Studie für die
RTR GmbH, Österreich

Erstellung von Bottom-up Kostenrechnungsmodellen zur Ermittlung der Kosten der Zusammenschaltung in Festnetzen und Mobilnetzen

Hier: Mobilfunknetz

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Contents

List of Figures

List of Tables

0 Introduction and structure of the model

This document provides the high level specification for the bottom-up cost model of a hybrid mobile network incorporating both 2G GSM and 3G UMTS technology, and the description of the general structure of the corresponding software tool, referred to in the sequel by RTR 2G/3G. This document intends to inform RTR and market players on the structure of the cost model, the technology and network assumptions, the optimisation approaches regarding the efficiency of the network and finally the calculation of the efficient costs of the regulated mobile services.

Bottom-up cost models generally consist of two main parts, i.e.

- Network design and dimensioning, and
- System assignment and cost calculation.

Network design and dimensioning in turn is subdivided in three parts, i.e. the:

- Logical layer,
- Physical layer, and
- Control and management layer

The RTR-2G/3G model uses the notion of 'scenario' for defining the basic geographical subdivision of the territory to be covered by the mobile network to be modelled where this total territory may, for example differ according to whether certain mountainous areas are to be included or not. For this purpose the RTR-2G/3G model uses a scenario generator which generates the covered topology of Austria and determines the main input data for a given network to be modelled.

This document is divided into four chapters where the first outlines general aspects and the tasks of the scenario generator; the second chapter outlines aspects and tasks of the network design, dimensioning and system assignment, the third chapter presents the cost modelling, and the fourth chapter outlines general aspects of the tool structure for the RTR-2G/3G model.

1 Network architecture, services and scenario generation

The network design and configuration for a mobile operator depends on the parameters of the operator (service portfolio, market share, coverage requirements, and equipment type) and demographic and geographic parameters (population, type of terrain, building concentration and so on). A particularly critical design parameter is the mix of 2G and 3G technology.

In Austria, mobile operators still have large 2G legacy networks, It is to be expected that during the next few years operators will tend to continue to use these networks which on the one hand are already largely amortized but on the other are still functional for certain demand constellations. Given, however, that demand for 3G services expands and also equipment manufacturers and vendors are replacing their 2G equipment stock by new 3G equipment, all new network deployments will in the future be based on 3G technology.

As a conclusion of the above paragraph, in the glide path to 3G and beyond, mobile network operators will install 3G equipment in previously existing 2G sites. New sites will be only or at least mainly 3G based. The replacement will start in the areas with a large demand of mobile broadband demand, typically urban areas, and will continue with the remaining, less populated (suburban and rural) areas. New entrant operators will use only 3G technology. Constrained availability of spectrum may also lead to a situation where mainly in urban areas in addition to the provision through UMTS also provision through GSM remains the temporarily efficient combination. In all these cases, a hybrid network incorporates areas that are simultaneously served by UMTS and GSM technology.

It should be noted that the cost of the 2G network parts in a 2G/3G hybrid network is an opportunity cost. It is driven by the opportunity of still being able to offer satisfactory service to a portion of the customer base while, at the same time, running the risk of not satisfying all of these customers because this is only 2G service. The alternative would be to install 3G technology now, which in the long run will anyhow be the more cost effective option. In particular cases, where 2G structures are already fully amortized, their actual out-of-pocket cost would consist only of the cost due to operating and maintaining them. For an external observer, the opportunity cost of the 2G network parts is not ascertainable; it needs to be estimated by some way of approximation.

From a modelling point of view, it will be possible to develop a hybrid network where in urban areas with high data demand provision occurs through GSM and UMTS technology. As we noted above, this can only be a temporarily efficient network. Where in reality such a network is observed, this is due to the process of transition where a 2G network (having become obsolete) is gradually replaced by a 3G network. Nevertheless, the model will provide this option. It should be clear, however, that whenever a hybrid network is observed in reality, with this situation having come about through gradual introduction of 3G technology into a pre-existing GSM network, the determination of its cost through a bottom-up cost model, which by construction assumes that a network using both technologies is rolled out *now*, can only approximately capture the cost of these actual networks.

Question 1:	Do you agree with the above characterization of the 2G/3G hybrid networks? Do you agree with the above characterization of the cost of 2G technology? How long do you intend to use 2G technology in your mobile network? When it comes to the installation of new sites, do you still install 2G technology in new sites?

When applying GSM technology, the model considers that an operator gets spectrum either in only one frequency, 900 or 1800 MHz, or in both of these. The last case leads to a dual band operator. As shown in section 2.1, the model considers in this case an optimal distribution of the GSM traffic between spectrum resources of both frequencies.

The first section of this chapter describes the hybrid GSM/UMTS architecture and its corresponding services, the second section the data input requirements, the third section considers aspects of the preparation of the raw data for network planning and the final section 1.4 exposes a scheme for the service and traffic description.

1.1 Hybrid GSM/UMTS network architecture and corresponding services

Both 2G as well as 3G mobile networks consist in the logical network of a four level network resulting at the physical level in a network consisting also of four parts:

- A cell structure consisting of base station sites, or simply “sites”. A site may have UMTS, GSM equipment or both and may be composed of several cells due to sectoring;
- An aggregation network which connects base station sites to controller units (BSCs for 2G or RNCs for 3G)
- A backhaul network part which connects radio controller units with switching units, and
- A core network which connects the switching units and provides control units such as registers and service units as SMS and MMS centres.

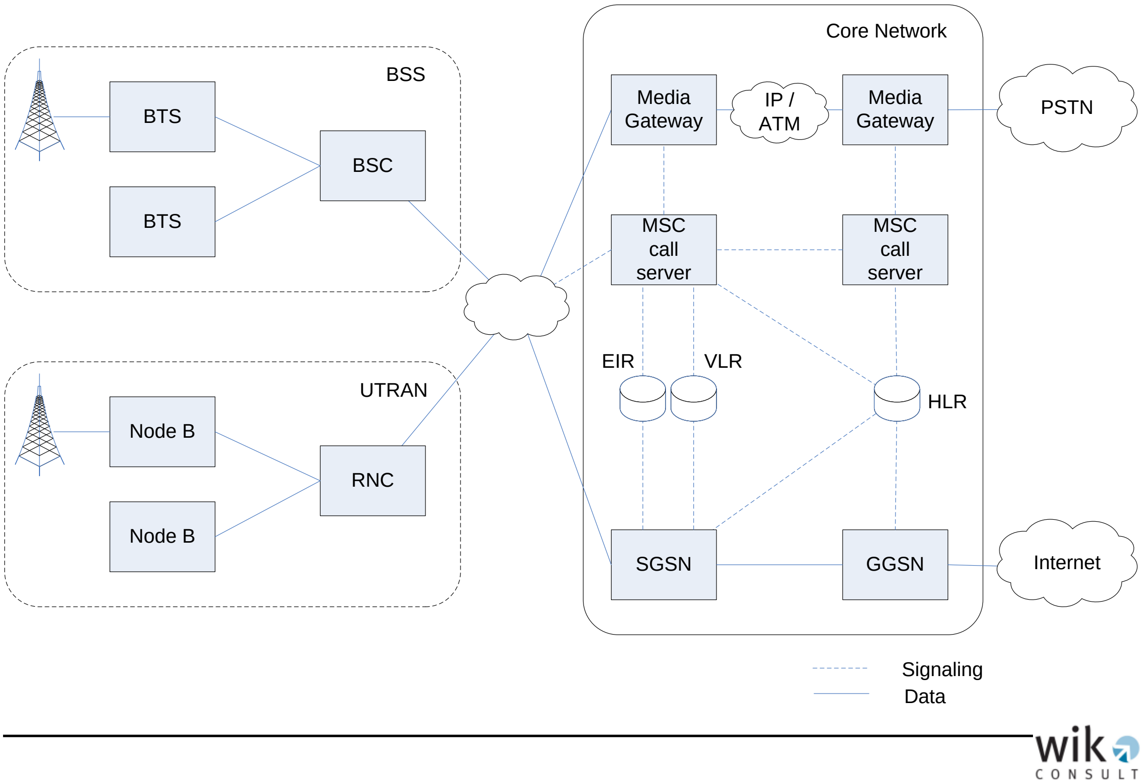
Table 1-1 provides an overview of the nomenclature used allowing us, as appropriate, to use the same designation for similar units or functionalities which in their specific network environments have their specific names. Note that in the physical network one of the cell sites in a given area connects to all sites and is in the model referred to as 'cell hub'.

