Concept of a QoS aware Offer Planning for GPRS/EDGE Networks

A. Kunz, S. Tcaciuc, M. Gonzalez, C. Ruland, V. Rapp

***Abstract*— A new era in wireless services has begun by introducing of packet oriented services as an extension of the GSM networks. New mobile devices allow the user to be always connected to the digital information world, accessing a large variety of services. The nature of the offered services cannot be described just as one global service, because the capacity demand and time constraints vary from service to service. The Quality of Service (QoS) parameters describe these service requirements.**

Mobile network providers, that want to provide information services based on QoS, have to plan their networks and their network capacity according to the users demand.

This paper addresses the challenge of QoS aware network planning and introduces a prototype of GSM-EDGE radio access network offer planning, called GOTOR. This approach provides a concept for the whole planning process, including circuit switched and packet switched dimensioning as well as coverage prediction and definition of QoS profiles.

GOTOR provides a rough network planning for estimating the efforts and costs of a network with the required properties. It is used as an offer tool, which means it is a tool that supports hardware supplier's sales personnel to make offers.

The capacity planning process has to consider all the Teleservices together. The traditional concept of pre-computed tables or empirical formulas is not able to provide flexible user profiles and QoS requirements, because multiplexing of statistical appearances of the packets of all Teleservices depends on the traffic models and the number of users.

***Index Terms*— QoS, Coverage Planning, Capacity Planning, GPRS/EDGE**

I. Motivation

Network planning is a very complex process and different aspects of the radio characteristics, users behavior, capacity demands etc. must be taken into account.

Current network planning tools consider only best effort service for all applications because the radio access networks were not able to guarantee QoS before release ′99 of 3GPP specifications. In previous releases the mechanisms for QoS in the radio access network were not able to support different QoS demands for one user simultaneously. This has consequences in planning results and user satisfaction and it is necessary to take the QoS requirements of each application of every user into account during the planning process.

The QoS aware planning increases the complexity of the planning process since it is not possible to handle all the services simultaneously in a static way.

This paper proposes a strategy of radio access network planning under QoS aspects.

High price of radio resources and their limited availability does not allow the network providers to support a high number of users with a high grade of service. Not all of the users need the same network performance at the same time and not all of them are willing to pay a higher price for better QoS, which they did not order.

Network providers need capacity planning for the mixture of the expected user behavior in the observed region in order not to waste any of the limited resources. This is done by introducing "User Profiles", which consist of one or several Teleservices. The individual Teleservice of a user profile has different QoS requirements, which should be specifically defined according to the policies of the service provider (QoS Profiles).

A Teleservice must be described by an analytical model that corresponds to the real traffic observed in the network.

Planning a large area can be very difficult, therefore an observed area, called "Project", is divided into regions, called "Scenarios". Each scenario has uniform environment characteristics, capacity requirements and hardware configuration.

Several QoS requirements have to be simultaneously satisfied by the radio access network, because of the existence of diverse types of users with different demands. Main points redefined by GOTOR are:

- The structure of the input parameters to offer the flexibility required in the planning process.
- The capacity planning based on a Traffic Simulator to guarantee the demand for the different Quality of Services.

II. Planning Tool Architecture

The approach for the planning tool architecture is based on a modular structure. New requirements can be treated as add-on modules, which can be designed and plugged later into the platform.

Planning tool architecture is presented in Figure 1. The

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steps in the planning process are described by four main functionalities and each one handles the results of different modules:

- **Input Parameters:** describes the environment, hardware characteristics and user demands.
- **Coverage Prediction:** the cell or sector coverage is estimated based on the environment and hardware characteristics.
- **Capacity Dimensioning:** required capacity is calculated with respect to the user demands.
- **Output Results:** generates reports of the dimensioning process.

Planning results and their accuracy strongly depend on the description of the requirements. A good structured and friendly designed user interface allows a proper definition of the desired network.

Each scenario within a project can have its own radio conditions and hardware configuration. The "Coverage Prediction" is achieved based on these parameters.

This function is implemented by the "Link Budget" module. It calculates the maximum allowed loss for the current conditions respecting the balance of all gains and losses of the transmission path. The cell size is computed based on the corresponding propagation model. The prediction of interference levels, performed in the "Interference" module, serves as one of the input parameters for the calculation of the capacity of a traffic channel used by the "Packet Switched Capacity" module.

