The paper presents a new analytical method for blocking probability determination in Iub interface in the UMTS network. In our consideration we use a modified model of full-availability group with multi-rate traffic as a model of the Iub interface. The proposed scheme is applicable for cost-effective Iub resource management in 3G mobile networks and can be easily applied to network capacity calculations.

Keywords: UMTS, Iub, blocking probability

1. INTRODUCTION

Universal Mobile Telecommunication System (UMTS) using WCDMA radio interface is one of the standards proposed for third generation cellular technologies (3G). According to the 3GPP (ang. 3rd Generation Partnership Project) recommendations, 3G systems should include services with circuit switching and packet switching, transmit data at a speed of up to 2 Mbit/s, and ensure access to multimedia services [1].

The dimensioning process for the UMTS system should make it possible to determine such a capacity of individual elements of the system that will secure – with the assumed load of the system – a pre-defined level of GoS (Grade of Service). With dimensioning the UMTS system the most characteristic constraints are: radio interface and Iub interface. When the radio interface is a constraint, then, in order to increase the capacity, access technology should be changed or subsequent branches of the system should be added (another NodeB). If, however, the constraint on the capacity of the system results from the capacity of Iub interface, then a decision to add other stations (nodes) can be financially unfounded having its roots in incomplete or incorrect analysis of the system. This means that in any analysis of the system, a model that corresponds to Iub interface should be routinely included.

Due to the possibility of resource allocation for different traffic classes, the capacity determination of WCDMA radio interface is much more complex than in the case of GSM systems. The capacity of the WCDMA interface is limited by the increase in interference which is caused by the users serviced by other cells of the
system who make use of the same frequency channel, as well as by the users making use of the adjacent radio channels and by the multipath propagation occurring in the radio channel. To ensure an appropriate level of service in UMTS, it is thus necessary to limit the interference by decreasing the number of active users or the allocated resources employed to service them. Several papers have been devoted to traffic modelling in cellular systems with WCDMA radio interface [2 - 8].

To date, however, no Iub models that take the dynamic resource allocation for different services into account have been considered simultaneously by any author. This article presents a blocking probability determination method for a cellular system with Iub interface and dynamic resource allocation scheme.

The article has been divided into five sections. Section 2 discusses basic dependencies describing Iub interface in UMTS network. Section 3 presents an analytical model applied to blocking probability determination for static and dynamic resource allocation for different traffic classes. The following section includes the results obtained in the study of the system. The final section sums up the discussion.

2. Iub INTERFACE IN UMTS NETWORK

Let us consider the structure of an UMTS network presented in Fig.1. The network consists of 4 functional blocks designated respectively: User Equipment, UTRAN - UMTS Radio Access Network, CN - Core Network and external networks.

![Fig.1. Elements of the UMTS network structure](image)

1 The following notation has been adopted in Fig. 1: USIM-UMTS subscriber identity module, ME-Mobile Equipment, RNC –Radio Network Controller, MSC/VLR –Mobile Switching Centre/Visitor Location Register, HLR-Home Location Register, SGSN-Serving GPRS Support Node, GMSC-Gateway MSC, GGSN-Gateway GPRS Support Node, Uu-radio interface, Iub-interface connecting Node B and RNC, Iur-interface connected with RNC, Iu- interface connecting RNC and MSC (IuCS) or with SGSN (IuPS).
In the dimensioning process for the UMTS network, an appropriate dimensioning of the connections in the access part (UTRAN) has particular significance, i.e. the radio interface between the user and the NodeB and the Iub connections between the NodeB and the RNC (Radio Network Controller). The issues pertaining to radio interface dimensioning are widely discussed in the subject literature, for example in earlier works of the authors, whereas those dealing with dimensioning of Iub interface have not been raised so far.

Figure 2 shows two ways of the organization of the Iub interface. It is assumed that separate dedicated groups are designed to service R99 traffic (Release 99) [14] and HSPA (High-Speed Packet Access) [13] (Fig. 2a) or that the capacity of the Iub interface makes just one group and the resources that are unused by R99 traffic are assigned for HSPA traffic transmission (Fig. 2b). The figure also shows exemplary classes of services that are part of traffic designated either as HSPA or R99. Preselected parameters of the services are presented in Table 1.

