

Mobile communication networks

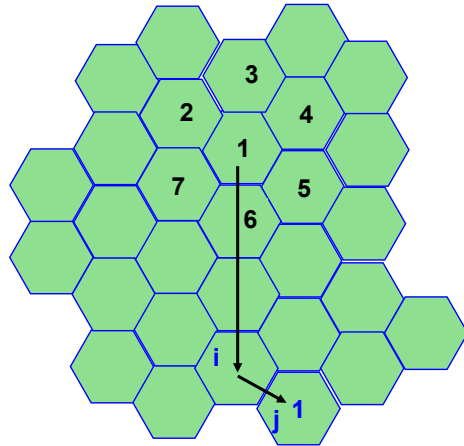


Interference behaviour

Politecnico di Torino
2006



The cluster topology



The axes may define
the reuse distance (the distance
between co-channel cells)

Number of cells belonging to the cluster

$$M = i^2 + j^2 + ij$$

2

TELECOM LAB
ITALIA

The interference behaviour inspiring the frequency allocation to the cells is a very complex phenomenon. The chapter devoted to the Engineering will clarify some concepts. However, the concepts developed so far are enough to improve the comprehension of the interference mechanism.

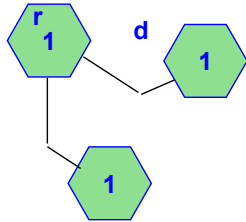
In particular, the considerations developed in this extension allow to evaluate roughly the relationship arising between the C/I requirements and the cluster cardinality M .

The frequency allocation is typically performed in such a way that a minimum value of C/I (*Carrier su Interference*) is fulfilled. C/I represents the system quality and is usually represented in dB.

$$[C/I](\text{dB}) = 10 \log_{10}(C/I)$$

The C/I requirements $(C/I)_{\min}$ depends on the system we are referring to. For instance, analogue systems require that the value of 16-18 dB is reached while GSM demands for a value around 9-10 dB. The $(C/I)_{\min}$ is tied to e.g. the kind of modulation adopted and other characteristics of the radio system.

Carrier to Interference



$$P_R(C) = \frac{P_T(C) \cdot G(m) \cdot G(B_m)}{r^\alpha} \cdot \left(\frac{\lambda}{4\pi}\right)^2$$

$$P_R(I_i) = \frac{P_T(B_i) \cdot G(m) \cdot G(B_i)}{d^\alpha} \cdot \left(\frac{\lambda}{4\pi}\right)^2$$

$$C/I = \frac{P_R(C)}{\sum_i P_R(I_i)} = \frac{1}{6} \cdot \left(\frac{d}{r}\right)^\alpha$$

uniform conditions and selection of the (6) closest co-channel stations

$(C/I)_{\min}$ used to evaluate the cluster dimension M

$$\frac{d}{r} = \sqrt[3]{3M} = \left[6 \cdot \left(\frac{C}{I}\right)_{\min} \right]^{1/\alpha}$$

3

TELECOM LAB
ITALIA

A rough evaluation of the interferential effect may be done by considering just the geometrical characteristics of the coverage. If the cluster is constructed in an ordered way, M (cluster cardinality) can be calculated by means of the two *co-ordinates* represented in the previous figure, describing the path connecting two homologous cells (two cells using the same sub-band). M can have a limited number of values (i and j are integer numbers). Typical number for M are: 1, 3, 4, 7, 9, 12, 13, ..

It can be demonstrated that the distance d arising between the centres of two co-channel cells is:

d/r is the cluster dimension.

A conservative case arises when the mobile terminal is located at the edges of the cell where it is roaming. In this condition, it is easy to represent the relationship arising between M and the minimum value of C/I required by the system (see figure).

- $P_R(.)$ is the power received by *m* (the mobile phone), characterized as:
 - (C): *useful* power
 - (I_i): interference power, due to the co-channel cell *i*
- $P_T(.)$ power transmitted by the station:
 - where the mobile is roaming: $P_T(C)$
 - which is assigned the same frequency (co-channel interference) *i*: $P_T(I_i)$
- $G(m)$; $G(B_m)$; $G(B_i)$ gains in reception of *m* and base stations respectively
- α propagation coefficient.