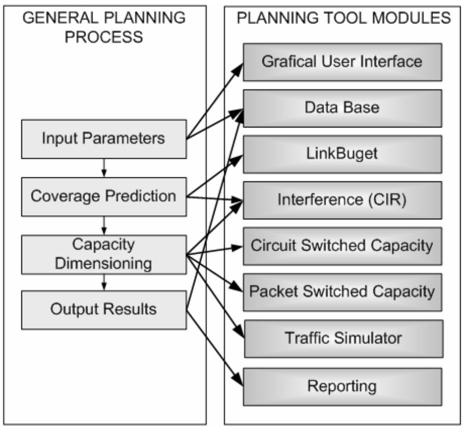

Figure 1: Planning Tool Architecture

The capacity dimensioning computes the amount of necessary hardware components, required to transport user data with desired QoS within the current scenario. This task is performed by three modules:

- "Circuit Switched (CS) Capacity": Responsible for dimensioning the CS services.
- "Packet Switched (PS) Capacity": Responsible for dimensioning the PS services.
- "Traffic Simulator": simulates different user profiles with their Teleservices simultaneously in order to evaluate the individual QoS performance within a given network capacity.

The "Output Results" generate reports within the "Reporting" module.

III. Data Handling

To provide the QoS demanded for the variety of user types, new definitions have to be introduced in the planning process. These new definitions are summarized as follows:

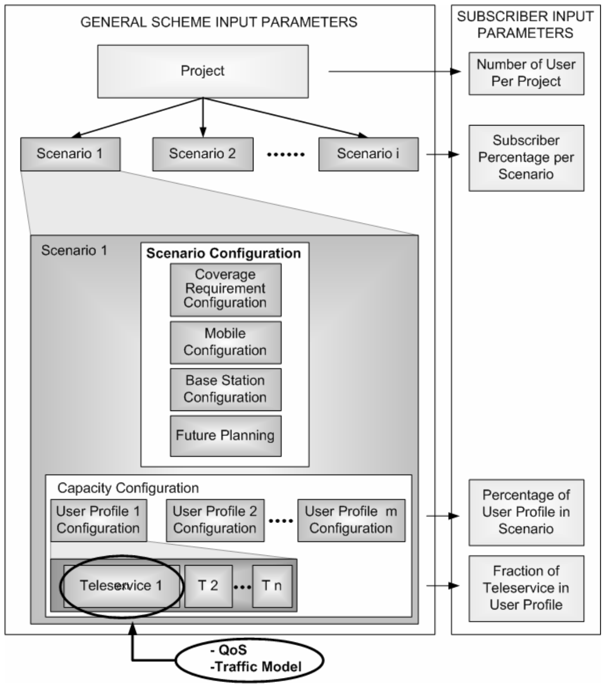

Figure 2: General Scheme of Input Parameters

- **Scenarios:** are used to formally specify the requirements of a planned region, different scenarios form a **Project**. The information of a scenario can be divided in three main parts:
  - o Coverage Requirements,
  - o Users/Capacity Requirements,
  - o Hardware Requirements.

  Coverage Requirements are described by the area and the landscape of the region, density and height of the buildings etc.

  Users/Capacity Requirements in case of a QoS aware planning is done by the definition of the user profiles, which includes the information about traffic and mobility of the users in the current scenario.

  Hardware Requirements e.g. mobile class, number of available frequencies, BTS generation and its configuration has to be selected from the parameters provided by the hardware manufacturer.
- **User Profiles:** Organizing users in categories according to different characteristics as amount of traffic, kind of

service and user satisfaction or costs.

- **QoS Teleservices:** Definition of QoS profiles for each type of traffic model according to the policies of the service provider. A QoS profile contains parameters to describe the traffic behavior in terms of precedence, delay, reliability, peak throughput and mean throughput. Enhanced QoS mechanisms in UMTS/GPRS ([1]) are provided by multiple Packet Data Protocol (PDP) contexts and management functions. New attributes are added for characterizing the QoS parameters with the new QoS mechanisms [2].
- **Traffic Models:** Realistic traffic estimation by mean of traffic models according to the characteristics of each Teleservice. The traffic models are described by distribution functions for the statistical processes of the burst size and the interarrival time (Figure 3).

