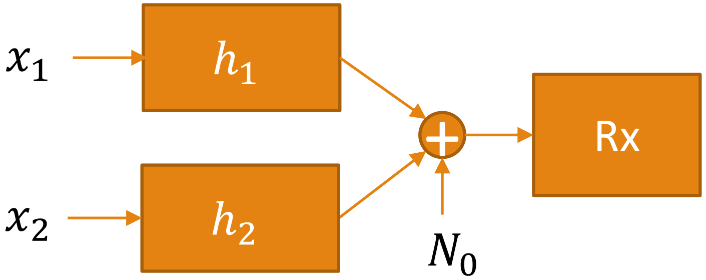
- NOMA with SIC allows simultaneous transmission in the same resource block by subtracting signals from different sources.
- In two-user downlink scenario, assume the channel condition of UE1 is better than UE2, the BS transmits multiplexed signal as below.
- By SIC, UE2 decode signal x_1 then subtract it from the received signal to attain its own signal x_2, and UE1 simply decode for signal x_1 regardless presence of x_2.



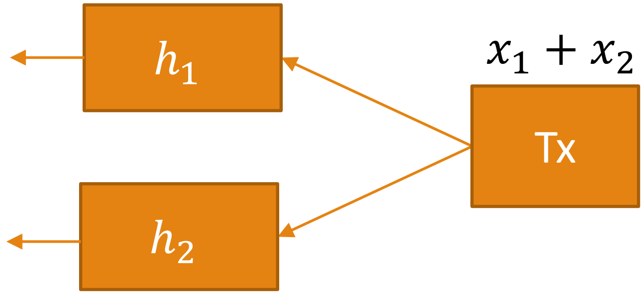


Signal multiplexing

- Access of two-user in uplink



- Access of two-user in downlink



Ideal SIC model (1/2)

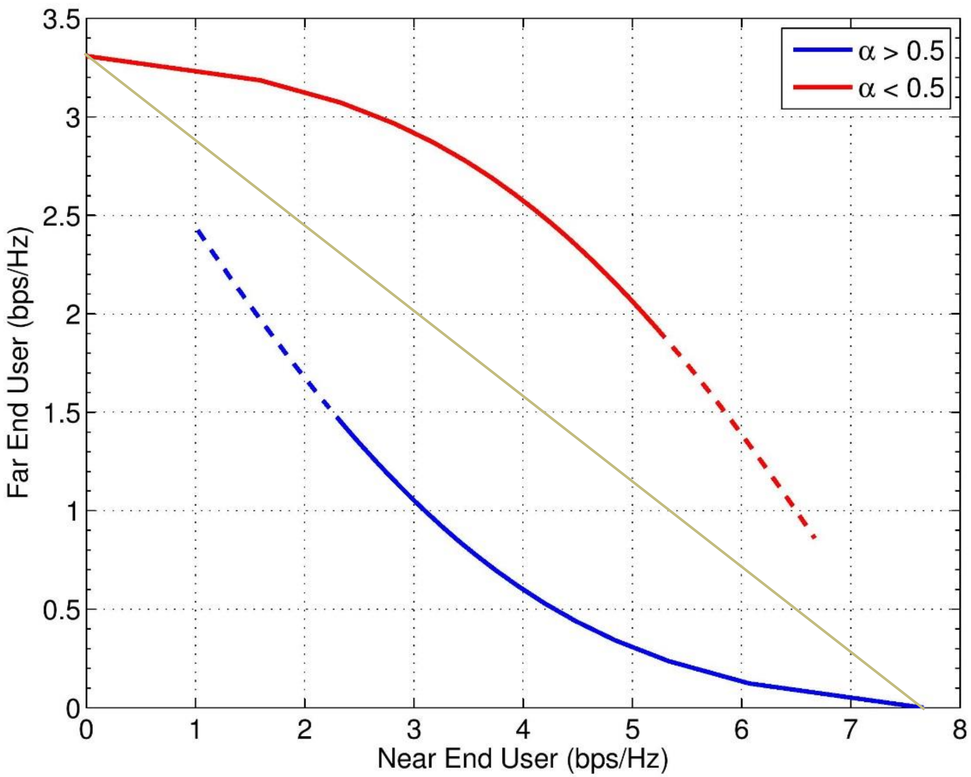
- Assume data signals with greater power can be decoded successfully.

