Proceedings of the 4th WSEAS Int. Conf. on Information Security, Communications and Computers, Tenerife, Spain, December 16-18, 2005 (pp531-534)

# Interference analysis in 2.5G network

FILIP GLEISSNER, STANISLAV HANUS
Institute of Radio Electronics
Brno University of Technology, Faculty of Electrical Engineering and Communication
Purkyňova 118, 612 00 Brno
CZECH REPUBLIC

*Abstract:* - At the present time, data services have an inconsiderable impact on a network load and quality. This paper deals with interference analysis in 2.5G mobile network. Particularly with optimal method for allocated frequency spectrum utilization – service quality impact of used radio channels count review (mean C/I ratio). Simplified computer simulation of GSM network is used for analysis.

*Key-Words:* - GSM, GPRS, C/I, Wave propagation, Frame, Protocol, Radio channel

## 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.

Other solution could be retrieval of optimal standard, which (at a certain network load and quality) will improve provided services in terms of higher transfer rates and capacity increase.

## 2 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 uses three-sectorized antenna system (limited by its directional characteristic, see Fig.1)

Basic antenna parameters:

- Radiation function $F(\varphi, \vartheta)$,
- Main beam angular width,
- Backward radiation factor,
- Side beam level.

Among other important parameters belongs the directivity factor D and its dB expression

$$G = 10.\log(D), \quad (1)$$

denoted as antenna gain.

Graphical expression of relative radiation function absolute value represents previously mentioned directional characteristic.

Antenna system in this model is idealized – side beams and backward radiation factor are considered to be negligible. Antenna gain is optional, main beam angular width is approximately 60°.

### 2.2 Wave Propagation and Attenuation

Radio wave attenuation is caused by various factors, such as terrain obstacles, reflection, atmosphere etc. In this simulation, COST 231– Walfish – Ikegami (C-W-I) radio propagation model is utilized [1]. It seems to be proper from the difficulty, application conditions and result accuracy point of view.

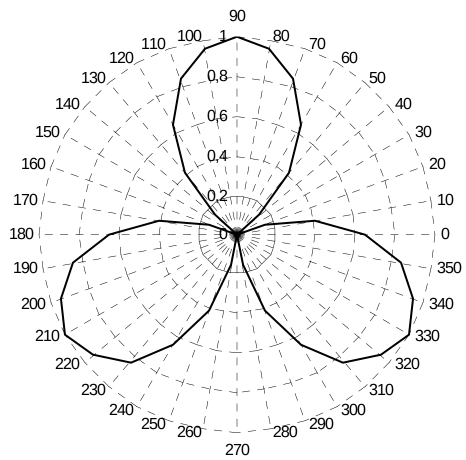


Fig. 1: Directional characteristic of BTS antenna system.

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

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

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 (2) to the simple dB representation

$$P_p = P_v + G_1 - L_p. \quad (3)$$

## 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).

Hereby parameters of C-W-I model were chosen:

- heights of buildings $h_r$ = 22 m,
- widths of roads w = 10 m,
- building separation b = 20 m,
- road orientation with respect to the direct radio path $\varphi = 90°$,
- base station antenna height $h_{BS}$ = 25 m,
- height of mobile antenna 1, 7 m.

These parameters were chosen for a 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 $I_i$ .

For mean C/I ratio in a certain point is applied relation (valid for cell networks with TDMA)

$$C / I \ (dB) = 10 \log \left[ S_d \Big/ \sum_{i=1}^{n} I_i \right], \quad (4)$$

where $S_d$ is useful signal level, $I_i$ is interference level on the same radio channel from i-th base station [4].

Gain $G_1$ and transmitting antenna peak power $P_v$ are set at the input of simulation. From (3), 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, 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.

## 2.4 Implementation

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 [3].

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. Time utilization of physical channel is quite distinct for HTTP and FTP. While HTTP exploits channel regularly in short-term intervals, FTP exploits channel in longer time interval (larger files transfer) and thus limits network capacity.

## 2.5 Data Load Model

### 2.5.1 HTTP session

Using HTTP, user can download and browse web pages (WWW).

Considerable parameters:

- 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 [5] (see table 1).

Table 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 |

Proceedings of the 4th WSEAS Int. Conf. on Information Security, Communications and Computers, Tenerife, Spain, December 16-18, 2005 (pp531-534)

#### 2.5.2 FTP session
FTP session represents one-directional dataflow – transfer of objects from FTP server to FTP client in 95% cases. We do not consider impact of control connections. 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 [6] are shown in table 2.

Table 2: Significant parameters of FTP session.