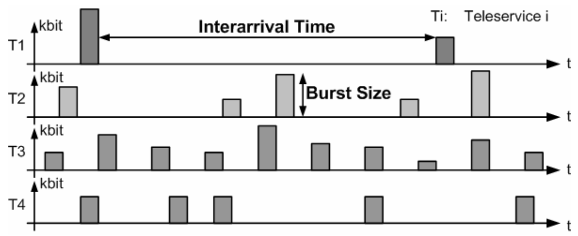

Figure 3: Statistical traffic behavior

The new definitions in combination with a traffic simulator provide full flexibility for all kinds of services for nearly all possible kinds of scenarios. A structure for these parameters is shown in Figure 2.

IV. Coverage Prediction

The coverage prediction of the maximal cell size is performed by the Link Budget module. In order to estimate the cell radius, a corresponding propagation model must be applied and the maximum allowable loss with a balance of all gains and losses on the transmission path must be computed.

The balance of gains and losses provides the maximal path loss that can be covered by the hardware in order to receive the field strength greater than a certain threshold.

The empirical propagation models that are generally used for the path loss estimation are:

- Hata model [3] for frequencies lower than 1500 MHz and
- "COST 231-Hata-Model" for frequencies higher than 1500 MHz and additional lognormal margins for improved coverage probability [4].

The Link Budget algorithm is presented in Figure 4.

When the estimated cell radius is less than 1 Km, a modification of the path loss model is introduced, because Hata and COST 231-Hata-Model provide no realistic results for short distances. For this case a combination of the Free-Space Propagation and Hata-Model is applied.

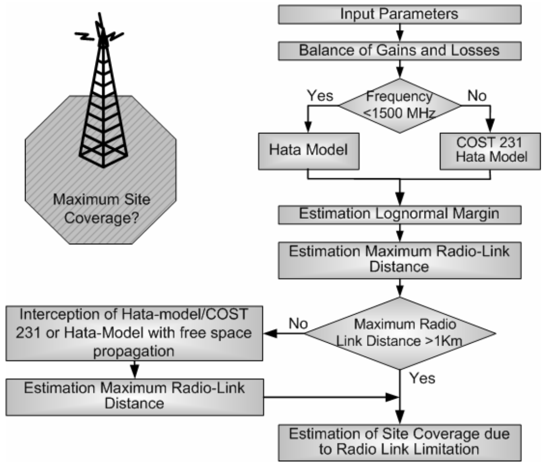

Figure 4: Link Budget Algorithm

The interception point between the Hata-Model and the Free-Space propagation is situated at about 5m. The modified near range section meets Hata at 1km and the free space formula at a distance of 20 m from the base station.

V. Capacity Dimensioning

A mobile user is expecting the full range of services e.g. data and voice. In this chapter, an algorithm used for dimensioning the network, for both CS and PS services, is discussed. This algorithm uses the results of the CS and PS dimensioning algorithms. Figure 5 shows the flow chart of the capacity planning algorithm.

First, the maximal number of transceivers (TRX) per site, the amount of available time slots as well as the number of time slots accessible for the transfer of the CS and PS traffic is calculated. This is done by subtracting the number of time slots, reserved for the signaling from the total number of available time slots.

The number of initial base stations, required to cover the desired area is calculated using the site size computed by the Link Budget module. Based on these results, the total amount of traffic of the Teleservices is divided by the number of base station. This results in traffic per base station.

Next, the amount of time slots, required for the transfer of the CS and PS traffic at one base station, is calculated under QoS aspects. These calculations are done using the algorithms, presented in the next subchapters. Finally, the number of TRXs is calculated according to the computed number of time slots.

The number of base stations in the area will be increased and the process will be repeated, if the number of TRXs is higher than the maximal number of TRXs that could be installed at one base station. This will be done until the number of computed TRXs is less or equal to the maximal number of TRXs that could be installed at one base station.

A reconfiguration algorithm can be applied in order to optimize the amount of hardware, if the number of computed TRXs is less than the maximal number of allowed TRXs per base station. This algorithm will decrease the number of TRXs per sector that will allow an asymmetric configuration of the base stations (for example 1/1/2, 2/3/3 etc.).