$$R_b^{(\mathrm{sic})}(k) = W_b \log_2 \left(1 + \frac{|h_{k,b}|^2 P_{k,b}}{\sum_{\substack{i=1 \\ \frac{|P_{i,b}|^2}{N_{k,b}} < \frac{|P_{k,b}|^2}{N_{i,b}}}}^{K} |h_{k,b}|^2 P_{i,b} + W_b N_{k,b}} \right)$$

- The sum of power allocated is constrained, i.e.

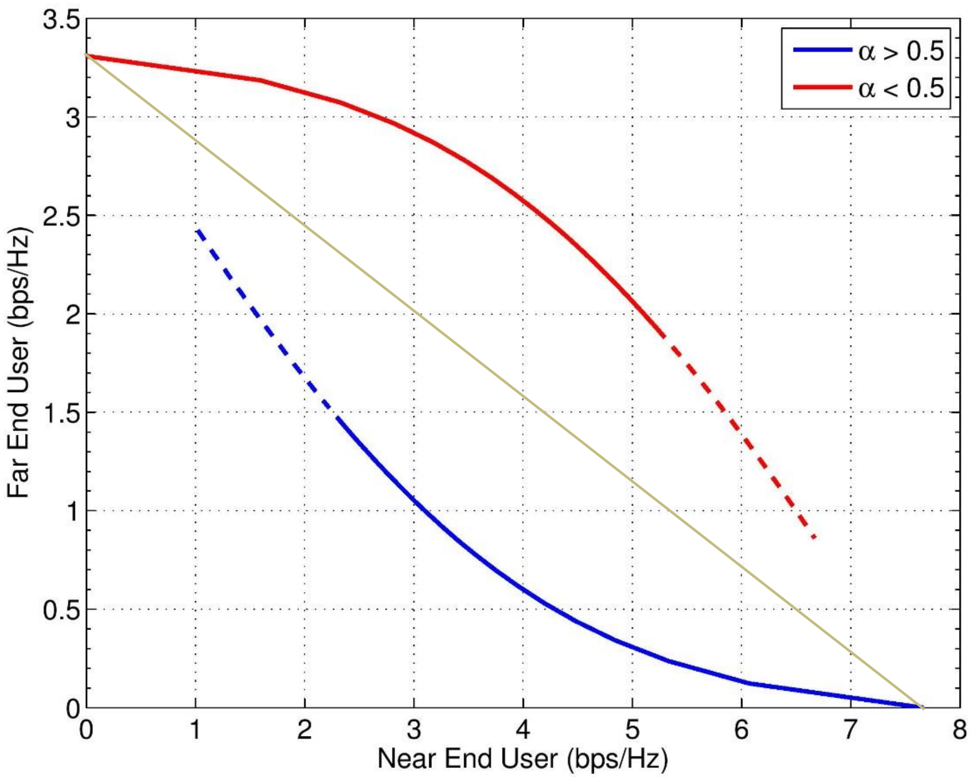
$$P = \sum_{i \in I} P_{i,b}$$

- In two-user case, define α as power allocation factor on near-end user.



Ideal SIC model (2/2)