Given the minimum value of C/I, the minimum dimensions of the cluster that fulfil the C/I requirements can be calculated.

Outage probability

Long-term fading $p(m_d) = \frac{1}{\sigma_d \sqrt{2 \cdot \pi}} \cdot \exp\left(-\frac{(m_d - \mu_d)^2}{2 \cdot \sigma_d^2}\right)$

Short-term fading $p(r/m_d) = \frac{\pi r}{2m_d^2} \cdot \exp\left(-\frac{\pi r^2}{4m_d^2}\right)$

Cell outage probability



$$P_{out} = 1 - p[(C/I) > (C/I)_{min}] = 1 - \int_0^{2\pi} \int_0^R \int_{C/I_{min}}^{\infty} \Gamma(r, \theta) \cdot W((c/i)/r, \theta) d(c/i) \cdot dr \cdot d\theta$$

4

TELECOM LAB
ITALIA

In function of the cluster dimension it is possible to calculate the probability that the area portion where the value of C/I is greater than the assigned threshold:

$$F = \frac{1}{S} \sum_i (\text{surface portions } S_i :: p[C/I > (C/I)_{min}])$$

The propagation condition are those already studied in the Propagation extension. C/I is a random variable subject to local fluctuations (short term) modelled by the Rayleigh distribution and long term fluctuations which can be represented by the log-normal distribution.

Short term fluctuations are normally faced by the demodulator, the long term behaviour is taken into account to predict the service areas. Given an elementary portion of the service area, it is assumed that within this portion, the mean value μ_d and the standard deviation σ_d of the random variable m_d (which follows, by turn, a log-normal distribution) depend only from the distance from the antenna, its power and its gain.

$$\Gamma(r, \theta)$$

represents the probability that a mobile is in a small area of polar co-ordinates (r,θ). Now, for each one of these elementary area, the *useful* contribution generated by the antenna where the mobile is located and the contribution due to the co-channel cells can be calculated, being the nature of the phenomenon always the same.

Through analytical considerations, the probability density function related to the *random variable* C/I conditioned to the mobile position (r,θ) may be calculated:

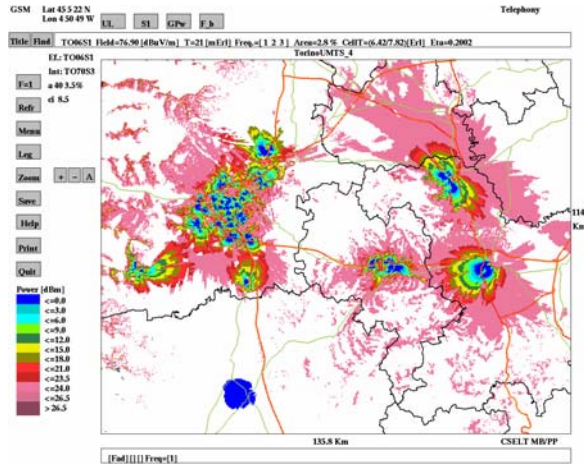
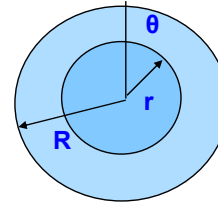
$$W_{C/I}((c/i)/r, \theta)$$

The outage probability of the cell is then calculated as indicated in the figure.

Mobile location probability

$$\Gamma(r, \theta) = \frac{2\pi r}{\pi R^2}$$

uniform distribution
of mobile within the
cell



outage fraction
as a basic tool to
plan cellular
network

TELECOM LAB
ITALIA

The previous considerations are often used in the planning process of the cellular networks. In particular, in the phase when the coverage has to be defined, it is necessary to verify that at least over a portion F of the territory, the minimum value of C/I is guaranteed:

$$p((C/I) > (C/I)_{\min}) > F$$

Then relationship may consider the real user density over the territory which is, in general non uniform. In this case, F is not simply a ratio between areas. For rough evaluations, it may be assumed that the distribution of mobiles in the area is uniform: F is then a ratio between areas.

The figure shows the outcome of a planning where the *outage* areas can be deduced from the (complementary) service areas.