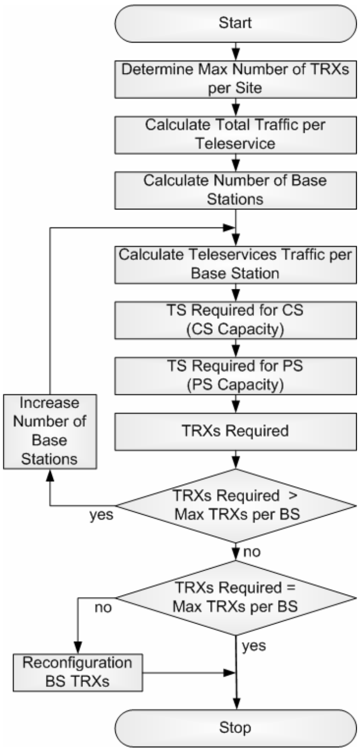

Figure 5: Capacity Dimensioning Algorithm

The capacity dimensioning algorithm is used to calculate the number of base stations in the region, required for the transfer of the specified Teleservice traffic, taking into consideration the QoS, hardware limitations and the results from the Link Budget module (e.g. Coverage Limitation).

A. CS Planning

Circuit switched services are described by a Poisson arrival and serving process. The Erlang-B formula is usually used to compute the number of required time slots for the CS services with a certain blocking rate. However, for the case that there are several types of CS services that can be differentiated by the different number of required time slots per TDMA frame, the dimensioning is performed by using the Multi Erlang-B Algorithm [5].

The Multi Erlang-B Algorithm allows computing the number of required resources for eight categories of CS services, depending on the number of bundled slots and the corresponding blocking requirements. Each category should have the same QoS requirements. Services with different QoS requirements in the same category, e.g. services bundling three time slots (TS) with different blocking rates, can not be handled directly by the Multi Erlang-B Algorithm. For this case, one approach is considered for multiplexing CS services with different QoS requirements together for dimensioning the number of required resources.

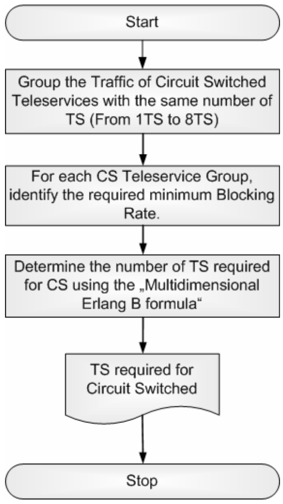

Figure 6: CS Capacity Planning

This approach, called "MinQoS", sorts the different CS services into the existing eight categories, depending on the number of time slots. The Erlangs of all services within each category are summed up and the minimal blocking probability is used by the Multi Erlang-B Algorithm. The CS capacity algorithm is presented in Figure 6.

B. PS Planning

The packet switched traffic can not be handled like the circuit switched traffic, because the interarrival times and size distributions are usually not Poisson processes.

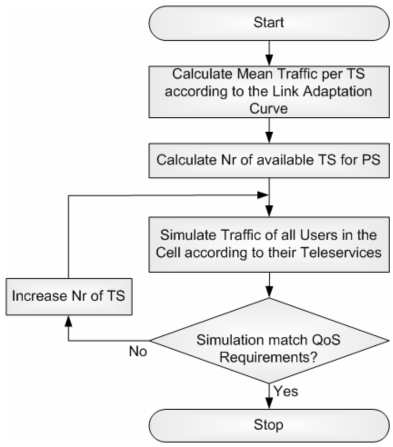

Figure 7: PS Capacity Algorithm

The goal of the PS planning is to check, if the requested traffic with the different QoS requirements match the available resources. The algorithm for the PS planning is presented in Figure 7. At first, the average amount of traffic is computed, which the actual base station is able to transport in one packet data traffic channel (PDTCH). This depends on this C/I, Frequency Hopping (FH) and the available modulation schemes. The total number of time slots that can be used to transfer the PS services is calculated from the total number of time slots minus the number of time slots allocated to the CS services. To solve this problem, a traffic simulator can be used. The traffic simulator, shown in Figure 8, simulates different user profiles with their Teleservices simultaneously in order to evaluate the individual QoS performance within a given base station capacity. Depending on the results, the network capacity can be increased or decreased and the simulation is repeated until the QoS performances match the requirements.