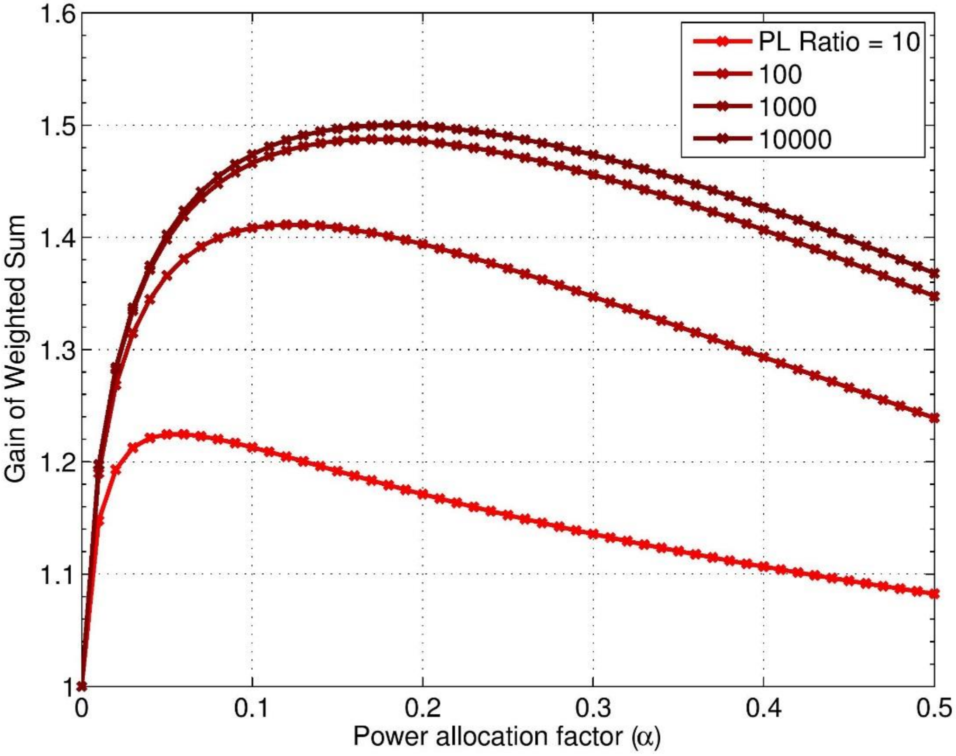
- Define performance metrics as follows,
- $R_1 = \alpha W log_2(1 + SINR_1)$
- $R_2 = (1 - \alpha) W log_2(1 + SINR_2)$
- The grey line shows the linear combination of rates when only one of the user is in service.



Performance Gain Metrics

$$Gain = \frac{1}{R_1(P)} R_1(\alpha P) + \frac{1}{R_2(P)} R_2((1-\alpha)P)$$

- As the difference of the PL ratio increase the gain in weighted sum also increases.
- The maximum of Gain slowly converges as the PL Ratio increase.



Ideal SIC model issue

- The ideal model of SIC based on Shannon capacity has several issues
- Error propagation: Capacity is calculated assumes zero-error when decoding former stages before extracting users own signal, however once error occurs, SIC performance degrades.
- Imperfect channel estimation: To remove effect of users' interference, receiver has to compensate channel perfectly, otherwise residual error also cause degradation.