("Tabela 1. Exemplary services with constraints in ATM layer (PS-non real time)"

<table>
<thead>
<tr>
<th>No</th>
<th>Service</th>
<th>$R_{DL}$ peak rate (kbps)</th>
<th>DL overhead</th>
<th>$R_{UL}$ peak rate (kbps)</th>
<th>UL overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AMR 12,2</td>
<td>12.2</td>
<td>40%</td>
<td>12.2</td>
<td>40%</td>
</tr>
<tr>
<td>2</td>
<td>CS 64</td>
<td>64</td>
<td>25%</td>
<td>64</td>
<td>25%</td>
</tr>
<tr>
<td>3</td>
<td>PS 384/64</td>
<td>64</td>
<td>30%</td>
<td>384</td>
<td>28%</td>
</tr>
<tr>
<td>4</td>
<td>HSPA</td>
<td>Various (max. 7.2 Mbps)</td>
<td>30%</td>
<td>Various (max. 7.2 Mbps)</td>
<td>30%</td>
</tr>
</tbody>
</table>
3. MODEL OF THE SYSTEM

The Iub interface in UMTS network can be treated as the full-availability group (FAG) with multi-rate traffic. Let us assume that the total capacity of the Iub is equal to $V$ BBU. The interface is offered $M$ independent classes of Poisson traffic streams having the intensities: $\lambda_1, \lambda_2, ..., \lambda_M$. The class $i$ call requires $t_i$ BBU to set up a connection. The holding time for calls of particular classes has an exponential distribution with the parameters: $\mu_1, \mu_2, ..., \mu_M$. Thus, the mean traffic offered to the system by the class $i$ traffic stream is equal to:

$$ a_i = \frac{\lambda_i}{\mu_i}. \quad (1) $$

The demanded resources in the group for servicing particular classes can be treated as a call demanding an integer number of the so-called BBU (Basic Bandwidth Units) [9]. The value of BBU, i.e. $t_{PJP}$, is calculated as the greatest common divisor of all traffic classes offered to the system:

$$ t_{PJP} = \text{GCD} (R_1, ..., R_M), \quad (2) $$

where $R_i$ is the amount of resources demanded by class $i$ call in kbps.

Both ways of Iub organisation presented in Fig. 2 can be described by multidimensional Markov process which can be expressed by one-dimensional Markov chain. Occupancy distribution in FAG can be described by Kaufman-Roberts recursion [10, 12]:

$$ n \ P(n) = \sum_{i=1}^{M} a_i t_i \ P(n-t_i), \quad (3) $$

where $P(n)$ is probability of state $n$ BBU being busy, and $t_i$ is the number of BBU required by a class $i$ call:

$$ t_i = \frac{R_i}{t_{PJP}}. \quad (4) $$

The total capacity of the Iub interface is also expressed in BBU:

$$ V = \frac{V_{lib}}{t_{PJP}}, \quad (5) $$

where $V_{lib}$ is the physical capacity of Iub interface in kbps.

The diagram in Fig. 2 corresponds to (3) for the system with two call streams ($M=2$, $t_1=1$, $t_2=2$). The $y_i(n)$ symbol denotes reverse transition rates of a class $i$
Model of Iub Interface in the UMTS network

Fig. 3. Fragment of a diagram of the one-dimensional Markov chain in a multi-rate system \((M=2, t_1=1, t_2=2)\)

Service stream outgoing from state \(n\). These transition rates for a class \(i\) stream are equal to the average number of the class \(i\) calls serviced in state \(n\). Based upon \([10]\), the reverse transition rate for class \(i\) calls in \((n+t_i)\) state is equal to:

\[
y_i(n + t_i) = \begin{cases} 
  a_i P(n) / P(n + t_i) & \text{for } n + t_i \leq V, \\
  0 & \text{for } n + t_i > V.
\end{cases}
\]  

(6)

This parameter determines the average number of class \(i\) calls serviced in state \(n\) \([9, 10]\). The value of \(y_i(n)\), in a given state of the group, forms the basis of the method of occupancy distribution calculation in the group presented in Fig. 4.

Figure 2a shows the organisation of the Iub interface according to which it is divided into two dedicated groups servicing independently R99 and HSPA traffic. The analysis of such a system corresponds to independent analysis of two FAGs servicing multi-rate traffic. In each case it is possible then to determine, after determining the occupancy distribution \(P(n)\), the blocking probability \(B_i\) for class \(i\) stream on the basis of the formula:

\[
B_i = \sum_{n=V-t_i+1}^{V} P(n).
\]  

(7)

Figure 2b shows a more complex case in which HSPA traffic can use resources dedicated to R99 traffic. This takes place when R99 traffic does not entirely make use of the allocated resources and occupies at least \(G\) BBUs, where \(G < V\). Such a case can be interpreted as a dynamic limitation of resources for R99 traffic classes which is accompanied by not limited HSPA traffic. In order to determine the occupancy state of the group in which, there is dynamic limitation of resources, we introduce the parameter \(G(n)\), defined in the following way:

\[
G(n) = \sum_{i=1}^{M} \left\lfloor y_i(n) t_i \right\rfloor \quad \text{for } i \in S,
\]  

(8)

where \(S\) is a set of constrained traffic classes (for example R99 traffic classes). The parameter \(G(n)\) determines the average number of BBUs being busy by calls of selected (constrained) classes, in the state \(n\).
In the proposed model we search for such a constrained state \( n \), in which the number of BBUs being busy by calls of constrained classes meets the condition:

\[
G(n) = G. \tag{9}
\]

Finding such a state of occupancy \( n \) (designed later as \( N \)) determines a possibility of limiting access to the resources of the system for traffic classes that belong to the set \( S \). We assume that in all states older than \( n \) only those classes which have no constraint are serviced (Fig. 4).