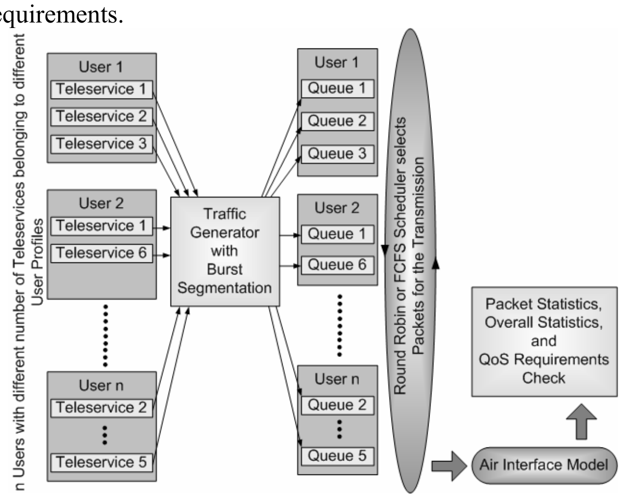

Figure 8: Traffic Simulator Concept

The simulation is aborted in order to save the computation time, if any of the QoS requirements are not met during the simulation. In that case an estimation of additional base stations is performed. On the other hand, when the simulation is successful, which means the QoS requirements are supported, a reconfiguration (e.g. decrease of the number of TRXs) is done.

VI. Planning Example

The GOTOR tool allows configuring the network as accurate as desired. The area can be divided into scenarios with different requirements on environment and hardware. The accuracy of planning is optimal when all different requirements are matched with the same number of scenarios.

Figure 9 shows an example with three different regions (Rural, Urban, Highways) which is described in one project and three scenarios.

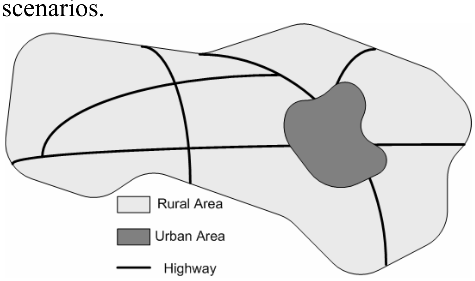

Figure 9: Planning Example

User Profile	Home User		Business User		Student User	
Teleservices / Percentage	Voice	100%	Voice Email HTTP	50% 30% 20%	Voice SMS	80% 20%

Table 1: User Profile Description

The user profiles in each scenario are defined in Table 1 and Table 2 shows their main parameters.

	Rural	Urban	Highway
Nr. Of Users	50000	49000	1000
Size/Length	330 km²	35 km²	20 km
Max. TRX	4	8	2
Max. PDTCH	4	8	8
MS Bundles	2 TS	4 TS	4 TS
MCS	CS1-2 FH	CS1-9 FH	CS1-4
Freq. Reuse	4/12	3/9	3/9
User Profiles	50% Home 50% Student	30%Business 40% Home 30% Student	100% Business

Table 2: Scenario Description

Using these and other information about the scenarios, GOTOR will compute the following offer of Table 3:

	Rural	Urban	Highway
Sector Size	10 km²	0,177 km²	6,667 km
Limitation	CS Capacity	PS Capacity	PS Capacity
TRXs Req.	264	1584	6
PDTCH Req.	0	8	4
Sites Req.	11	66	3

Table 3: Planning Results

VII. Outlook

The presented framework covers only 2G and 2.5G technologies but this concept can be applied to any other technology. The planning process is based on the user profiles which are used by the network providers. Previous approaches do not consider the QoS requirements of the users. Instead of creating such an offer tool for each technology (e.g. 3G, 4G etc.), a better approach will be an universal offer tool that combines all technologies within a common platform. While the coverage planning could be technology independent, the concept of the traffic simulator has to be adapted to the desired technology.

Acknowledgment

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References

[1] 3GPP TS 22.060 “General Packet Radio Service (GPRS);Service description, Stage 1, Release 5”.
[2] 3GPP TS 23.107 “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Quality of Service (QoS) concept and architecture (Release 5)”
[3] M. Hata “Empirical Formula for Propagation Loss in Land Mobile Radio Services”, IEEE Tran. on Vehicular Technology”, Vol. VT-29, No. 3, August 1980, p. 317-325
[4] “Digital Mobile Radio Towards Future Generation Systems” COST 231 Final Report
[5] Villy B. Iversen, “Teletraffic Engineering Handbook”, Technical University of Denmark, 2002