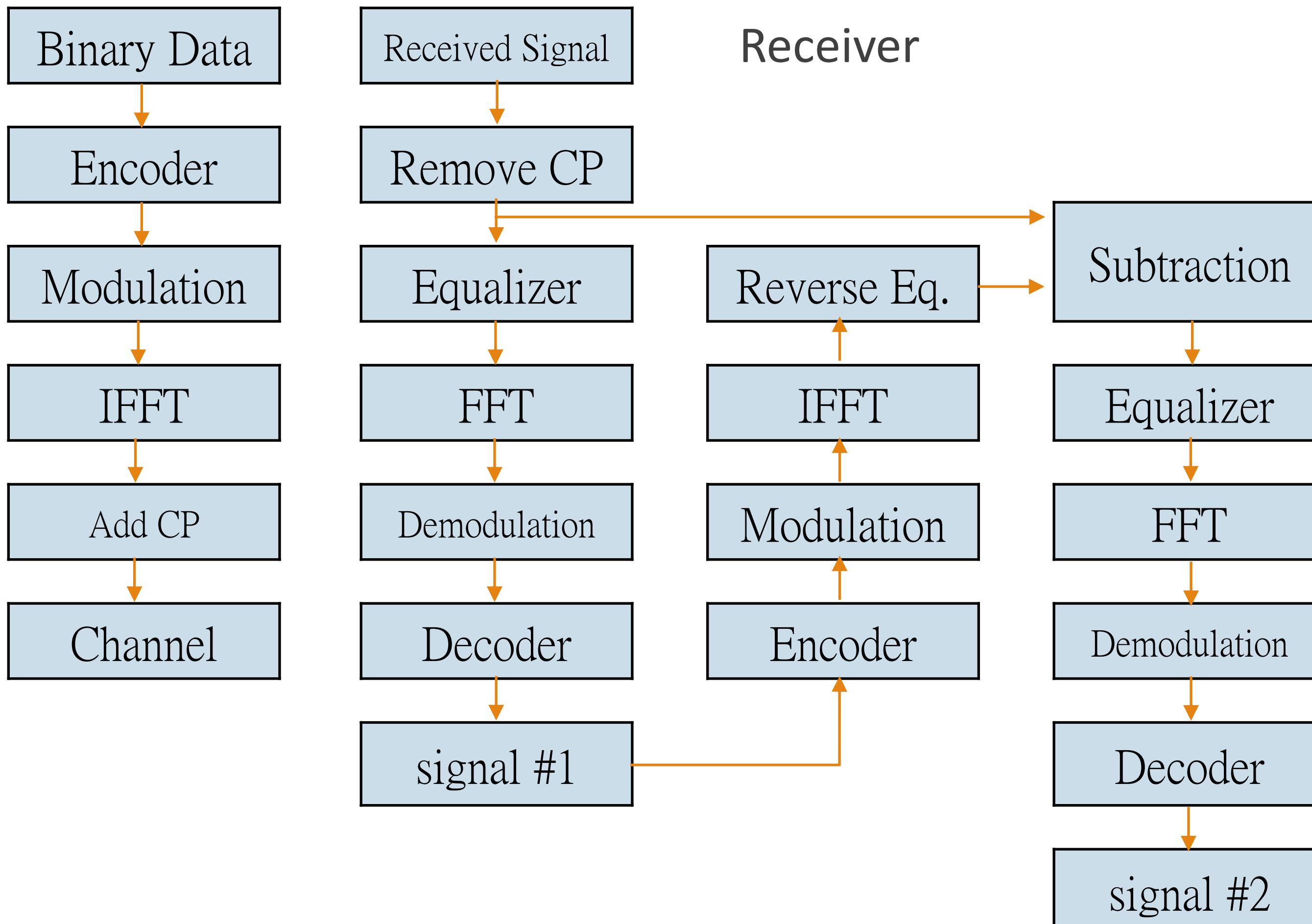
Simulation Tools

- IT++ is a C++ library of mathematical, signal processing and communication classes and functions. Its main use is in simulation of communication systems and for performing research in the area of communications.
- Originated from former department of Information Theory at the Chalmers University of Technology, Gothenburg, Sweden.
- Supports basic mathematical operations, signal processing (e.g. filters, FFT, DFT), Communications (e.g. modulator, standard channel model), Protocol simulation (e.g. queues, packet generators).
- The simulation is built base on IT++ and other external libraries (BLAS, LAPACK and FFTW libraries).

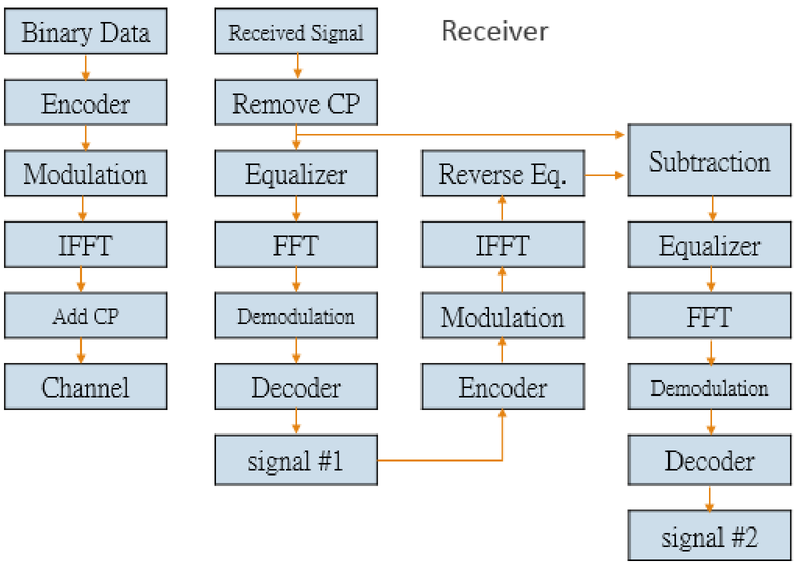
[3] IT++ project main page, http://itpp.sourceforge.net/4.3.1/

