DATA AND VOICE TRANSMISION INTERACTION IN GSM NETWORK

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ABSTRACT

This contribution deals with interference analysis and optimalization in 2.5G mobile network. The principles of system (network model, wave propagation, data load simulation, traffic modeling, etc.) and the results obtained (C/I ratio dependency on the radio channels allocation) are presented. Simplified computer simulation of GSM network is used for analysis.

1   INTRODUCTION

Data transmissions have a considerable participation on network load nowadays. So interferences in the network extensively grow up and qualitative scale represented by C/I ratio fall in the entire network. From this reason, methods which will decrease level of interference and improve quality of service have to be implemented. In part 2, mathematical model (antenna system, wave propagation, C/I computation and data load) is explained, consequently, experimental results are presented in part 3.

2   THE NETWORK MODEL

The Network model is determined for measurement of the mean C/I (Carrier to Interference) ratio during the communication between BTS and MS in downlink (DL) direction in regular square net. C/I ratio is dependent particularly on the network configuration, frequency hopping, transmitting power, network load etc.

2.1   ANTENNA SYSTEM

Proper antenna system selection enables limitation of interference level and determines covered area. Every BTS in this model uses three-sectorized antenna system (limited by its directional characteristic). The antenna system in this model is idealized – side lobes and backward radiation factor are considered to be negligible. Antenna gain is optional, main lobe angular width is approximately 60°.

2.2   WAVE PROPAGATION MODEL

Radio wave attenuation is caused by various factors, such as terrain obstacles,

reflection, scattering etc. In this simulation, COST 231– Walfish – Ikegami (C-W-I) radio propagation model is utilized [1]. This model enables improved estimation of wave attenuation in the urban environment. It includes more data to describe the character of this special environment.

Signal power in the point of reception is counted from radio communications equation

$$P_p \eta_2 = P_v \eta_1 G_1 \left(\frac{\lambda}{4\pi r} \right)^2 W^2 G_2 \ , \tag{1}$$

where P_p is input receiver power, P_v is transmitter power, $\eta_{1,2}$ are antenna feeders efficiency, $G_{1,2}$ are antenna gains, W is wave attenuation caused by obstacles and term $(\lambda/4\pi r)^2$ is wave attenuation caused by free space propagation.

Providing:
- Antenna feeders are considered to be lossless, $\eta_{1,2} = 1$,
- Receiving antenna is omnidirectional, $D_2 = 1 \Rightarrow G_2 = 0$ dB,
- Wave attenuation caused by obstacles and wave attenuation caused by free space propagation form the term L_p [1],

we can convert equation (1) to the simple dB representation $\quad P_p = P_v + G_1 - L_p \ . \tag{2}$

2.3 C/I COMPUTATION

Path-loss factor L_p is counted in the entire network for central DL frequency of GSM900 (approximately 945 MHz). Parameters for C-W-I model were chosen for medium sized city. Base station antenna is always situated above roof-top levels of adjacent buildings. Each of these parameters could be changed in the source code of simulation, so we can easily modify model to the different situations. Wave attenuation is therefore only distance dependent.

Mean C/I ratio computation – received signal level from each BTS is counted in each measuring point, the strongest signal is determined. Base station (TRx) of the strongest signal then determines level of the useful signal S_d and also specify the frequency of interfering signal I_i .

The mean C/I ratio is determined by relation (valid for cell networks with TDMA)

$$C/I \ (dB) = 10 \log \left[S_d \bigg/ \sum_{i=1}^{n} I_i \right], \tag{3}$$

where S_d is useful signal level, I_i is interference level on the same radio channel from i-th base station, n is number of all interferers [3].

Gain G_1 and transmitting antenna peak power P_v are set at the input of simulation. From (2), received signal level P_p in each measuring point from each BTS is counted, the useful signal and the strongest interfering signal are chosen. Minimum acceptable power to the system is -105 dBm for usable signal, lower value is not considered. In this way, C/I value is obtained in each measuring point. Calculation of mean C/I in the entire network is executed afterwards.

The network load is simulated by the number of timeslots (TS) simultaneously utilized, that is converted to mean effective output power afterwards. The load is different for each BTS and is different in time as well.

Time is stepped after 13 TDMA frames in the model – it corresponds to 60 ms, which is minimal time for a change of output power with respect to power control [2]. Time interval of 13 frames could model short-term load that data transmission is. Character depends on the type of service used, e.g. HTTP, FTP, SMTP etc. These services are with respect to load very

different.

HTTP session

Parameters describing HTTP session: mean page requests during the session, time between downloading two separate pages (time between page, which has been completely downloaded yet, and request on the next, user dependent), one page could be divided into the several objects (text, images, etc.) – considerable parameters are number of objects per page, size of objects, and time between downloading two different objects [4] (see table 1).

Tab. 1:   *Significant parameters of HTTP session.*

Parameter	Mean Value
Pages per session	5
Time between pages (s)	12
Objects per page	3
Time between objects (s)	0,5
Object size (B)	3700

FTP session

Parameters describing File Transfer Protocol session are these: total volume of data transferred during one session, size of each transferred object, time interval between transferring two different objects (finishing of one and starting of next).

Duration of any session is characterized by its total data volume to be transferred. Important values [4] are shown in table 2.

Tab. 2:   *Significant parameters of FTP session.*

Parameter	Mean value
Total data volume (B)	32768
Object size (B)	3000
Time between connections (s)	4

SMTP session

SMTP (Simple Mail Transfer Protocol) session represents downloading e-mail messages from mail servers by means of e-mail client. We do not consider the direction of transfer, only the data load, which this protocol causes.