Table 1-1: Nomenclature applied in the RTR 2G/3G model

Designation of functionality	**Nomenclature in**			**Network part**	
	2G GSM	3G UMTS	RTR model	Logical	Physical
Radio cell site	BTS	Node B	Cell site	Cell deployment	Cell site aggregation
District hub	BTS-hub	Node B hub	Cell hub	Aggregation	Hub aggregation
Radio controller	BSC	RNC	Controller node	Backhaul Logical Network	Backhaul Physical Network
Switching, routing and control functions	MSC	SGSN	SwRo node	Core Logical Network	Core Physical Network

A simplified graphical overview over the logical structure of this hybrid network and its corresponding functional units is provided in Figure 1-1. Note that this figure shows the architecture of a 2G/3G network with its corresponding functional blocks. In case of hybrid cell sites, with either 2G or 3G being overlay, the hybrid configuration will be realised at the level of the physical implementation; on the logical level 2G and 3G cells are determined independently on the basis of the volumes of the corresponding services.

Figure 1-1: Architecture of a hybrid GSM/UMTS Mobile-Network (UMTS based on Release 4) with its corresponding functional units



As regards services to be provided by the modelled network, for the GSM system they were primarily conceived to provide voice services over circuit switched units. Therefore, all planning efforts were oriented towards providing the corresponding quality of service (QoS) and grade of service (GoS) for voice services. However, also message services such as SMSs or low speed data services such as 9.6 Kbps circuit switched modem services have become increasingly relevant. At the end of the nineties and as an intermediate step before the introduction of 3G services, packet data services became very important for 2.5G services and the consequent GPRS technology. The capacity requirements for all services are based on the number of fixed capacity units referred to as 'slots', with the exception of SMSs which share the capacity provided for signalling traffic.

As regards the 3G service profile, this is more complicated than in the case of 2G due to the different features of the radio network interface and the way the cell planning is performed.

Initially, it is required to distinguish between an application service and a physical service. An application service is defined in relation to the user, while a physical service is defined in relation to the amount of resources required in the physical layer. The RTR

2G/3G model defines the services on the application layer independently of its realisation either in 2G or in 3G technology. Hence the RTR 2G/3G model has to perform 2G and 3G cell deployment applying the parameters of the corresponding physical layer services as defined from the 3GGP and hence assuring a correct cell deployment which fullfills the corresponding traffic demand. Therefore, in the cell deployment part, the model transforms the requirements of the user applications in the operator's service briefcase into the capacity requirements of the physical services.

As a consequence the RTR 2G/3G model considers a common service profile for both 2G and 3G technology at the application level and transfers these values into the physical parameter of UMTS when 3G technology is applied and into GSM/GPRS when 2G technology is applied. Section 1.4 of this chapter specifies this aspect in more detail.

As regards cell deployment, GSM sites will handle GSM traffic and UMTS sites will handle UMTS traffic. The model allows considering in an area sites with both UMTS and GSM equipment, based on corresponding parameter values. These thresholds are input parameter to the model for urban, suburban and rural areas. Additionally the model considers that in specific areas, both GSM and UMTS technologies could be collocated in the same site (hybrid sites). In this case the model considers that part or the traffic is handled by the GSM technology while the remaining part of the traffic is handled by the UMTS technology.

For this purpose the model considers the following parameters indicating:

- Density thresholds for urban, suburban and rural areas,
- Whether a hybrid network with both GSM and UMTS is considered,
- Traffic that will be handled in part by GSM equipment and in part by UMTS equipment, in case of hybrid sites.

Table 1–2 shows the resulting types of networks related to the option values for the mix between GSM and UMTS. Note – as will be discussed later – that the traffic distribution in case of hybrid cell sites is provided by corresponding input parameters to be provided from the model user.

Table 1-2: Type of network configurations considered by the model and its relation with the corresponding options

Type of network	Hybrid network	Hybrid sites	User density threshold for applying UMTS	Traffic sharing between 2G and 3G in sites
Pure GSM	No	No	Not Applicable	No
Pure UMTS	No	No	Zero	No
Hybrid network, without hybrid sites	Yes	No	Yes	No
Hybrid network, with hybrid sites	Yes	Yes	Yes	Yes

Question 2: Do have comments regarding the appropiateness of the hybrid 2G/3G network architecutres as presented here?

1.2 Main input data for the 2G/3G network model

An important part of the modelling exercise is the process of collecting relevant data about the geography and demography of the country. Information is extracted from public sources on the following categories:

- Postal areas or settlement districts
- Geography, and
- Distribution of residential, working and tourist populations.

An overview of different data inputs needed to generate the list of inputs on the basis of which modelling will be carried out is provided below:

- Identifier of the postal area or settlement district (POA/SeDi);
- Name of the POA/SeDi:
- Size of the area covered by the POA/SeDi (in km²);
- Population of the POA/SeDi;
- Number of tourists;
- Number of working people in it;
- Classification of population density (urban / suburban / rural), consistent with the thresholds for the different 2G and 3G technologies, provided separately for each

POA/SeDi. Depending on these thresholds, the cell deployment provides a hybrid *network* with pure cell sites in an area either being 2G or 3G. Table 1-3 shows an example with two possible value-sets one representing a dominant UMTS deployment and the other one a dominant GSM deployment;

- The possibility of hybrid *areas* is introduced by an additional option where the model user indicates the distribution of the total traffic over the two technologies (e.g. all voice traffic over GSM and all data traffic over UMTS). The provision of hybrid cell sites can be selected indivudally for each area type (rural, suburban, urban) and applies for all GSM cells following from the threshold criterium as mentioned in the previous bullet;

- The application of EDGE for GSM cells and HSPA for UMTS cells can be selected again individually for each area type;

- Topographic features such as

(a) Topology of the POA/SeDi regarding the slope given within the POA/SeDi. In the RTR 2G/3G model the complete POA area is classified according to the three categories ‘flat’, ‘hilly’ and ‘mountainous’ and the decision is done by minimal and maximal values of the slope in the corresponding topographical point. Table 1-4 shows an example of possible values;

(b) Optionally: particular POA/SeDi areas which lie above a corresponding altitude, e.g. 2000 m. For these areas the model would assume that the mobile operator will not provide any coverage.

Question 3:	What is your view on excluding coverage (from a network planning perspective) above a certain altitude?

- Frequency and spectrum assignment should be provided in flexible form mainly for UMTS where

- Table 1-5 shows an example. Concerning GSM the model provides the facility to consider dual band for GSM with first and second selection where in second selection remaining traffic from first selection overflows to second selection;

- For each POA/SeDi, the file specifies whether the operator has to consider any kind of frequency capacity restriction. Depending on the frequency reduction that the operator has to face, each POA/SeDi is classified to four categories (no restriction, low restriction, medium restriction, and high restriction) and must be provided separately for GSM and UMTS.

Table 1-3: Example for density thresholds for GSM and UMTS deployment

Case	Area type	GSM		UMTS	
		Lower threshold in pop./km^2	Upper threshold (pop./km^2)	Lower threshold (pop./km^2)	Upper threshold (pop./km^2)
UMTS dominant	Urban	---	---	1500	---
	Suburban	---	---	500	<1500
	Res./rural	100	<500	---	---
GSM dominant	Urban	1500	2000	>2000	---
	Suburban	500	<1500	---	---
	Res./rural	100	<500	---	---

Table 1-4: Example for the classification of the topography by slope values

Topographical attribute	Minimal slope value	Maximal slope value
Flat	0	2.5
Hilly	>2.5	7.5
Mountainous	>7.5	---

Question 4: What is your view on the relevant parameters as referred to in Tables 1-3 and 1-4?

Table 1-5: Example for a typical frequency and spectrum assignment in case of four operators[1]

Frequency Band	GSM Spectrum (MHz)	UMTS Spectrum (MHz)
800	Not Applicable	9.8
900	6.25	0
1800	16.25	0
2100	Not Applicable	15
2600	Not Applicable	0

1 Note that when GSM is considered in its classical band 900 and 1800 MHz, UMTS cannot use them without causing interference problems mainly in hybrid cells. Hence in case an operator wants to apply the favourable propagation in the MHz domain bandwidth in the 800 MHz domain, must be provided for UMTS. The model does not consider a re-assignation for GSM outside of 900 and 1800 as GSM is a bridge technology and will not any more be used under long term development.

Spectrum sharing among technologies on frequency bands below 1 GHz is not efficient from a network planning point of view. In case of the 900 MHz band and following the values in Table 1-5, spectrum sharing among 2G and 3G will result on only 6 available frequencies/ TRX per cluster due to the 5MHz UMTS blocks. This means that some typical frequency reuse patterns (for exameple K=7) are even not feasible. In case of reduced values of K, (for example K=3), There will be about 2 TRX per site, which can serve a maximum of 14 active users (Considering only a single slot for signalling). It seems not efficient to maintain all the 2G infrastructure for a so reduced capacity, that furthermore could be easily absorbed by the UMTS infrastructure.

Question 5:	Do you agree to our argument regarding spectrum sharing among technologies within the same frequency band or do you see other relevant considerations?

