Télécom Paris

Deliverable 4 - Group 1

TELECOM205 - Projet de synthèse : système de communications

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1 Compute the rejection rate at the basestation versus K

1.1 Look-Up Table

Relationship Formula between BER and FER : $BER = 1 - (1 - FER)^{\frac{1}{N*log2(M)}}$

Thus, with N = 100, FER = $1e-2$, BER only depends on number of bits per symbol M. We are comparing between three types of modulation : BPSK, 8-QAM and 16-QAM. The calcuated BER for these modulations are as below :

$$BER_{BPSK} = 1e-4$$
$$BER_{8-QAM} = 3.4e-5$$
$$BER_{16-QAM} = 2.5e-5$$

Next, based on the graphs of BER vs. Eb/No plotted in D1, we deduce the Eb/No required to achieve BER calculated. For each modulation, we deduce the minimum Eb/No for channel 1, 2, 3. Since we need Es/No instead of Eb/No, Es/No need to be calculated as :

$$EsNo(dB) = EbNo(dB) + 10 * log10(log2(M))$$

Minimum Es/No for each channel using ZF equalizer :

$$Es/No_{min\ bpsk} = [8.75, 13.5, 22]$$
$$Es/No_{min\ 8qam} = [12, 15.1, 24] + 10 * log10(3)$$
$$Es/No_{min\ 16qam} = [12.145, 18, 24] + 10 * log10(4)$$

Minimum Es/No for each channel using DFE equalizer :

$$Es/No_{min\ bpsk} = [8.5, 11, 14]$$
$$Es/No_{min\ 8qam} = [11, 15, 17] + 10 * log10(3)$$
$$Es/No_{min\ 16qam} = [12, 145, 16, 19] + 10 * log10(4)$$

1.2 Rejection Rate for different Bitrate

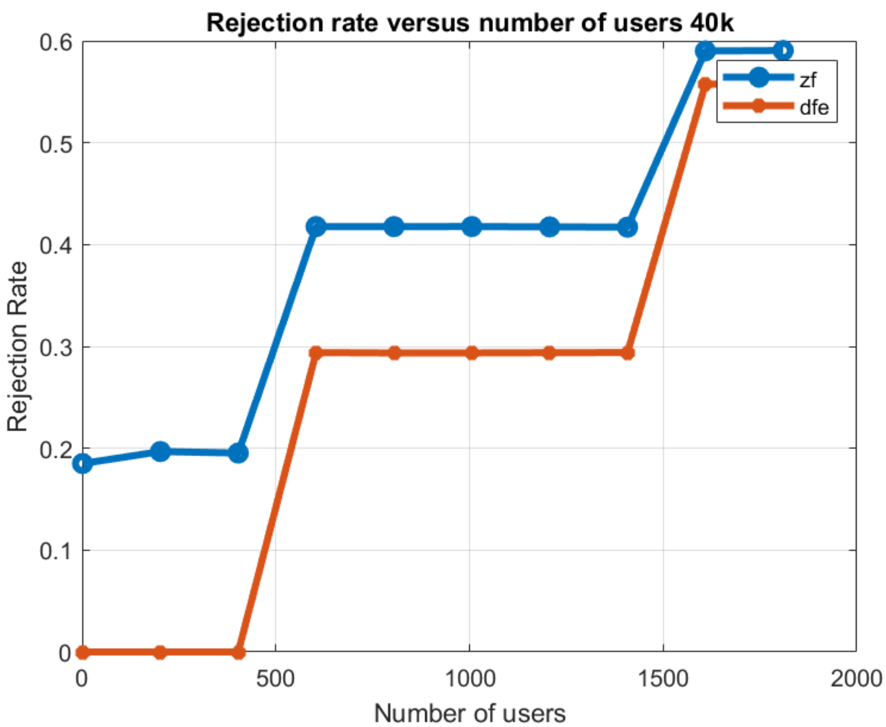

FIGURE 1.1 – Rejection rate versus number of users at R=40k

At R=40k, it can be seen from the plots that there are three levels. The first level goes from 0 users up to nearly 400 users. The second level goes from 400 users up to nearly 1400 users. The third level goes from 1400 up to 2000. We move from one level to another because the modulation constellation used changes. First, when there are very few users, BPSK is used. Then, when there are more users, 8QAM is used, then when there is a lot of users, 16QAM is used. Also, we observe that DFE performs better than ZF.

