TD INF567

CDMA Cellular Access

Version: 26 Feb. 2020

1 Typical SINR and throughputs

In cdmaOne, the highest spreading factor is $n = 128$. A typical target Eb/N0 is 8 dB. In UMTS the highest spreading factor is $n = 512$. A typical target Eb/No is 6 dB.

Question 1 *Compute the target SNR in dB in cdmaOne and in UMTS. Compare the useful received signal level with the thermal noise power.*

In UMTS, the uplink DPDCH (Dedicated Physical Data Channel) is transmitted in phase (using only the I branch) with a spreading factor $n \in \{4, 8, 16, 32, 128, 256\}$. A typical channel code rate is 1/2.

Question 2 *What are the maximum and the minimum data rates on the uplink DPDCH of UMTS?*

In UMTS, the downlink DPDCH is transmitted in QPSK and multiplexed in time with a physical control channel DPCCH (Dedicated Physical Control Channel). The overhead of the DPCCH is approximately 15%. Full rate speech is transmitted at a typical data rate of 22 kbps with channel coding rate of 1/2.

Question 3 *What is the spreading factor of the DPDCH when voice is transmitted on the downlink?*

In HSDPA (High Speed Downlink Packet Access), the modulations are QPSK and 16-QAM and the spreading factor is $n = 16$. A UE can be served with a maximum of 15 codes. The minimum channel coding rate is 0.1 and the maximum coding rate is 0.97.

Question 4 *What is in a cell the number of available codes with spreading factor* 16*? Why can't we allocate all these codes to a single UE? What is the maximum user data rate?*

Consider the uplink of a UMTS cellular network with a maximum radio load of 0.85. The target Eb/N0 for voice is 6 dB and the spreading factor is $n = 128$. The other-cell interference factor is $f = 0.6$.

Question 5 *What is the number of voice channels in a cell?*

2 Outage probability with imperfect PC

We consider the uplink of a CDMA cellular network. We assume that power control based on signal level is not perfect, so that the signal received from a user u can be written $S_u = S^* X_u / E[X_u]$. All r.v. X_u are i.i.d. and $10\log(X_u)$ is a zero-mean Gaussian r.v. and standard deviation σ_{PC}. User u is active with probability p and we define ν_u the Bernouilli r.v. as $P[\nu_u = 1] = p$. We now drop index u whenever there is no ambiguity. Users are assumed to be Poisson distributed with parameter λ.

Question 6 *Show that* $E[X^n] = e^{\frac{1}{2}(n\sigma_{PC}h_0)^2}$, *where* $h_0 = \ln(10)/10$.

Question 7 *Let* Y_i *be a set of i.i.d. random variables and* N *a discrete r.v. with values in* $\{0, 1, ...\}$. *Show that* $E[\sum_{i=0}^{N} Y_i] = E[N]E[Y]$ *and* $Var[\sum_{i=0}^{N} Y_i] = E[N]Var[Y] + E[Y]^2 Var[N]$.

Question 8 *Show that the outage probability can be written as:* $P_{out} = P[\frac{IN}{X} > \frac{S^*}{\gamma' E[X]}]$, *where* $IN = I + N$ *is the sum of all received powers (other-cell interference plus inner-cell received power including useful signal) plus noise,* $\gamma' = \gamma/(1+\gamma)$ *and* γ *is the threshold SINR.*

We decompose the total received power as follows: $I = I_{in} + I_{ex}$, where I_{ex} is the other-cell interference and I_{in} is the inner-cell total received power.

Question 9 *Give an expression of* I_{in} *as a function of* N_{UE} *the number of users in the cell and other parameters of the model. Compute* $E[I_{in}]$ *and show that* $Var[I_{in}] = p\lambda S^{*2} e^{\sigma_{PC}^2 h_0^2}$.

For the other-cell interference, we make the classical assumption that there exist two factors, f and f' such that: $E[I_{ex}] = fE[I_{in}]$ and $Var[I_{ex}] = f' Var[I_{in}]$. We consider an interference limited system, in which noise power can be neglected. We approximate the distribution of IN/X by a Gaussian distribution with same mean and variance.

Question 10 *Compute the expectation and the variance of* IN/X *and derive the outage probability as a function of these expectation and variance.*