Depending on the input parameter for the selection of 2G or 3G and the application of hybrid cell sites, the following types of cells sites for EDGE and HSPA will follow:

- GSM/GPRS e.g. in rural areas where an operator does not expect strong data traffic
- GSM/EDGE e.g. in rural or suburban areas where significant data traffic occurs, but UMTS installation is not considered
- GSM/UMTS e.g. in suburban or urban areas where part of the traffic (mainly voice) should be handled by GSM
- UMTS e.g. in suburban or urban areas where sufficient data traffic justifies a pure UMTS deployment
- UMTS/HSPA e.g. in urban areas where users with new types of devices are expected to require high speed data services
- GSM/UMTS/HSPA like before but part of the traffic (mainly voice) is already handled by GSM.

Note that the objective of the cell deployment is to determine the number of network resources (sites, BTSs, TRXs for GSM and Nodes B for UMTS) required in a geographical district. Therefore the information about the POA/SeDi has to be adapted to derive these districts. The process for the conversion of the POA/SeDi with their related information into districts is quite complex. The RTR 2G/3G model provides these tasks as explained in the next section.

1.3 Scenario generator

The objective of the scenario generator is to adapt the raw input data on postal areas (POAs) or settlement districts (SeDis), as the case may be, to the requirements of network design to be carried out by the model. Its main task is to form districts with essentially homogeneous conditions, for which then cell deployment can be performed based on features that can be assumed to be the same within each district.

The starting point is a file containing the list of POA/SeDis with the relevant information, described in section 1.2, ordered according to density of population (urban, suburban and residential/rural POA/SeDis). Using these inputs, the module proceeds to join POA/SeDis which are geographical neighbours as expressed by the distances between their centres, see Table 1-6.

Table 1-6: Examples for the parameter values for forming districts[2]

Type of parameter value	Residential/rural	Suburban	Urban
User density (population./km^2)	>0	500	1000
Geographical distance between centres of areas (km)	10	8	5

Question 6:	What is your view on the relevant parameter values in Table 1-6 for Austria?

The aggregation procedure, shown in Figure 1-2, works as follows:

- The list of POA/SeDis is ordered in a way that urban POA/SeDis are at the top, suburban POA/SeDis are in the middle, and rural POA/SeDis are at the bottom;
- Within each class the POAS/SeDis are ordered according to population density;
- The algorithm starts with the POA/SeDi at the top of the list and in the following always selects the one of the remaining (not yet aggregated) POA/SeDis with the highest population density;
- Having so identified a POA/SeDi to which other suitable POA/SeDis are to be aggregated, the algorithm compares its population (working people and residents) density with given thresholds. If the density is above the maximum threshold it will

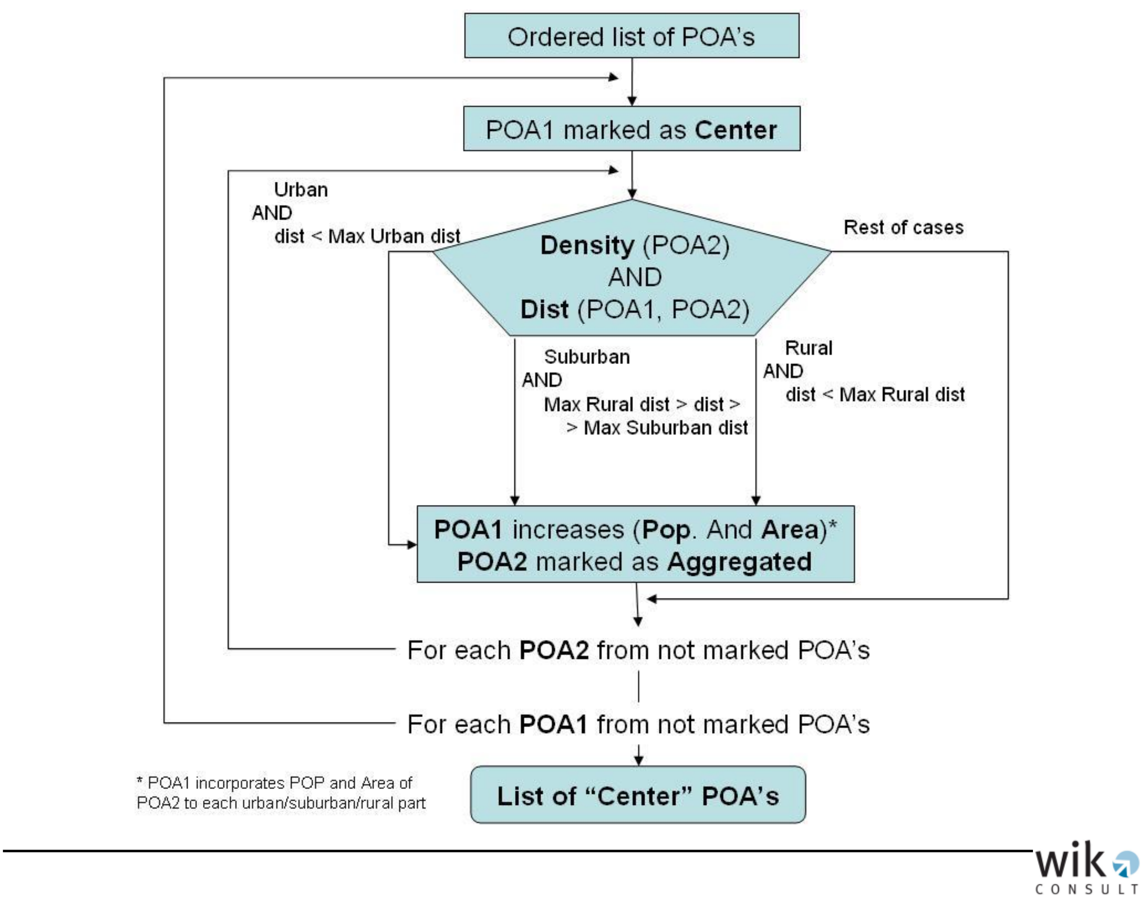
2 These values are always illustrative approximations. The relevant values for Austria still have to be determined. Tables 1-3 and 1-6 are correlated and have to be aligned.

use the maximum aggregation radius and aggregate all (not yet aggregated) POA/SeDis the centres of which are within this radius;

- If the density is between the middle and maximum thresholds, the algorithm will use the middle aggregation radius accordingly; and
- If it is between the minimum-middle thresholds, the algorithm will use the minimum aggregation radius.

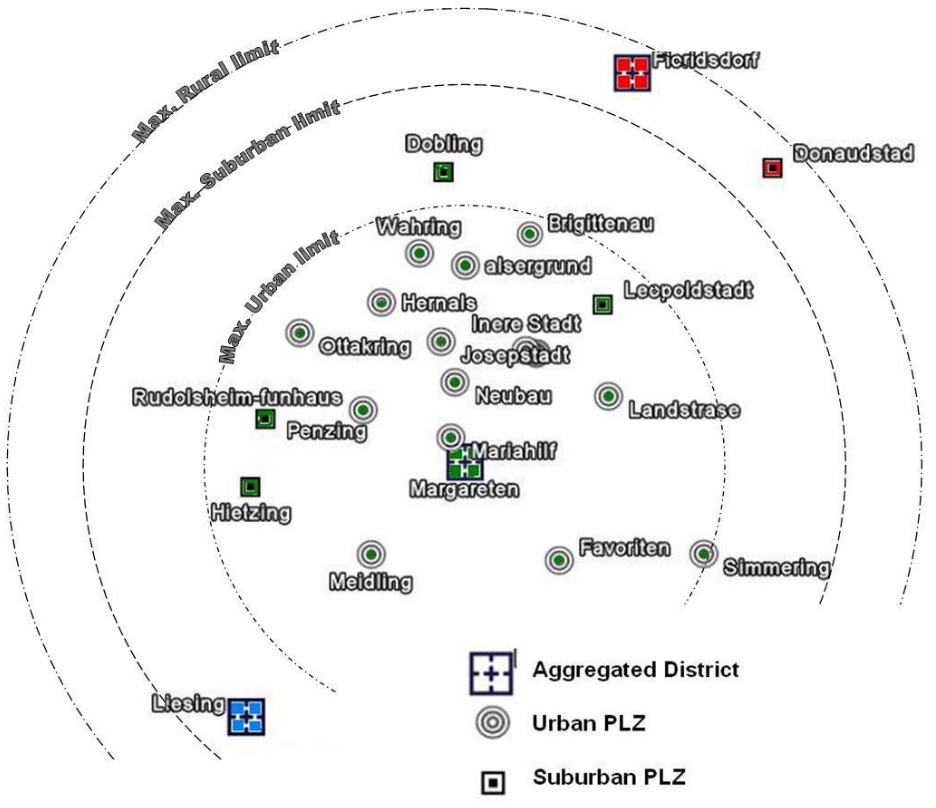
Carrying out the procedure in this order ensures that POA/SeDis to be aggregated are most likely of the same class as the aggregator POA/SeDi.

