S72-238 WCDMA systems

Tutorial 5 15.01.2002.

Solutions

1.

Erlang capacity of the system.

In the system are 4 cells in each cell are 237 users. Each user generates load 25 $mErlangs$.

a) What is the blocking probability in one cell when in the cell are available 8 channels?

b) What is the blocking probability when the cells are combined and served by one big cell with 4×8 channels?

c) What is average call arrival time in one cell? What will be average arrival time in the big cell? The average call duration is $100\ s$.

1.

a)

The blocking probability in a cell is calculated by Erlang B formula:

$$B(N,\rho) = \frac{\frac{\rho^N}{N!}}{\sum_{n=0}^{N} \frac{\rho^n}{n!}},$$

where, m is number of channels and ρ is offered load.

The load in a cell is calculated as load for one user, ρ_1, multiplied with the amount of users in the system, N.

$$N\rho_1 = 237 \cdot 0.025\ [Erlangs] = 5.925\ [Erlangs]$$

Inserting that into the equation we get approximately

$$B(8, 5.93) = 11.8\,\%$$

b)

When the cells are combined in the service area will be four times more users

$$4 \cdot N \cdot \rho_1 = 4 \cdot 237 \cdot 0.025 = 23.7\ Erlangs$$

The blocking probability will accordingly be

$$B(32, 23.7) = 1.98\,\%$$

Calculations shows that there exist the following relationship

$$B(Nm, N\rho) < B(m,\rho),$$

where, N is bigger than one.

c)

The load is calculated as $\rho = \dfrac{\lambda}{\mu}$ where λ is the mean arrival rate of users and μ is the mean holding time.
In a small cell the average arrival time is
$\lambda = \rho \cdot \mu = 5.925 \cdot \dfrac{1}{100} = 0.005925 \ s$.
In a big cell we get
$\lambda = \rho \cdot \mu = 23.7 \cdot \dfrac{1}{100} = 0.237 \ s$.

2.

How many users can one cell serve when WCDMA system contains a mix of different type of users:

- $5\,\%$ high speed users with data rate $8 \ \frac{kbit}{s}$ and requiring SIR target 7 dB
- Three data users with data rate 64 $\frac{kbit}{s}$ users with target SIR requirement $5 \ dB$.
- Rest of the users are slow moving speech users ($8 \ \frac{kbit}{s}$) requiring SIR target $5 \ dB$.

The neighbouring cell interference factor $i = 0.5$.

2.

In order to estimate the capacity with different type of users we have to express all different type of data rates and target SIR values in terms of comparable values. This comparison can be made based on some shared resource they occupy. In CDMA system such resource can be described either by amount of total available power, data rate they reserve or amount of reference users given service represents. In other words we estimate the size of total available resources, for example data rate, and calculate for given service mix how many users can be allocated into this data rate when different services occupy different data rate.

Because we are asked to calculate how many users can be allocated into the system we select the size of available resource to be amount of voice users with target SIR $5 \ dB$ that can be allocated into the system. The voice user with target $SIR \ 5 \ dB$ is a basic resource unit. In order to calculate the total amount of users in the system we have to describe other type of users in related to the basic users.

First we look how much resources a user with the data connection 64 $\frac{kbit}{s}$ demands. We express the data rate in terms of the basic user data rate. Such data user occupies 8 times higher data rate and also comparable 8 times the power.

That can be shown as following.
We assume that the interference level is same for data and voice users. Because the $\mathrm{target} \ SIR$ are same we can write

$$\frac{P_1}{I}\frac{W}{R_1} = \frac{P_2}{I}\frac{W}{R_2}$$

$$P_1 = \frac{R_1}{R_2} P_2$$

In other words one user power of the data user is related to the voice user power by $\frac{R_1}{R_2}$. In our case this constant is 4 i.e. one user with data connection with rate $64\ \frac{kbit}{s}$ occupies 8 times more resources compared to a voice user. One data user "corresponds" to four voice users.

The data rate for users of type 1 and type 3 are the same $\frac{R_1}{R_3}$. For comparing the occupied resources we express the target CIR_1 of type 1 user in terms of the CIR_3 and from there calculated what would be the user data rate if the required CIR for the type 1 would be same as for type 3 users.

In this way it is possible to transfer the increase of required SIR_1 target of users type 1 to the comparable increase of the data rate $R_3 = R_1' = C \cdot R_1$. This can be calculated by transferring the increase in SIR target, C, to the increase of the data rate, R_1'.

Let denote the relationship between the two SIR

$$SIR_3 = \frac{SIR_1}{C} \Rightarrow CIR_3 = \frac{CIR_1}{C},$$

$$CIR_3 \frac{W}{R_1} = \frac{CIR_1}{C} \frac{W}{R_1} = CIR_1 \frac{W}{CIR_1},$$

$$CIR_1 = \frac{1}{C} \frac{P_{r1}}{I_{\text{int}ra} + I_{\text{int}er} + N}.$$

We can write the impact of higher data rate as increase of transmitted power $P_{r1}' = P_{r1} C$.