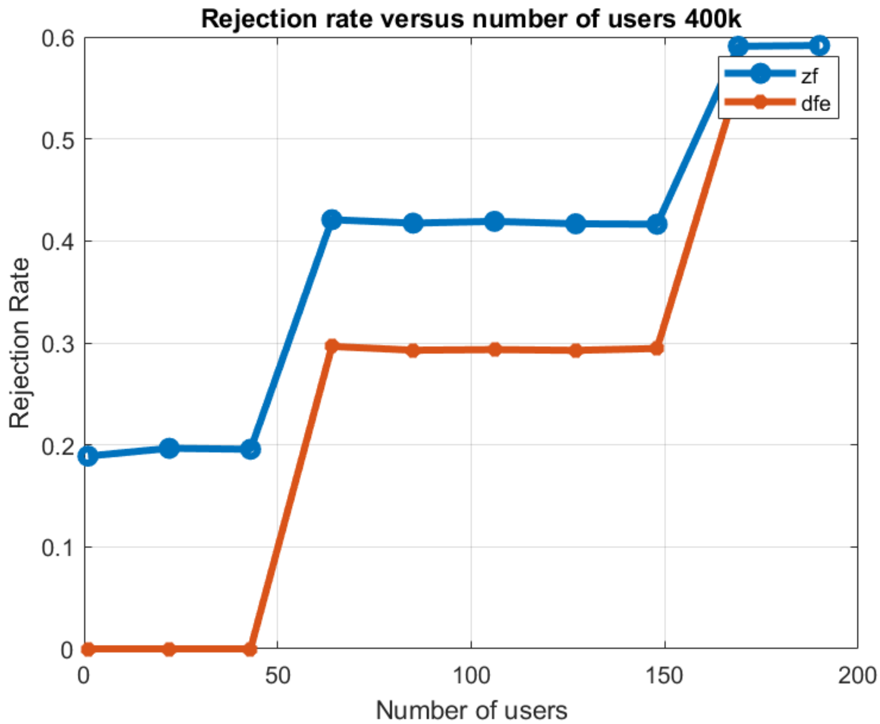

Figure 1.2 – Rejection rate versus number of users at R=400k

At R=400k, the number of served users decreases. The first level now goes from 0 to only 40, the second level goes from 40 up to 150, then the third level goes from 150 up to just 200.

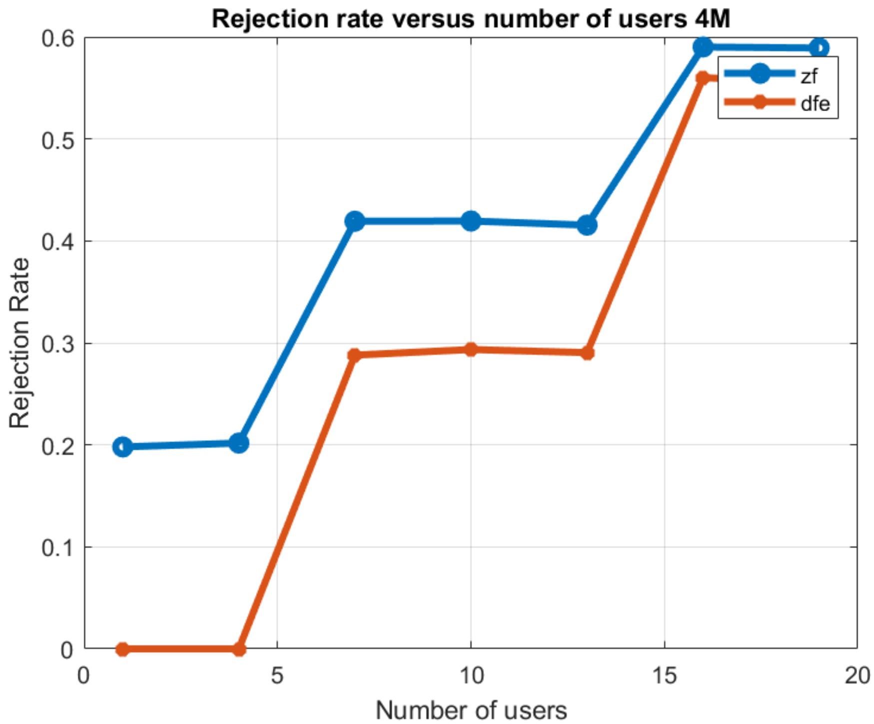

FIGURE 1.3 – Rejection rate versus number of users at R=4M

At R=4M, the number of served users decreases more and more. The first level goes from 0 up to 4, the second level goes from 4 to 13, the third level goes from 13 up to just 20.