Figure 1-2: POA's aggregation procedure



Under this scheme the aggregation procedure results in the population of several POA/SeDis being aggregated to a kernel POA/SeDi (aggregator), which has been selected under the condition that its population density is higher than the remaining other ones, to form a district. Starting from the POA/SeDi with the highest population density, this process is repeated for all POA/SeDis. When a POA/SeDi is aggregated to a district it is marked to avoid it being aggregated with another POA/SeDi in future iterations of the algorithm. After each aggregation step, the algorithm stores any new district in the district list. Note that urban, suburban and rural areas are concepts associated to each SeDi (referred to by the central POA) depending on the POAs which are aggregated. Individual POAs only have one class assigned to them (urban, suburban or rural). Each POA which is aggregated increases the corresponding SeDis by its characterized population (urban, suburban or rural) and its characterized area (as urban, suburban or rural area). Figure 1-3 shows a practical example based on the city districts (corresponding to concrete POAs) of Vienna. District aggregation starts with an initial classification into urban, suburban and rural POAs, identifying the most important urban ones (greatest values of population density). In this case, accordingly with the maximum distances based restrictions, three aggregated districts appears: Margareten, Florisdorf and Liesing (in green, red and blue). The rest of the POAs are aggregated to them, mainly to the most important one (Margareten). The resulting SeDi includes 15 urban POAs (all of them are nearer to Magareten than the "urban" maximum distance) and 4 suburban POAs (all of them nearer to Margareten than the "suburban" maximum distance). Each aggregation then has its own distribution of classes depending on the type of included POAs. Note that Florisdorf (the second greatest density value) aggregates all the nearest POAs (following the same distance restrictions) from the rest of not aggregated POAs.

Figure 1-3: Example of a POA aggregation process applied to a limited region



Note that in using this procedure not all POA/SeDi's will be aggregated. There may be some large rural POAs/SeDis for instance which become districts by themselves because they are not aggregated due to not fulfilling the distance and/or density thresholds.

Following the resulting aggregation scenario, the decision regarding the cell types to be installed in the various SeDis can be taken, determining the type for each subarea (urban, suburban, rural) in each SeDi, using six identifiers with values as shown in Table 1-7, where the six types correspond to the cell types presented in chapter 1.2. The decision over the cell type is taken in a software module before the cell deployment is carried out.

Table 1-7: Preferred cell type technology identifiers

Cell type	Identifier	Related parameters
GSM/GPRS	1	GSM "up to" user threshold for each area type
GSM/EDGE	2	As type 1
UMTS	3	Upper to GSM and GSM/UMTS thresholds[3]
UMTS/HSPA	4	As type 3
GSM/UMTS	5	GSM/UMTS "up to" user threshold for each area type
GSM/UMTS/HSPA	6	As type 5

Note already here, that the scenario generator and the network design and dimensioning modules described in the next chapter require a large set of input parameters which all influence the result of the network modelling. Chapter 4 will show that these parameters are subdivided into two classes:

- Internal parameters the values of which are calibrated by the WIK and which are not visible at the user interface; and
- External parameters the values of which must be introduced into the model by the user of the model and hence are visible at the user interface.

Values of parameters are stored in data files and thus there will be both internal and external data files. As explained in chapter 4, each external data file is visible in

3 When in a specific arera the threshold value is higher than the one for GSM or GSM/UMTS automatically UMTS is applied and the unique condition between both thresholds is that the GSM/UMTS one must be higher than the GSM one. Threshold value examples appears in Table 1-3.

corresponding MS Excel worksheets while internal data files remain hidden for the regular model user[4].

The final working scenario is automatically obtained in accordance with the set of the established configuration parameters. Starting from the initial list of POAs, the result will be a new modified list containing all parameters required for the configuration of the network as provided in the following modules. During the configuration process, the Excel application allows to modify each parameter (between a list of “editable” ones[5]) individually. With these modifications, several scenarios are defined and they are available to be calculated (by the rest of the modules) individually or they define a set of sequentially executed scenarios. As an additional feature, sensitivity studies are provided. Modifications over concrete parameters include the definition of ranges of values or predefined lists of them. All the variations are included into the same set of resulting scenarios, being available for the rest of the modules[6].

Individual variations over editable parameters and sensitivity study are features included into the rest of the modules (solved one by one) but establishing the corresponding relationships between each modules inside the executions sequence.

1.4 Service description

Services in 2G/3G and in next generation mobile networks can be described at different levels. The highest level is the description of individual activities of the user in applying different applications which, at the end, defines common services categories. The lower level, at the physical layer, is defined by the physical services. As 2G and 3G networks are using different technologies in the radio access part, the description of the services has to be provided separately for both technologies.

This section provides the service description scheme for the 2G/3G model and is divided into two subsections, the first one describes the service categories and the

4 As discussed in Chapter 4, an experienced model user and expert in corresponding fields would be able to change also the internal parameter stored in internal data files and thereby recalibrate the model. For this purpose, WIK will provide internal documentation to RTR with corresponding data file descriptions.

5 All the global and generic parameters, not included into a “list of” are considered ”editable” and the sensitivity study would be possible, e.g. Urban density threshold. For the rest, e.g. a concrete POA density, directly over the files modifications would be recommended. Sensitivity is not considered in this case.

6 Note that for the sensitivity study a large number of scenarios might result and might cause a strong set of data files which even might overcome the space on the disks. Hence the user has to apply this facility under a strong responsibility. For the same reason the sensitivity analysis provides for each scenario only a variation in one parameter at each time. Thus, when a user considers the variation of two parameters in an interval of six steps e.g. 0,4 0,6, 08, 1,0, 1,2, 1,4, 1,6, 1,8 of the basis value 2*8=16 scenarios are generated and in case of three parameters 3*8=24 scenarios. If an automatic variation would have been provided for all combinations it would result in the example 8*8=64 combination and in case of three parameters 8*8*8= 504 combinations.

corresponding traffic classes for QoS considerations while the second one shows the characteristics of the corresponding GSM and UMTS bearer servers and their correlation with the service categories.

1.4.1 Service and service category description

A first description of services and its classification into a limited set of service categories were developed from the UMTS Forum and published in a corresponding paper[7]. The work was carried out by an Ad-Hoc Group of Traffic Characteristics of the Spectrum Aspects Group (SAG) inside the UMTS Forum, with the participation from operators as BT, O2, Telia-Sonera and vendors as Ericsson, Nokia or Siemens.

The final report considers the following general assumptions:

- Traffic Loads are based on forecasted traffic for 2010.
- The study is based on a West European representative country.
- Urban environment (where the majority of 3G traffic is expected to occur)
- Total Population: 60 million and a Workforce Population of 30 million.
- Maximum Mobile Penetration Rate: 90 %
- Maximum 3G Data Penetration Rate: 60 % of mobile subscribers.

The study analyses the service categories shown in Table 1-8[8].

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7 3G Offered Traffic Characteristics, Final Report, November 2003.

8 There is an additional service category, named Location Based Service. The 2G/3G model does not consider this last one due to the low bandwidth requirement and corresponding traffic.

Table 1-8: Service categories and description, source [UMTS-Forum-2003]

Service Category	Service Description	Market Segment
Mobile Intranet/Extranet Access	A business 3G service that provides secure mobile access to corporate Local Area Networks (LANs), Virtual Private Networks (VPNs), and the Internet.	Business
Customised Infotainment	A consumer 3G service that provides device-independent access to personalised content anywhere, anytime via structured-access mechanisms based on mobile portals.	Consumer
Multimedia Messaging Service (MMS)	A consumer or business 3G service, that offers non-real-time, multimedia messaging with always-on capabilities allowing the provision of instant messaging. Targeted at closed user groups that can be services provider- or user-defined. MMS also includes machine-to-machine telemetry services.	Consumer
Mobile Internet Access	A 3G service that offers mobile access to full fixed ISP services with near-wireline transmission quality and functionality. It includes full Web access to the Internet as well as file transfer, email, and streaming video/audio capability.	Consumer
Simple Voice and Rich Voice	A 3G service that is real-time and two-way. Simple Voice provides traditional voice services including mobile voice features (such as operator services, directory assistance and roaming). Rich Voice provides advanced voice capabilities (such as voice over IP (VoIP), voice-activated net access, and Web-initiated voice calls, and mobile videophone and voice enriched with multimedia communications.	Consumer and Business

The UMTS Forum considers for each service category a set of applications. Table 1-9 shows the mapping of the applications to the corresponding service category.