System Architecture

Transmitter



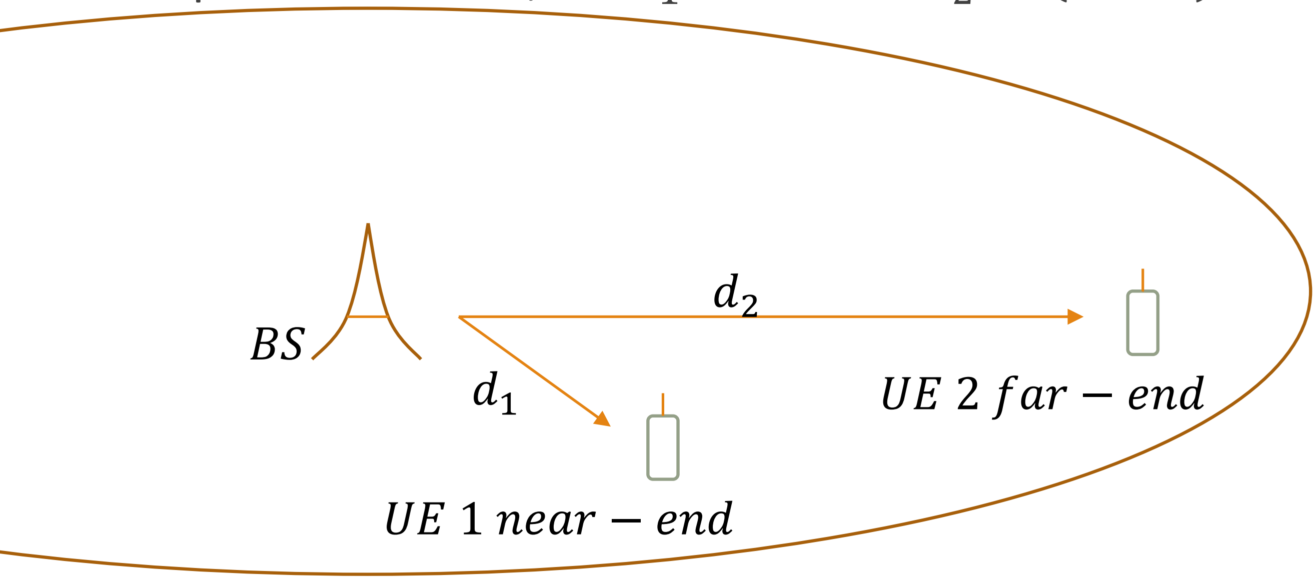
Parameters and values



Parameters	Simulation settings
FFT size	2048
Carrier frequency	2.6 GHz
Coding scheme	Convolutional Code
Cyclic Prefix	144 samples
Modulation	BPSK, QPSK, 16QAM
Channel	AWGN, 3-tap multipath
BS power	4 W
Background noise	-144 dBm
Pathloss model	Hata model, medium sized city
Equalizer	7-tap MMSE