The only parameter is data volume (size of e-mail) transferred during the session. Average e-mail size is 10 kB after [4].
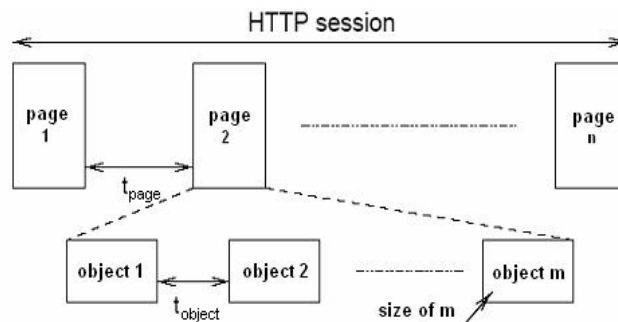
Fig. 1:   *HTTP session model.*

3   ALLOCATED RADIO CHANNELS COUNT IMPACT ON C/I RATIO

The frequency hopping scheme *1x1 uniform* [3] is used in this model. This plan is very simple, but it is not ideal from interference point of view. With few allocated radio channels, it limits possible network load considerably. Therefore, we will analyze allocated radio channels count impact on mean C/I ratio in the entire network in this part.

Simulation Parameters
Base station traffic: 4.128 Erlangs (mean real value, same for each BTS by reason of results independence on traffic, same for voice and data),
Maximum antenna output power: 46 dBm (with respect to BTS distance), Gain: 10 dB,
Distance between base stations: X = 500 m,Y = 500 m,
Measure points distance: x = 50 m, y = 50 m,
Simulation duration (in real time of network): ~ 60 s (T1 = 10, results obtained for higher values are practically identical, T1 is superframe number),
Radio channels count: 3 – 18.
Additional parameters for data: Coding scheme: CS-2,
RLC block size [2]: 32 B;during 60 ms (~13 TDMA frames) 3 blocks are transmitted = 96 B,
Statistical protocol utilization: HTTP 70 %, FTP 10 %, SMTP 20 %.

Voice Traffic Results
C/I dependence on radio channels count can be divided into three sections (see fig. 2):
In first section (up to 4 channels), we can observe expressive rapid growth of mean C/I. In second section (4 – 7 channels), slope of curve is less than in the first section, but the quality of service still grows. In third section (above 7 channels) happens to slow continuous growth of C/I value (c. 0.5 dB per allocated channel).

Further increase of radio channels count is not effective from the radio resource allocation point of view. Thus we can make conclusion that optimal radio channels count allocated to the base stations is approximately from 6 to 10. Voice traffic (continual load) shows fixed increase (though minimal for certain number of channels) of C/I, unlike data transmission (see below).

Data Traffic Results
C/I dependence on radio channels count can be divided into two parts (see fig. 2):
In first part (up to 8 channels), we can observe growth of mean C/I. In second part (above 8 channels) happens to slow increase of C/I and from certain value there is almost no increase.

Therefore optimal radio channels count allocated to the base stations is approximately 8. Data traffic shows from certain number of radio channels allocated almost no growth of C/I. It is given by burst nature of data transmission and its character – transmission and reception only in the case of demand, and channel sharing by multiple users. The system thus utilizes spectrum effectively. (Lower mean C/I is caused by time averaging of power compared to voice traffic – variation of periods, when are data transmitted and when are not).

Mixed Traffic Results
The measurement with mixed traffic (simultaneous voice and data traffic) was performed for comparison. Traffic was also 4.128 Erlangs, divided evenly between voice (2.064 Erlangs) and data (2.064 dataErlangs, CS-2).

From resulting graph we can observe, that initially (up to 7 channels) impact of data traffic is expressive in dependence on radio channels allocated (steeper increase of C/I), but after data character is asserted – very gentle growth of C/I. Data utilizes spectrum effectively and for higher number of allocated channels, there is sufficient free capacity for voice calls.
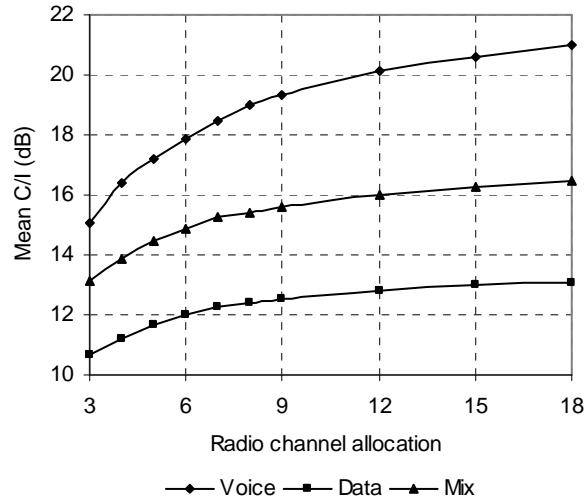
Fig. 2:   *Mean C/I ratio dependency on radio channels count.*

4   CONCLUSION

Mathematical model for simplified simulation of 2.5G GSM network (antenna system, wave propagation and attenuation, load implementation and C/I computation) is described in this paper.

We've concentrated on analysis of frequency spectrum utilization of GSM system (voice transmission) and GPRS system (data transmission). Service quality impact of used radio channels count review was performed.

Optimal number of radio channels allocated to the base stations should be approximately from 6 to 10. Voice traffic shows fixed increase (though minimal for certain number of channels) of C/I, unlike data transmission, which shows from certain number of radio channels, allocated almost no growth of C/I. Thus GPRS utilizes spectrum effectively.

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