Table 1-9: Applications and its mapping to corresponding UMTS service categories

	Mobile Intranet/ ExtraNet Access	**Customized Infotainment**	**Mobile Internet Access**	**Multimedia Messaging Service (MMS)**	**Rich voice and video**	**Simple voice and video**	**Location-Based Services**
Type of user	B	C	C	C	B	B/C	B/C
Email Management	x	x	x				
Video/Audio Streaming	x	x	x				
Info Search	x						
File Download Upload	x						
Intra/Extra Web Browsing	x						
Portal Browsing/Shopping		x	x				
Mobile Gaming		x	x				
Music Video Download		x	x				
MMS				x			
Real time voice service					x	x	
Real time video service					x	x	
LBS Advertising							x
Navigation							x
Personal Tracking							x
Telematics							x
Fleet Tracking							x

In addition the UMTS Forum provides a set of attributes for the service categories and corresponding applications which are:

- Sessions per month / Service
- Percentage of Origin/ Destination (M2M, M2F, F2M)

- Uplink Downlink ratio.
- File size Uplink/Downlink (Kbytes)
- Busy Hour traffic percentage

The 2G/3G model takes these applications and service categories as a starting point but updates the service category definition to be coherent with current schemes, as shown in Table 1-10. This allows, as it will be shown later in this section, an easier mapping to corresponding traffic classes for QoS.

Table 1-10: Service categories used in the 2G/3G model

Service	Description
Real Time Voice	Two way voice service communication between two people
Other Real Time	Aggregated traffic of other real time services such as Rich Voice, Videoconference, Multimedia, and even Real Time Gaming
Streaming	Video Streaming, typically from servers located in external networks.
Business Data	Data communications with stringent requirements in terms of QoS, (Delay and Jitter, PER) as VPN, Intranet Communications.
Best Effort Mobile Interconnection	Data communications with low QoS constraints accessing external services, Web Services, Shopping, external e-mail.
Best Effort Mobile Provider	Data communications with low QoS constraints accessing services provided by the mobile operator by means of mobile portals.

The relation among application services defined by the UMTS Forum and those considered in the model are shown in Table 1-12, using the colour encoding shown in Table 1-11.

Table 1-11: Color encoding used in Table 1-11.

Service in the model	Color
Real Time Voice	
Other Real Time	
Streaming	
Business Data	
Best Effort Mobile Interconnection	
Best Effort Mobile Provider	

Table 1-12: Relation among the service categories defined by the UMTS Forum and those considered in the model.

UMTS Service Category	Application Services	Model Services
Mobile Intranet/Extranet Access	E-Mail Management	Business Data
	Video / Audio Streaming	
	Info Search	
	File Download / Upload	
	Intra-Extra, or Web	
Customised Infotainment	Email Management	Best Effort Mobile Provision
	Video/Audio Streaming	Streaming
	Portal Browsing / Shopping	Best Effort Mobile Provision
	Multimedia Download	Best Effort Mobile Provision
	Mobile Games	Other Real Time
Multimedia Messaging Service (MMS)	MMS	Best Effort Mobile Provision
Mobile Internet Access	Email Management	Best Effort Mobile Interconnection
	Video/Audio Streaming	Streaming
	Web Browsing / Shopping	Best Effort Mobile Interconnection
	Multimedia Download	Best Effort Mobile Interconnection
	Mobile Games	Other Real Time
Rich Voice	Low Resolution Video or multimedia (C)	Other Real Time
	Video Only (C)	Other Real Time
	Video Only (B)	Other Real Time
	Multimedia Video Conference (B)	Other Real Time
SimpleVoice	Voice Business	Real Time Voice
	Voice Customer	Real Time Voice

Question 7: Which service categorisation do you use for network planning purposes?

For each of these service categories the characteristic values of corresponding connections have to be estimated; these are:

- Average bandwidth upstream (mBu) and downstream (mBd)
- Average length of packets upstream (mLu) and downstream (mLd)

- Average duration of the service
- Source- destination relation with:
  - mobile to mobile (M2M)
  - mobile to fixed (M2F)
  - fixed to mobile (F2M)
  - mobile to a server outside of the considered network (M2ICP)
- mobile to a server inside of the network (M2MobServ)
- Mapping to a corresponding traffic class for QoS differentiation

The values of the characteristics of each service category are an input to the model. They must be provided by the user. Table 1-13 shows some values solely for illustrative purposes.

Table 1-13: Example for the service category characteristics.

service characteristics	mBu	mBd	mLu	mLd	dur min	M2M	M2F	F2M	M2ICIP	M2MobSer	QoS class
dimension	kbps	kbps	bytes	bytes	min						
real time voice	7.8	7.8	25	25	3,000	0.4	0.3	0.3	0	0	1
other real time serv.	64	64	100	100	4,000	0	0.8	0.2	0	0	1
streaming to content serv	1	64	3.0	256	5,000	0	0	0	0.7	0.3	2
guaranteed data with bus server	1	9.6	30	256	1,000	0	0	0	0.9	0.1	3
best effort to general server	1	9.6	30	256	3,000	0	0	0	0.6	0.4	4
SMS	9.6	0	100		0.001	0	0	0	0	1	4
MMS	64	0	1000		0.002	0	0	0	0	1	4
Mobile Broadband Access	7,200	14,400	256	256	0.5	0	0	0	0.4	0.6	4

Question 8:	Does the above service categorization cover your service portfolio? If not, what services are missing here? Please provide the relevant information. Mobile broadband acces is defined as an stand alone category in order to cover the fixed-like and nomadic broadban access. Do you agree with this?

Finally the use of the service categories must be associated to the corresponding mobile users. For this purpose the 2G/3G model considers three types of users:

- Business
- Premium User
- Standard User

The corresponding values for the traffic matrix between user types and service categories are also an input to the tool. Table 1-14 shows an example only for demonstration purposes.

Table 1-14: Example for traffic values per user type corresponding to each service

Service and traffic/user	**Relative traffic portion per user for GSM in case of hybrid cell sites**	**BH traffic values per user in Erlang or nº of messages**		
		Business	Premium	Standard
real time voice	0.8	0.05	0.005	0.006
other real time services	0	0.01	0.0025	0
streaming to content services	0	0	0.005	0
guaranteed data with business server	0	0.002	0	0
best effort to general server	0	0.001	0.01	0.002
SMS	0	0.1	0.05	0.01
MMS	0	0.01	0.02	0
Mobile Broadband Access	0	0.01	0.005	0

It is important to note that hybrid sites consist of 2G and 3G equipment. 3G technology is much more efficient to deal with data traffic than 2G technology. Following this, the ratio for data services in Table 1-14 that has to be handled by 2G technology on hybrid sites is 0. This is consistent with the six site categories defined in section 1.2

Please note that the user profile distribution may change among the different area types. Therefore it is also required to introduce the percentages over the whole population of the area (urban, suburban and rural), of the different profiles. Table 1-15 shows an example to illustrate this concept. The real values depend on the characteristics of the country to be modelled.

Table 1-15: Example for the shares of user types

User type	rural	suburban	urban
Business user	0.025	0.075	0.100
Premium user	0.050	0.100	0.200
Standard user	0.925	0.825	0.700

Based on the traffic values in relation to the service categories and user types the 2G/3G model calculates for each district the aggregated traffic to be considered in the cell deployment and the dimensioning of the higher network levels. Table 1-16 shows an illustrative example for a virtual district considering a mobile penetration of 125% and a market share of 40%.

Table 1-16: Example for the aggregated traffic values per area in a fictive district

Description	Values			
mobile penetration	1.25			
market share	0.4			
area type	rural	suburban	urban	total-district
total nº of inhabitants	1000	10000	50000	61000
business user	12.5	375	2500	2888
premium user	25	500	5000	5525
standard user	462.5	4125	17500	22088
traffic per service BH-Erlang				
real time voice	3.525	46.000	255.000	304.525
other real time serv.	0.188	5.000	37.500	42.688
streaming to content serv	0.125	2.500	25.000	27.625
guaranteed data with business server	0.025	0.750	5.000	5.775
best effort to general server	1.188	13.625	87.500	102.313
SMS in Erlang	0.0002	0.0024	0.0156	0.018
MMS in Erlang	0,0000	0,0005	0,0043	0.005

1.4.2 Bearer service description for 2G/3G cell deployment

This section describes the particularities when considering the cell deployment concerning corresponding bearer services. This is mainly important for the UMTS cell deployment due to the WCDMA access technology while GSM/GPRS services/applications have to be mapped to a number of slots as bearer. This section shows in the first part the corresponding mapping for UMTS, in the second one for GSM and in the third one for Mobile Broadband Access.

1.4.2.1 Consideration about UMTS service mapping

The traffic of each service category resulting from the service categories definition exposed in the last section has to be mapped into one of a corresponding values of the UMTS bearer level resulting in corresponding physical services. Each of these physical services are defined by a set of attributes closely related to the network design. The main parameters are:

Average bitrate at the physical level

- Eb/No required in UL and DL
- Activity factor
- Blocking probability.