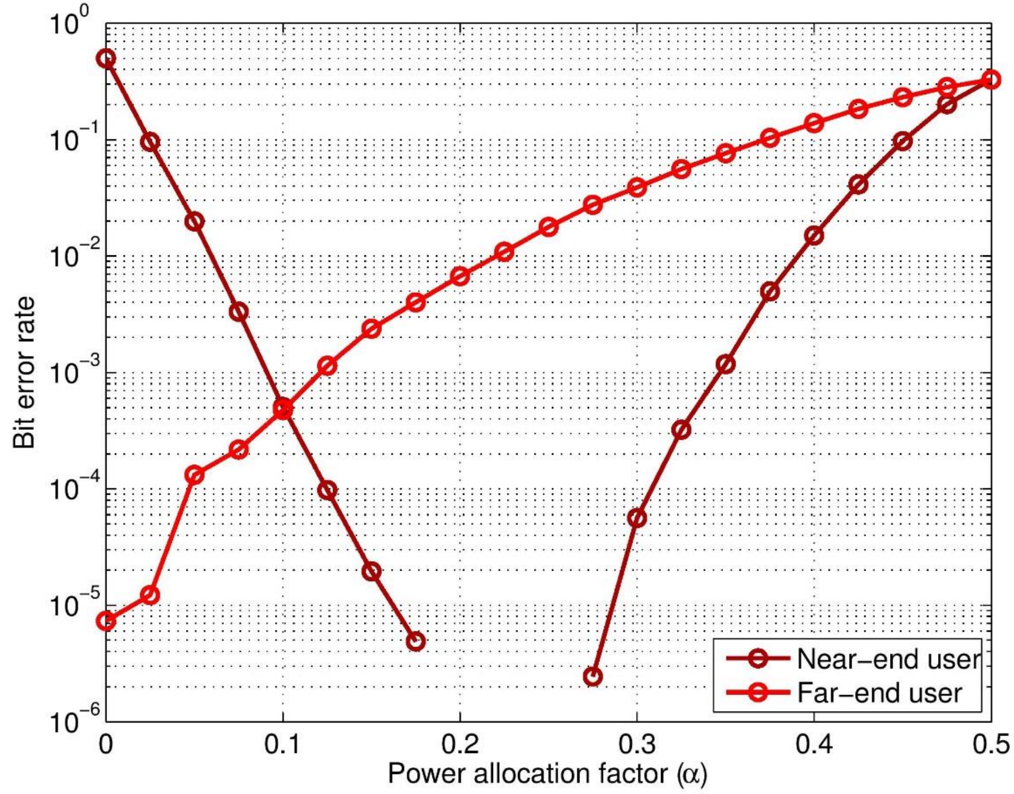
Simulation Scenario

- 2-user case in downlink scheme, distance of transmission are d_1 and d_2
- UE2 is far-end, UE1 is near-end user. BS allocates power to UEs by power factor α , i.e. $P_1 = \alpha P$ and $P_2 = (1-\alpha)P$.