The modification of the serviced process shown in Fig. 4 results in a transformation in the occupancy distribution \( P(n) \) into the generalised Kaufman-Roberts distribution:

\[
n P(n) = \sum_{i=1}^{M} a_{i} t_{i} \sigma_{i}(n-l_{i}) P(n-l_{i}) , \tag{10}
\]

where \( \sigma(n) \) is state-passage-probability between adjacent states of the process. In the system shown in Fig. 4, the parametr \( \sigma_{i}(n) \) can be determined in the following way:

\[
\sigma_{i}(n) = \begin{cases} 
1 & \text{for } i \in S \text{ and } n \leq N, \\
0 & \text{for } i \in S \text{ and } N > n, \\
1 & \text{for } i \notin S \text{ and each } n.
\end{cases} \tag{11}
\]

In the determination of the blocking probability of calls of individual traffic classes serviced in the system shown in Fig. 4, one has to take into consideration the differences in the availability of the group for different traffic classes. Therefore we get:
On the basis of the above considerations, the algorithm of blocking probability calculations in the Iub may be written as follows:

1. Calculation of offered traffic load \( a_i \) of class \( i \) (Eq. (1)).
2. Determination of the value of \( t_{PP} \) as the greatest common divisor (Eq. (2)).
3. Determination of the value of \( t_i \) as the integer number of demanded resources by class \( i \) calls (Eq. (4)).
4. Determination of state probabilities \( P(n) \) in the FAG (Fig. 3, Eq. (3)).
5. Calculation of reverse transition rates \( y_i(n) \) (Eq. (6)).
6. Determination of state \( N \) in which condition (9) is fulfilled.
7. Determination of the occupancy distribution \( P(n) \) in the modified Markov chain (Eq. (10)).
8. In the modified distribution (10) we check if, for a given \( N \), the condition (9) is met. If the condition is not fulfilled, then we adopt \( N=N\pm 1 \) and proceed to step 7.
9. Determination of blocking probabilities \( B_i \) for class \( i \) calls (Eq. (12)).

4. NUMERICAL EXAMPLES

The proposed analytical model of Iub interface is approximate one. Thus, the results of the analytical calculations of the Iub have been compared with the results of the simulation experiments.

The study carried out for users demanding a set of services (Tab. 1) and it was assumed that:

- a call of particular services demanded \( t_1=1680 \), \( t_2=8000 \), \( t_3=49152 \) and \( t_4=468000 \) BBUs in the uplink,
- a physical capacity of Iub in the uplink is equal to \( V_{Iub}=4 (R99)/7.2 \times 1.3 =13.36 \) Mbps,
- a capacity of Iub in BBUs in the uplink is equal to \( V=1 \ 360 \ 000 \) BBUs,
- one BBUs is equal to 0.001,
- the limitation \( G \) for release R99 is equal to 4 Mbps (4 000 000 BBUs).
- the services were demanded in equal proportions \( a_1t_1:a_2t_2:a_3t_3:a_4t_4=3:1:1:5 \).

Figure 5 shows the results obtained for traffic classes presented in Tab. 1. All the presented results show the robustness of the proposed method for blocking probability calculation. In each case, regardless of the offered traffic load, the results are characterised by fair accuracy.
The results of the simulations are shown in the charts in the form of marks with 95% confidence intervals calculated after the $t$-Student distribution. 95% confidence intervals of the simulation are almost included within the marks plotted in the figures.

5. CONCLUSIONS

The dimensioning process for the UMTS system should aim at determining such a capacity of the elements of the system that will allow – with the predefined load of the system – to ensure the assumed level of GoS (Grade of Service). In the dimensioning of the UMTS system the most characteristic constraints are: radio interface and the Iub interface.

The paper presents a new calculation method for blocking probability determination for traffic offered in the Iub interface. In our considerations, we use a modified model of the full-availability group with multi-rate traffic as a model of the interface. The calculations are validated by a simulation. The proposed method can be easily applied to 3G network capacity calculations.
REFERENCES