Based on the service categories and their corresponding parameters of the mobile network operator in question, the model will transform values of the service categories into corresponding physical services using the appropriate parameters to conduct the network dimensioning. Table 1-17 shows the values resulting from the service categories shown in table 1-13.

Table 1-17: Parameter values for the bearer service in WCDMA for the UMTS cell deployment

Service	UMTS BS/Radio Access Bearer	Binary Rate	Profile	Eb/No (UL)	Eb/No (DL)	Activity Factor	Ratio in HSPA
Real Time Voice	Conversational, AMR Speech Voice (Circuit Switched)	12.2	Static	3.1	4.6	0.67	0.2
		12.2	Multipath	4.5	6.7	0.67	
Other Real Time	Conversational (Circuit Switched and Packet Switched)	128	Static	0.3	2.7	1	0.5
		128	Multipath	1.5	5.3	1	
Streaming	Streaming (Packet Switched)	64	Static	0.3	2.6	1	0.8
		64	Multipath	2	5.3	1	
Guaranteed Data	Background (Packet Switched)	<384	Static	0.3	2.3	1	0.8
		<384	Multipath	3	5.2	1	
B.E. General Server	Interactive or Background (Packet Switched)	<384	Static	0.3	2.3	1	0.8
		<384	Multipath	3	5.2	1	
SMS / MMS	Interactive or Background (Packet Switched)	64	Static	0.3	2.6	1	0.2
		64	Multipath	2	5.3	1	

Question 9: Do you agree with the physical parameters (in terms of Binary Rate Eb/No, propagation profile/Voice codecs) described in the above table for the service categories included there?
If not, please provice a detailed list of the physical services, with the corresponding parameters, used for your network deployment.

Question 10: Services like videotelephony and circuit switched fax/modem are included in the Other Real Time category. Do you agree with this?

Question 11:	Are you planning to deploy HSPA/HSPA+ in all Nodes B (UMTS)? Is this currently the case? If not, please specify the conditions for the joint deployment (population density, area, traffic per user). Please specify the ratio of 3G data services which runs over native UMTS and over HSPA (or HSPA+).

Question 12:	Can you confirm the parameter values in Table 1-17?

The last line of Table 1-13 shows the Mobile Broadband Service category. The model considers that this service is 3G native and will only run over High Speed Packet Access technology. This issue is handle later on, in section 1.4.2.3. Additionally in the sites where HSPA is available, part of the UMTS native traffic may run over the HSPA physical service. The last column of Table 1-17 shows an example.

1.4.2.2 Considerations on BTS service mapping

Data services over 2nd Generation mobile systems are provided using two different technologies, circuit switching or packet switching. Concerning circuit switching technologies it is possible to use two different systems

- Modem Technology with a single slot, 14.4 Kbps.
- High Speed Circuit Switched Data with a variable number of slots, from 1 to 4 with 14.4 Kbps per slot which implies a maximum binary ratio of 57.6 Kbps.

Typical transmission techniques on packet switching in 2nd Generation mobile networks are:

1. General Packet Radio System (GPRS): This is an upgrade of GSM to provide data services. The binary rate in UL and DL depends on the Coding Scheme (CS) and the Multi Slot Class (MS) of the user terminal. Using the highest coding scheme (20 Kbps) and the multi slot class 10, which means 4 slots DL and 1 UL, the GPRS data rate is 80 kbps DL and 20 Kbps UL
2. Enhanced Data Rate for GSM Evolution (EDGE). This is a mobile technology that allows improved data transmission on top of GSM. The binary rate depends again on the coding and modulation scheme (MCS)

and the multislot class (MS) terminal. Using the highest coding, MCS-9 and the multi slot class 10, 4+1, it is possible to reach 236.8 kbps DL and 59.2 UL.

In order to establish a consistent service briefcase, the model will use the same service category, with some minor modifications, in order to consider circuit switched services. Table 1-18 shows the characteristic values and an example for its application in the corresponding areas assuming that EDGE is installed only in urban areas and hence GPRS is applied in suburban and rural areas.

Table 1-18: Characteristic values for the service categories in areas where 2G technology is applied (for asymmetric services, X/Y indicates the up- and download value)

Service	Technology	Slots	Vb (UL)	Vb (DL)
Real Time Voice	GSM	1	-	-
Other Real Time	GPRS	1 / 4	20	80
	EDGE	1 / 4	59.2	236.8
Streaming	GPRS	1 / 4	20	80
	EDGE	1 / 4	59.2	236.8
Guaranteed Data with Business Server	GPRS	1 / 4	20	80
	EDGE	1 / 4	59.2	236.8
B.E. General Server	GPRS	1 / 4	20	80
	EDGE	1 / 4	59.2	236.8
SMS/MMS	GPRS	1	20	20
HSCSD	GSM	4	57.6	57.6
Modem	GSM	1	14.4	14.4

Question 13: In the model, we consider EDGE as the top 2G technology because new deployments will be based on 3G. However, have you planned to deploy Evolved EDGE?
If yes, in which areas (urban/suburban/rural)? Please describe as deeply as possible the determinants for this deployment (data traffic per user, population density).

Question 14: Can you confirm the parameter values in Table 1-18?

1.4.2.3 Considerations on Mobile Broadband Access

Currently there is an important trend to substitute the fixed broadband access by mobile broadband access for a relevant user community. This is possible due to the evolution of the 3G technology by means of the different technologies specified in different releases of the 3GPP, from Release 5 to Release 8. The main use of these technologies is to provide broadband access in a similar way as xDSL or cable. Therefore these users can not be considered completely “mobile users” but “nomadic users” because they can change the location access, but, typically they are not moving while using the broadband service. Please note, that the main terminal for this access is a laptop or smart terminal, and the applications running over them, are not very compatible with a continuous movement (unless the user is on a train or similar transport option).

As it was mentioned above, this High Speed Mobile Broadband Access can be implemented using different technologies that are specified below.

- High Speed Downlink Packet Access (HSDPA). This technology was firstly introduced in the Release 5 specification (R5) of the 3GPP. It can reach a maximum of 14.4 Mbps in the downlink, using 15 multicodes and 16 QAM modulation. However, currently most advanced terminals only can reach a maximum binary rate of 7.2 Mbps.

- High Speed Uplink Packet Access (HSUPA), originally named Enhanced Uplink by the 3GPP. This technology was introduced in the Release 6 specification. With Category 6 terminals it can reach up to 5.7 Mbps.

- High Speed Packet Access (HSPA) can be considered as the generic name for the two above technologies.

- Evolved High Speed Packet Access (HSPA+). This technology was introduced in the release 7 of the 3GPP. The binary rates may reach 21.6 Mbps in Downlink with 64 QAM and 11.5 Mbps in the UL with 16 QAM. With 2x2 MIMO technologies it may rise to 28 Mbps or 42 Mbps, depending on the modulation.

Please note that the binary rates indicated above are peak rates which only apply under specific conditions with a strongly reduced number of users and under reception with a very high Signal to Noise Ratio. This implies that the users have to be closeby to the Node B site, which limits the performance of this technology.

As the HSPA and HSPA+ users are not mobile but nomadic, and as they can be seen as users applying a fixed-like broadband radio access technology, the model will consider a guaranteed binary rate per user to perform the deployment and network design. In this way, all users in the coverage area of the Node B will have, at least, the binary rate specified. Table 1-19 shows some tentative values for demonstration purposes. The real values must be specified by the model user as an input data.

Table 1-19: Input values for modelling the HSPA service

Guaranteed Binary Rate	Mobile Service Penetration	Market Share	Mobile Broadband Penetration
1 Mpbs	125	0.4	0.1

It is important to note that an increase of the guaranteed binary rate implies an increase of the Signal to Noise Ratio of the High Speed Downlink Shared (SINR) channel, and therefore a decrease in the coverage area of the corresponding Node B considering HSPA equipment for providing HSPA services in the corresponding area. Table 1-20 shows an illustrative example of resulting bitrates and required signal noise rates.

Table 1-20: Example of parameters for two HSPA configurations.