But also we can see it as increase of the transmitted data rate, in what case we can write

$$CIR_3 = \frac{W}{R_1 \cdot C} \frac{P_{r1}}{I_{\text{int}ra} + I_{\text{int}er} + N}$$

Now we thought about the system that CIR_1 and CIR_3 are same but SIR_1 and SIR_3 are different. In this model we think that the difference is because different coding gains.

$$\frac{R_1'}{R_1} = C.$$

For our parameters

$$C = \frac{SIR_3}{SIR_1} = \frac{10^{7/10}}{10^{5/10}} = 1.58.$$

The "high speed" data user occupies 1.58 times more resources compared to a slowly moving data user.

The number of data users in the system can now be calculated by first calculating amount of all the voice users in the systems. From this amount of users we subtract the amount corresponding to the data users $3 \cdot 8 = 24$ and as result we get the final amount of voice users k_v.

We know that 5 % of voice users use 1.58 times more resources than other voice users. That means in the amount of users there is still an overhead $0.58 \cdot 1.58 \cdot k_v$. The result is the final amount of voice users in the system.

Let assume that interference factor from the neighbouring cells is 0.5. For our parameters the total amount of voice users will then be

$$k_u = \frac{1}{(1+i)} CIR_3 = \frac{1}{(1+0.5)} 10^{7/10} = 101.19$$

After subtracting the data users the amount of voice users will be $k_v = k_u - 24 = 77.19$. The high speed voice users generate an additional overhead and remaining amount of voice users is $k_v - 0.58 \cdot 0.05 \cdot k_v = 74.95$. From this amount 5 $\%$ are high speed users ~ 3.74 and rest of them slow moving users ~ 71.2.

Total amount of users in the system is approximately $71 + 3 + 3 = 77$ users.

3.

Calculate the soft capacity of the system with parameters.

Bit rates	Speech	15	$\frac{kbit}{s}$
	Real time data	15	$\frac{kbit}{s}$
		64	$\frac{kbit}{s}$
Voice activity	Speech	65	%
	Data	100	%
Eb/No	Speech	4	dB
	Data 15	3	dB
	Data 64	2	dB
i		0.65	
Noise rise		3	dB
Blocking probability		2	%
Spread chiprate		3.84	$\frac{Mchip}{s}$

3.

Soft blocked capacity is the system capacity limited by the amount of interference in the air interface. It can be compared to the hard blocking capacity where hard blocking capacity is calculated for the number of channels with given neighbouring cell interference.

$$SoftCapacity = \frac{Erlang\ capacity\ with\ soft\ blocking}{Erlang\ capacity\ with\ hard\ blocking} - 1$$

In the book is given the algorithm for calculation the soft capacity.

a) Calculate the number of channels per cell, N, in the equally loaded case, based on the uplink load factor Eq. 8.12 (from the course book) .
b) Multiply that number of channels by $1+i$ to obtain the total channel pool in the soft blocking case.
c) Calculate the maximum offered traffic from the Erlang B formula.
d) Divide the Erlang capacity by $1+i$.

We calculate the amount of a load the system can serve in order to have the given noise rise. The noise rise is calculated together with the intercell interference:

$$Noise\_rise = \frac{1}{1+\eta_{UL}},$$

where the load, η_{UL}, is calculated as

$$\eta_{UL} = \sum_{n=1}^{N} (1+i) \frac{1}{1 + \frac{W}{\frac{E_b}{N_0} \cdot R_n} \nu},$$

where, i is neighboring cell interference, N is number of users, $\frac{W}{R}$ is coding gain, $\frac{E_b}{N_0}$ is target SIR, ν is voice activity factor.

By assuming all the users have same load in the cell we get

$$\eta_{UL} = N(1+i) \frac{1}{1 + \frac{W}{\frac{E_b}{N_0} \cdot R_k} \nu},$$

and from the noise rise we get the number of channels N

$$N = \left(1 - \frac{1}{Noise\_rise}\right) \frac{1}{(1+i)} \left(1 + \frac{W}{\frac{E_b}{N_0} \cdot R_k} \nu\right)$$

For given number of channels N we calculate the offered load ρ from the Erlang B formula

$$B(N,\rho) = \frac{\frac{\rho^N}{N!}}{\sum_{n=0}^{N} \frac{\rho^n}{n!}}.$$

We calculate the load that still satisfies the required blocking probability.

The trunking efficiency is defined as

$$Trunking\_eff = \frac{\rho}{N}.$$

Soft blocked capacity we calculate the number of channels and from it the offered load for the single cell. The actual soft capacity load is single cell load scaled down by the interference factor $(1+i)$.

$$N_{soft} = \left(1 - \frac{1}{Noise\_rise}\right)\left(1 + \frac{W}{\frac{E_b}{N_0} \cdot R_k} \nu\right).$$

$$B(N_s, \rho_s) = \frac{\frac{\rho^{N_s}}{N_s}}{\sum_{n=0}^{N_s} \frac{\rho_s^n}{n!}}.$$

Increase due to the soft capacity is relationship between the hard and soft capacity

$$\left(\frac{\rho_s}{\rho} - 1\right) \cdot 100\%.$$

Bit Rate	SIR	Voice activity	Hard blocked			Soft blocked		Soft capacity
			Channels per cell	Capacity	Trunking efficiency	Channels per cell	Capacity	
15	4	0.65	47.7	39.0	81.8	78.7	41.2 (68)	5.7
15	3	1	39.1	32	81.8	64.5	33.3(55)	4.1
64	2	1	11.7	7	59.6	19.4	8.5(14)	21.2