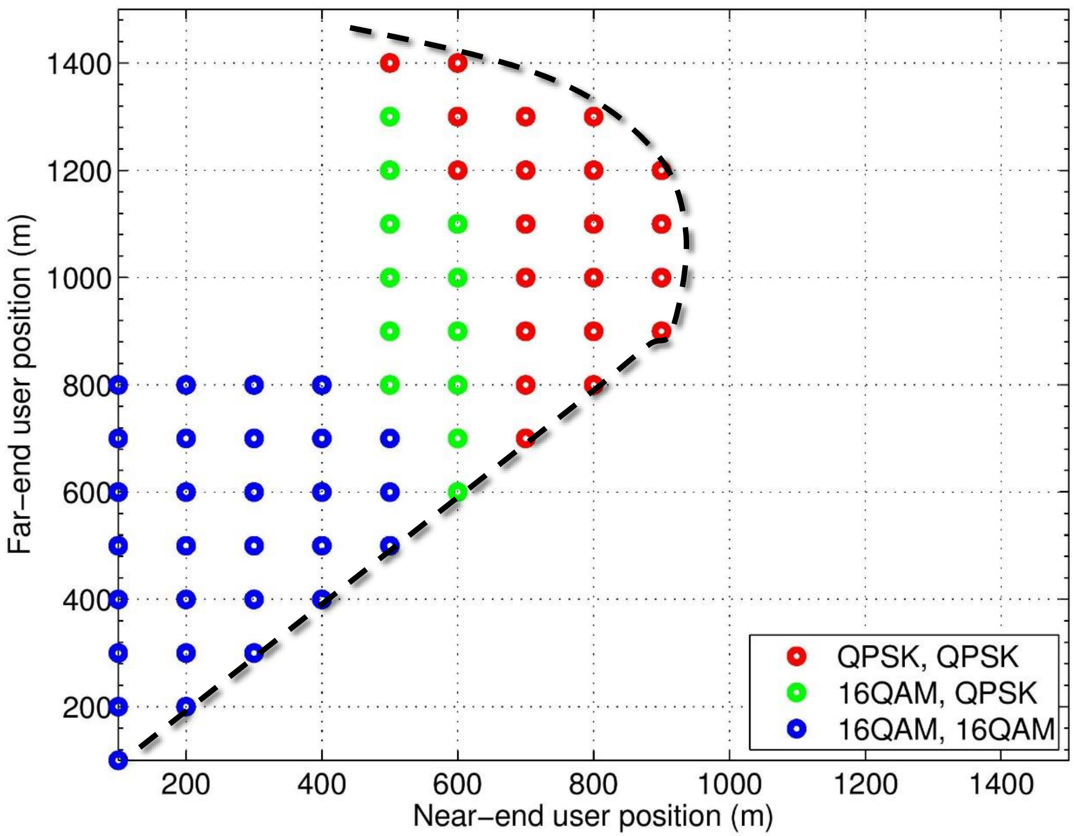
Simulation Result (1/3)

- QPSK, code rate ½ is used
- UE1 positions at 1km,
  UE2 positions at 2km
  BS at origin point.
- Error propagation cause degradation when power allocation factor come close to 0.5 .



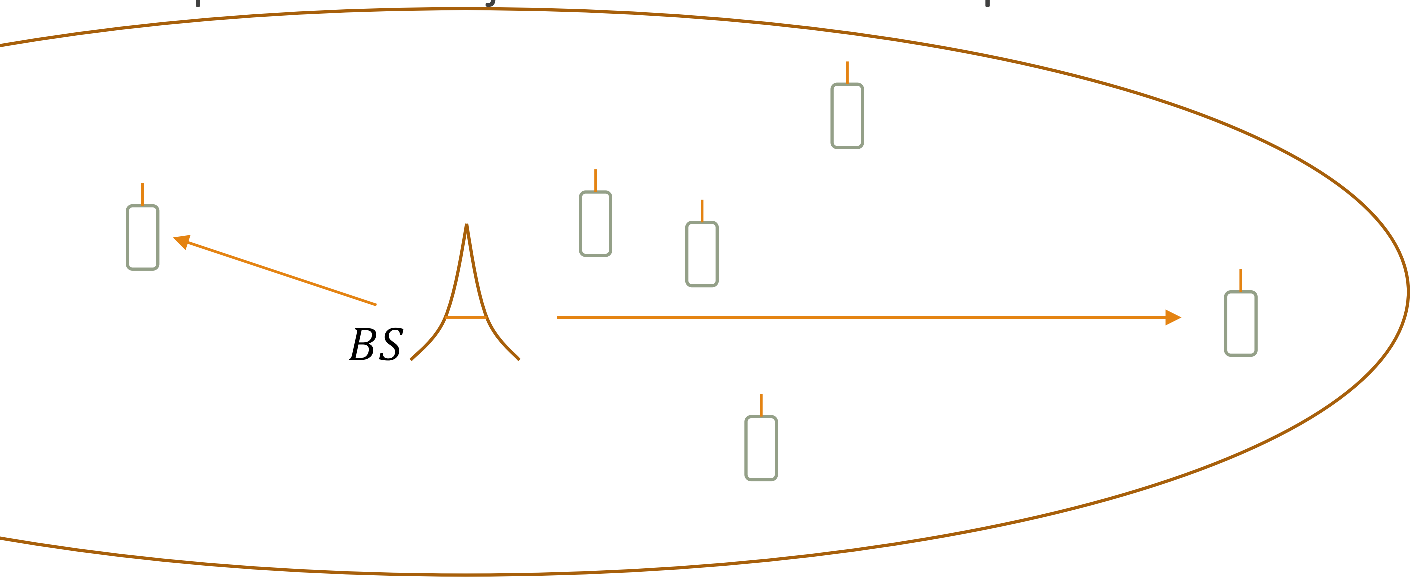
Simulation Result (2/3)