Modulation	**Instantaneous Single User Data Rate with 1 HS_PDSCH Code**	**SINR Required (BLER) 0.1**	**Extrapolation to 5 Codes**
QPSK	188.5	0.5 dB	1.8 Mbps
16 QAM	741.5	12	14. Mpbs

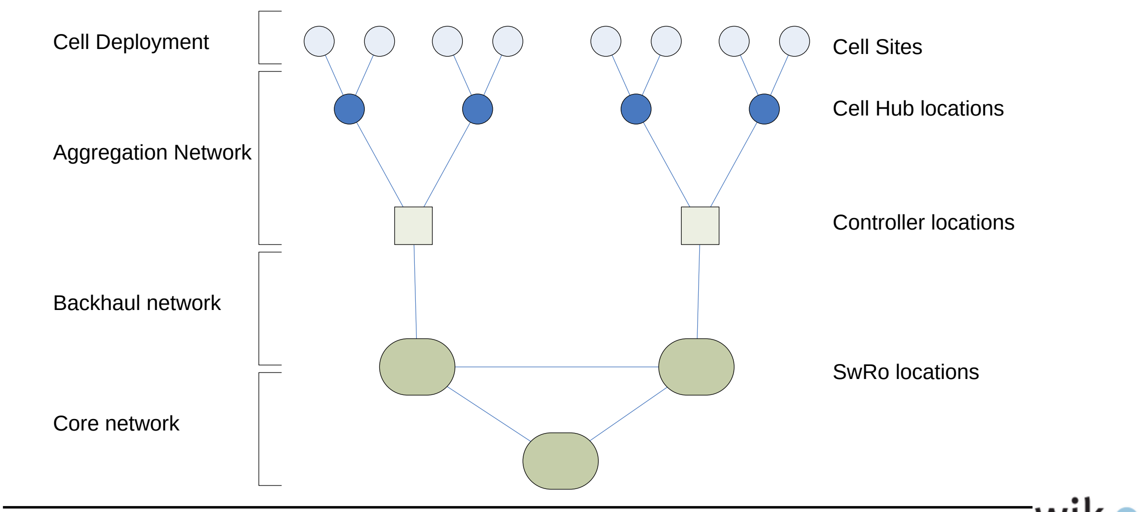
Question 15: What is your view on the modelling approach towards HSPA/Mobile Broadband Access?

2 Network design and dimensioning

The network design and dimensioning for the RTR 2G/3G model is provided for each network part, see Figure 2-1 and hence this chapter is subdivided into the following sections:

- Cell deployment separately for GSM and UMTS,
- Aggregation network design and dimensioning,
- Backhaul network design and dimensioning, and
- Core network design and dimensioning.

Figure 2-1: RTR 2G/3G model network diagram



The basis for the network design is provided by the scenario generator through the creation of the district. For the cell site, the model does not determine its exact geographical location but an equilibrated distribution in the corresponding zones (urban, suburban, and rural). The model considers in the central point of each district the installation of equipment serving as hub aggregator. This cell hub aggregator connects downstream in the hierarchy with the different cell sites and upstream with aggregator equipment situated in the controller node location. This repeats for the controller node locations where the controller node aggregator connects the different equipment situated at the location of BSC and RNC and provides the connections upstream to the core node locations.

The network design provides first the cell deployment based on the districts generator and the cell types in the areas of each district, both determined by the scenario generator. Following the determination of the cell deployment, the traffic load and the corresponding bandwidth values are calculated for each cell hub location. The model selects from these cell hub locations a subset where the controller nodes are installed and assigns each cell hub location to one of the controller node locations. This is repeated for determining the core node locations. Note that the model allows that the number of controller node locations is the same as for the core node locations; as a consequence the controller node equipment is in this case installed in the core node location in common with the corresponding core node location.

From the above follows that the traffic demand is routed hierarchically from the user equipment over all location types up to the core location where it is distributed in the direction of the destination. The traffic load in the different equipments and on the hierarchical connections determines the required bandwidth to be handled by the equipments in the nodes and transmitted over the connections.

The hierarchical star structure of the connections and the bandwidth aggregated on each connection determines the so-called logical structure. As the traffic is sent strongly over the hierarchy, no layer 3 routing equipment is required but only layer 2 switching equipment. For the dimensioning of this equipment, the model provides a generic description indicating the driver which determines the type and number to be installed. Hence different type of layer 2 equipments can be modelled by providing corresponding values for the maximal capacity for each driver. We estimate that the current layer 2 equipment is based on Ethernet technology and that the traffic demand requires signal groups in the range of 10 Mbps up to10Gbps.

This chapter describes the network design and dimensioning in a separate section for each network level. Hence section 2.1 describes the cell deployment, section 2.2 the aggregation network ranging from the cell sites locations up to the controller location. Section 2.3 describes the dimensioning of the controller nodes and the connections to the core node locations, and the core network design is describes in section 2.4. Section 2.5 is a summary of the topology and transmission technology as well as the redundancy concepts.

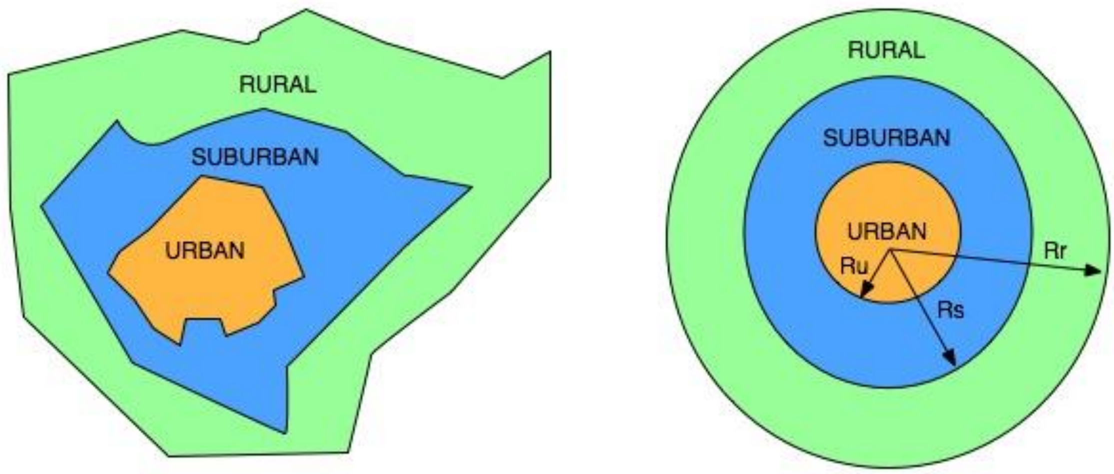
2.1 Cell deployment

The cell deployment is the first and the fundamental step in the design and dimensioning of any mobile network. It is based on the geographical locations of population centers (cities, towns etc) and the different services implemented by the operator. Cell deployment is concerned with the determination of the sites, the type of BTS (2G), including its number of sectors and TRX’s, and the type of nodes B (3G) and their number of sectors to be installed, over all the various districts provided by the scenario generator. For this purpose the module will use the data about the cities, towns and villages stored in the file for the districts, obtained from the scenario creator, and the traffic volumes of the different GSM and UMTS services demanded by the users.

The term "district" may refer to a division of a city (consisting of multiple districts), town or a small rural centre. For determining the cell areas, the module introduces the concept of an equivalent area where the whole district surface is mapped into an equivalent surface in form of a circle consisting of a kernel and two rings with its centre situated in the same geographical point as the centre of the real district formed from its constituting POA/SeDis and is calculated by corresponding basic formulas resulting from analytical geometry.

This subdivision of the district into a maximum of three areas – urban, suburban and rural – is based on the assumption that the user density and the other characteristics are homogeneous within each area, see Figure 2-2. As a consequence, the site configuration (cell range and capacity) in each area is the same and the output of this part of the model consists of a maximum of three site configurations for each district. The number of sites for each area is then obtained by dividing the size of the area by the size covered by a single site either by GSM or UMTS and, in case of hybrid areas, by both. The actual number of sites in an area is then the maximum of either the number of 3G or the number of 2G sites, whichever is higher. The technology with the lower number of sites will be accommodated on sites already reserved for the other technology.

Figure 2-2: Approximation of the District in the RTR 2G/3G model



The RTR model is a hybrid 2G/3G LRIC model and takes into account four network configurations with different options of combining 2G and 3G technology which are explained in section 1.1 and summarised in Table 1-2.

The main parameters required for each district for performing the cell deployment are directly obtained as output of the Scenario Generator module. These are as follows:

- Total number of inhabitants,
- Total geographical extension (km^2) / radius of the extension (km),
- Geographical coordinates of the district (central point)
- Type of topography classified into three categories, flat, hilly, mountainous,
- Classifications by user density (urban, suburban and rural) and district topography (flat, hilly, mountainous),
- Percentage of the geographical extension for each zone (urban, suburban and rural) in the district,
- Percentage of the inhabitants for each zone (urban, suburban and rural) in the District.
- Type of deployment 2G/3G (pure 2G or pure 3G or hybrid) for each area in the district resulting from the selected option of Table 1-2.

All these parameters are based on the input parameters for the scenario generation, mainly based on the lists of the POAs and the national roads. As shown in section 1.3, the district list is generated on the basis of the aggregation parameters and the individual characteristics of these POAs.

For each area in all districts considered, the cell deployment module will perform a 2G and a 3G deployment, implementing either pure areas or a combination of both in case of hybrid areas, depending on the option specified by the user.