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

#### 2.5.3 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 [6].

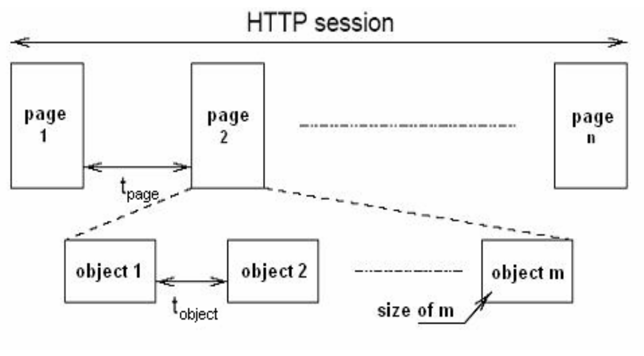


Fig. 2: HTTP session model.

## 3 Allocated Radio Channels Count Impact on C/I Ratio

Frequency plan 1x1 reuse is utilized in the network 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. We don't consider Power control effect by reason of its difficult implementation.

### 3.1 Voice Traffic
Base station traffic: 4.128 Erlangs,
(mean real traffic is chosen, same for each BTS, by reason of results independence on traffic),
Antenna gain: 10 dB,
Maximum antenna output power: 46 dBm (with respect to BTS distance),
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.

C/I dependence on radio channels count can be divided into three sections (see fig. 3):

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).

### 3.2 Data Traffic (GPRS)
Base station traffic: 4.128 dataErlangs,
(in comparison with 3.1, same traffic was chosen),
Antenna gain: 10 dB,
Maximum antenna output power: 46 dBm,
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),
Radio channels count: 3 – 18,

Coding scheme: CS-2,
RLC block size [3]: 32 B; during 60 ms (~ 13 TDMA frames) 3 blocks are transmitted → 96 B,
Statistical protocol utilization: HTTP 70 %,
FTP 10 %,
SMTP 20 %.

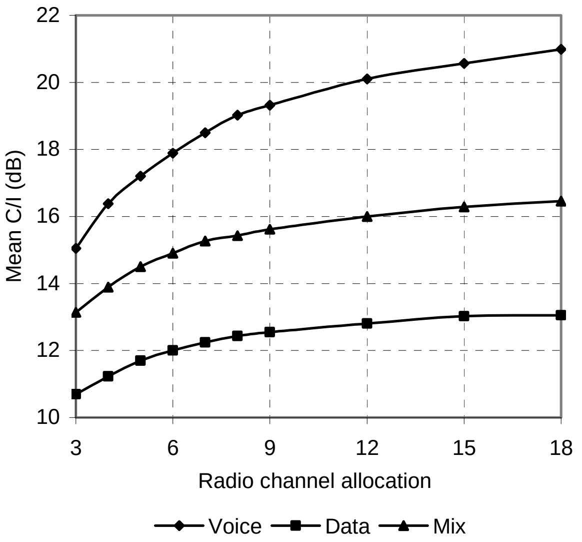


Fig. 3: Mean C/I ratio dependency on radio channels count.

C/I dependence on radio channels count can be divided into two parts (see fig. 3):

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 from the data services point of view.

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).

### 3.3 Mixed Traffic

The measurement with mixed traffic (simultaneous voice and data traffic) was performed for comparison. The same input parameters were used as in the chapters 3.1 and 3.2. Total (voice + data) 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, than 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.

## 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. Results obtained are presented in part 3.

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.

## Acknowledgement

This research is supported by the Grant Agency of the Czech Republic, Grant project No. 102/04/2080 and also Czech Ministry of Education, FRVŠ project No. IS 1840140. This research also represents a part of the Research Program of the Czech Ministry of Education MSM 262200011, Research of Electronic Communication Systems and Technologies and MSM 262200022, Research of Microelectronic Systems and Technologies MIKROSYT.

*References:*

[1] Digital cellular telecommunications system (Phase 2+). *Radio network planning aspects*. 3GPP TR 43.030 (version 6.0.0 Release 6), ETSI 2005.

[2] Mouly, M., Pautet, M. B. *The GSM system for mobile communications*. Cell&Sys. Copany, France, 1992, ISBN 2-9507190-0-7.

[3] Seurre, E., Savelli, P., Pietri, P.-J. *GPRS for Mobile Internet*. Artech House, Inc. Boston-London, 2003, ISBN 1-58053-600-X.

[4] Stavroulakis, P. *Interference Analysis and Reduction for Wireless Systems*. Artech House, Inc. Boston-London, 2003, ISBN 1-58053-316-7.

[5] Arlitt, M. F., Williamson, C. L. A Synthetic Workload Model for Internet Mosaic Traffic. In *Proceedings of the 1995 Summer Computer Simulation Conference*. Ottawa, Canada, July 1995, p. 24–26.

[6] Paxson, V. Empirically-Derived Analytic Models of Wide-Area TCP Connections. In *IEEE/ACM Transactions on Networking*, 2 (4), University of California, Berkeley, August 1994, p. 316–336.