- BER is constrained to be greater than 10^{-2}, modulation changes if the higher order modulation is possible.
- The system is limited by far-end user, for example, if UE2 (QPSK) is at 1400m, UE1 (QPSK) is limited in 600m, if UE2 is at 1200m, UE1 is feasible at 900m.



Simulation scenario

- Consider scheduling users in a single cell, all users has to be scheduled once in given time window.
- Assume there are 10 users randomly scattered in 1400 square meter plane. The objective is to maximize spectrum utilization.



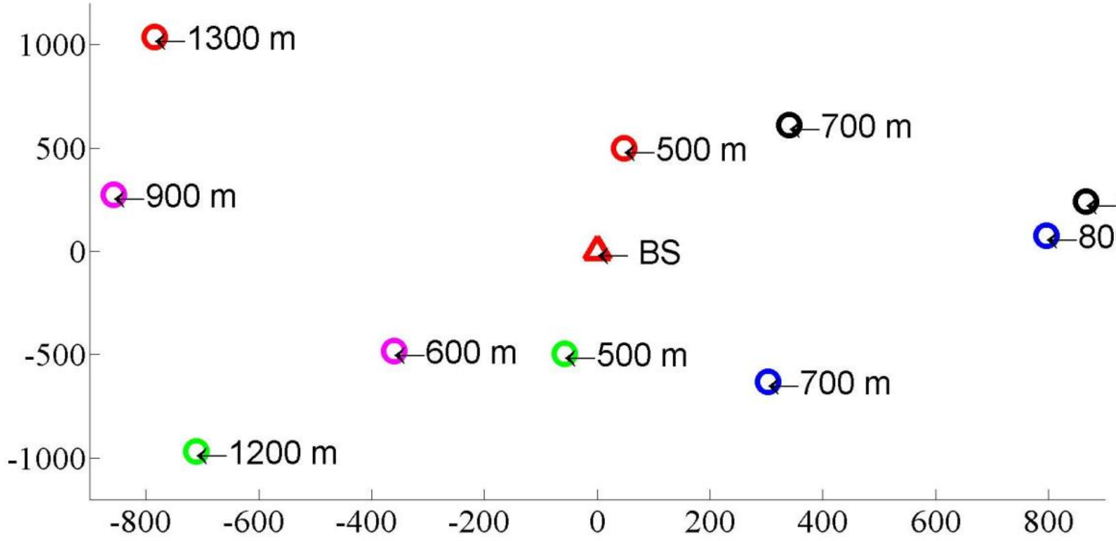
Scheduling algorithm

```
Sort distance of all users S descendingly
while S is not empty
    select  i = S.first
    for j ∈ S and j ≠ i
        if pair(i , j) is feasible
            if mod(i, j) > bestMod
                bestMod = mod(i, j)
                v = j
            end if
        end if
    end for
    if v is not NULL
        remove i, v from S
    else
        remove I from S
    end if
end while
```

Slot #1	#2	#3	#4	#5
QPSK(1300)	QPSK(700)	QPSK(900)	QPSK(1200)	16QAM(600)
16QAM(500)	QPSK(800)	QPSK(700)	16QAM(500)	QPSK(900)

- To schedule multiple users in a single cell, max support of simultaneous transmission is 2.

Slot #1 (α)	#2	#3	#4	#5
0.1	0.3	0.3	0.075	0.025



Reference

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- [3] IT++ project main page, http://itpp.sourceforge.net/4.3.1/
- [4] 3GPP TS 36.104 v8.2.0, May 2008

Q&A

Thank you for your attention.