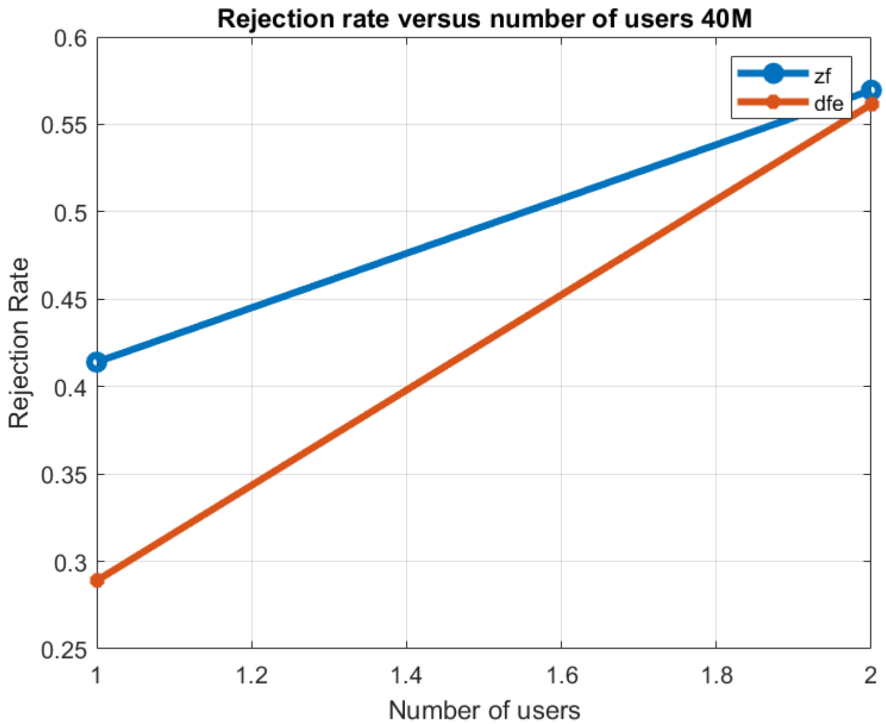

FIGURE 1.4 – Rejection rate versus number of users at R=40M

At R=40M, there are just maximum 2 users that can be served because the base station emits at B=30MHZ. Only 16-QAM can be used to support data rate of 40Mbps.

We observe that the number of users where the modulation used switches from BPSK to 8QAM or 8QAM ro 16QAM does not depends on the type of equalization used (ZF/DFE) at receiver. The change of level occurs at the same position with a fixed data rate. However, the number of users where the change of modulation occurs decreases when data rate increases as the higher constellation format is needed to allow users emitting at higher bit rate.

2 Raw data rate required on the optical fiber

2.1 DF : decode and forward

Maximum raw data rate with 16-QAM modulation = 20Msymbols * 4 = 80 Mbps. The base station decodes the received symbols and encode again with OOK modulation. Thus, it emits at maximum of 80Mbps to propagate signal in optical fiber.

2.2 QF : quantize and forward

The base station doesn't decode the received symbols. It just quantizes them and forwards them to the server. Therefore, knowing that B=30MHz and q=10 and 16 QAM uses two axis (I and Q), we can deduce the raw date rate.

Raw data rate = 30*10*2=600 Mbps.

Recalling that with the optical fiber we can achieve 2.5 Gbps up to 100km, the optical fiber is not the bottleneck of this C-RAN system, either with DF or QF.

3 Extra Credit : Multi-cell interference as additional noise

In our system, there are three cells aligned on the x-axis. Cell 1 is the main cell with Cell 0 and Cell 2 adjacent to the main cell. Each cell has a length and width of 1km and contains only one user. The base station is situated at the origin, which is the center of Cell 1. Each user operates with a BPSK modulation and each channel only considers path loss between user and the base station.

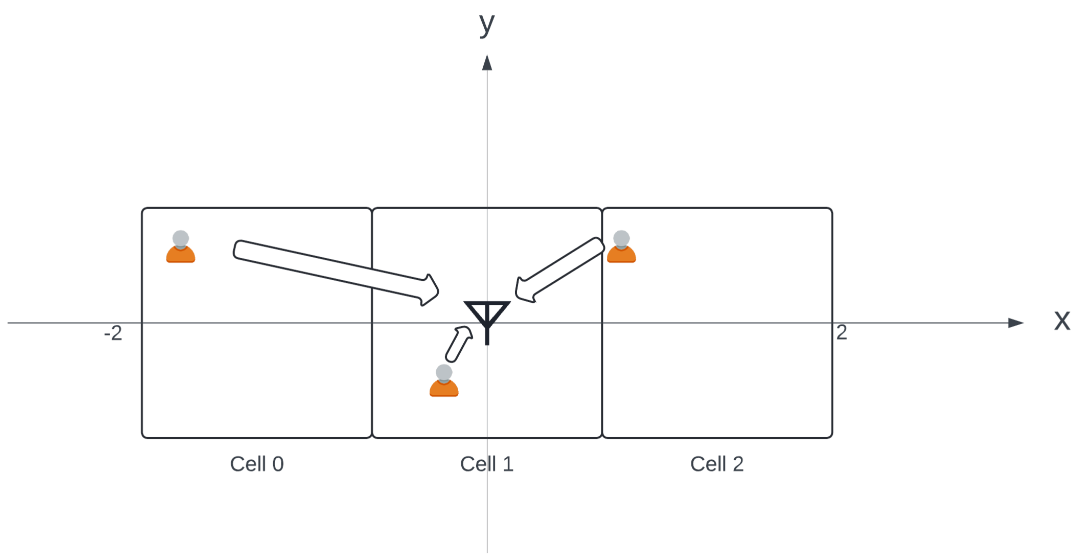

FIGURE 3.1 – Illustration of multi-cell interference

The three users emit their symbols to base station with different path loss. The base station decodes signal from user of cell 1, and the signals from user 0 and user 2 are considered as additional noise. The multi-cell interference is not managed at base station. Thus, the signal received at base station is :

$$Signal(Rx) = h_0X_0 + h_1X_1 + h_2X_2 + w$$

$[h_0, h_1, h_2]$ are the coefficients of attenuation of user0, user 1 and user2. $[X_0, X_1, X_2]$ are the symbols sequences sent. w is the noise AWGN.

To maximize the impact of multi-cell interference, transmitted power of signal from user 0 and user 2 are fixed at 20dBm, we then plot BER by changing transmitted power of user 1 from 0 to 20dBm. We run Monte-Carlo simulation of 1000 times for each transmitted power. In each simulation, the position of three users are randomly chosen in their cells.

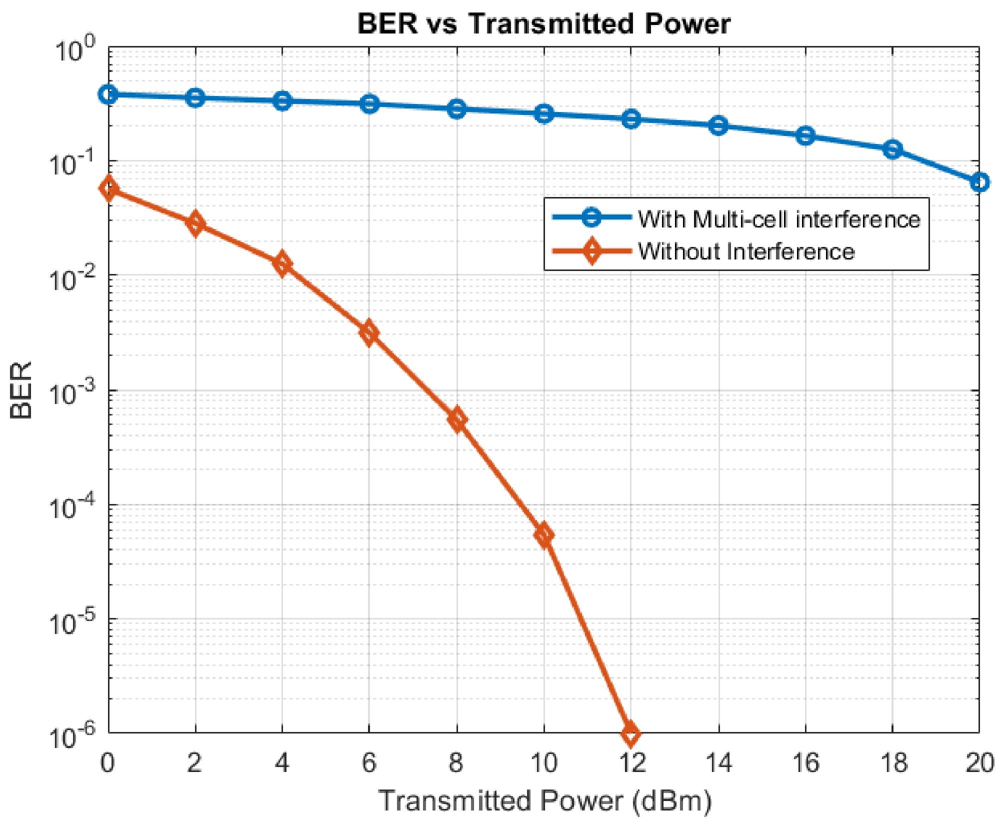

FIGURE 3.2 – BER versus transmitted power

We compare two cases where there is multi-cell interference (not managed) and when there is no interference ($y = h_1 X_1$). We observe that the system performance significantly decreases when there is multi-cell interference. When multi-cell interference is not managed at the receiver, the receiver fails to decode the symbols as the BER is very high. BER slightly decreases until $6 * 10^{-2}$ when transmitted power is increased until 20dBm.

To ameliorate the performance, receiver needs to handle multi-cell interference with a ZF receiver to eliminate multi-cell interference.