2.1.1 Cell deployment for 2G GSM

For each area in a district where a GSM deployment is going to be performed, the first calculation relates to the first band radius by propagation and traffic limits[9]. Depending

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9 The frequency and the spectrum of the first and second band is provided by corresponding input parameters in the scenario generator. If an operator gets spectrum on 900 Mhz and 1800 MHz, he will use 900 for the first band and 1800 for the second one while single band operators get assigned spectrum either 900 or 1800 MHz frequencies.

on the parameters of the BTSs[10], and the characteristics of the area under study, the model will select the most suitable one, in terms of power, sectors, number of TRX and other parameters. The main parameters of the BTS are

- Type of BTS: Macrocell, microcell, picocell
- Transmission power
- Transmitter / Receiver antenna gain
- Number of sectors
- Number of TRX per sector
- Average number of signalling traffic
- Number of slots reserved for handover.
- Reception sensibility and Noise Figure
- Cost of the site
- Cost of the equipment per sector

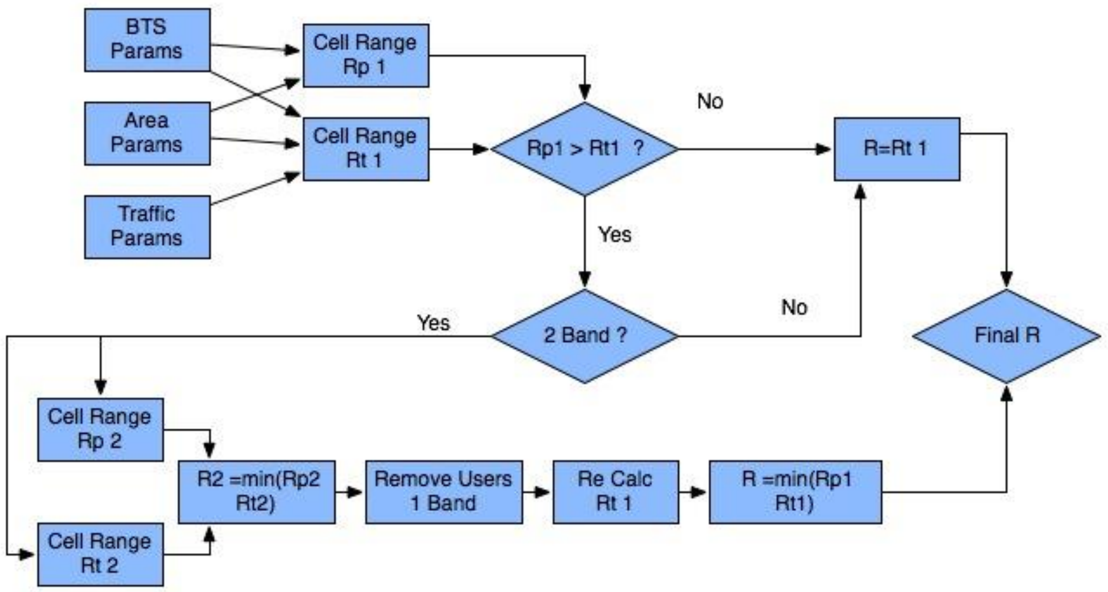
Note that if the BTS is traffic driven, sectoring will result in a larger cell range. If the resulting propagation radius is less than the traffic radius, the deployment has found a solution in the smaller radius. If the propagation radius is larger than the traffic radius, the process continues. Now the model checks whether the second band is available for the network deployment. If not, the cell is traffic driven and hence the cell range is the radius calculated by traffic. Otherwise, the model considers that a second band BTS is installed at the same site and hence the model has to calculate its cell range using the same methods as in the case of the first band including sectoring if possible. Please note that the model tries to optimize the deployment and therefore it will try to use the lowest possible frequency band that is the one with better propagation conditions. Then, the minimum value of the radius (either traffic or propagation radius) is chosen as the final one for the second band BTS. With this radius, the model calculates the equivalent population served by the second band BTS. Obviously, this process causes a reduction of the population that has to be served by the first band BTS. Then the traffic radius for the remaining population in the first band is calculated. The program selects between the traffic radius and the propagation radius of the first band previously calculated. Note that this value (the most restrictive one in the lower band) will be used for the calculation of the number of sites in the corresponding zone of the district. It is important

10 The number of possible sectors and other BTS related parameters are specified in an internal data file used as an input to the Cell Deployment Scenario.

to consider that the model provides the cell radius calculation for propagation and traffic separately because in 2G GSM the amount of traffic does not critically influence propagation, in contrast to the 3G UMTS cell radius calculation as outlined in the next section. Figure 2-3 provides a schematic view for the 2G GSM cell radius calculation.

Having conducted this process, the area covered by a single site is calculated by means of the cell radius. Thereafter, the minimum number of sites required to provide coverage in the specific area is calculated dividing the total surface of the area by the surface covered by the site. By means of a prioritizing factor, the cost of each possible solution (BTS configuration on 1st and 2nd band for 2G,) is calculated, and the minimum one is selected[11]. This process is repeated for each area in a given district. Therefore at the end of the cell deployment process the model provides the optimum configuration at the nationwide level and the corresponding information on traffic, types and numbers of items of equipment.

Figure 2-3: Global scheme for the cell radius dimensioning process in 2G GSM cells



11 These prioritizing factors depends on the cost of corresponding BTS or Node B equipment forms an internal data set and are calibrated when the corresponding cost are determined.

In 2G Cell Deployment there are some particularities that have to be considered:

- Macrocell layer: In the urban areas it is a typical practice to place some big BTS in order to enhance the coverage and to provide additional capacity. These BTS are usually known as "umbrella" cells. The RTR-2G/3G model considers this aspect optionally by the inclusion of an additional macrocell layer in the urban environment. The BTS of this layer will be propagation driven and will use only one single band. Hence the traffic not coverd by this macrocell, is considered by using the deployment procedure described above.

- Picocell increment: In dense urban areas and in some relevant points like airports, large malls or business centres, there may be shadow areas (where there is an important lack of radio signal due, for example, to tall skyscrapers) The model considers this effect by means of an increment factor, given as an internal input parameter, applied in case of urban areas where picocells are used; hence the total amount is increased by this factor. In case that this option is not used, the increment factor is fixed to one.

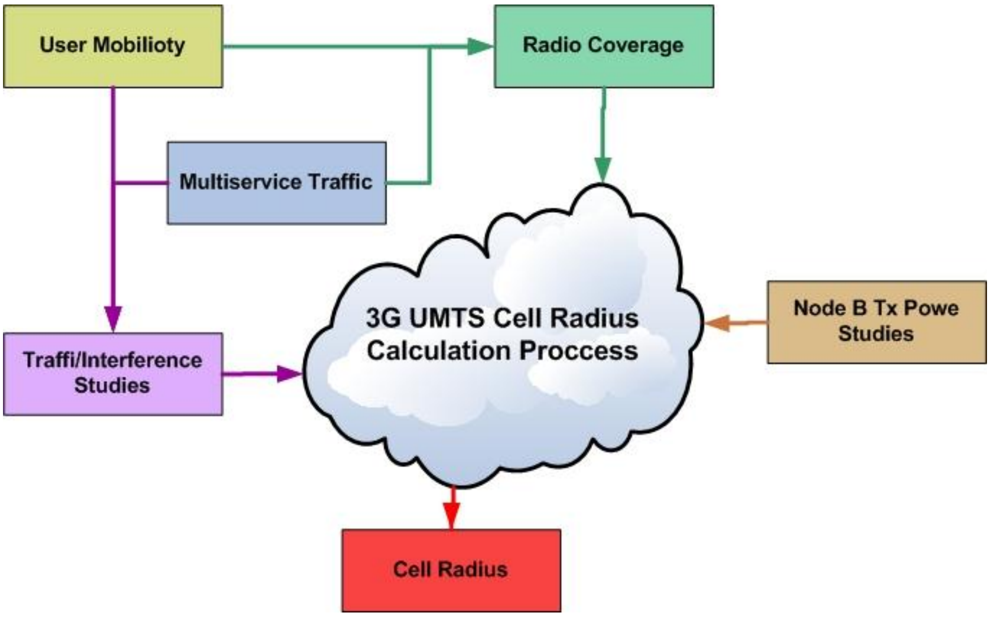
2.1.2 Cell deployment for 3G UMTS

The cell deployment assigns the optimum Node B configuration from a set of possible nodes B, specified as an input to the model, for each specific area of the district and for the set of physical services that are derived from the mobile network operator's set of user applications. The main values of the Node B parameters are

- Type of Node B: Macrocell, microcell, picocell
- Transmission power
- Transmitter / Receiver antenna gain
- Number of sectors.
- Maximum Interference Margin accepted
- Reception sensibility and Noise Figure
- Cost of the site
- Cost of the equipment per sector

In the optimization process, the model calculates the cell range of the Nodes B for each district included in the scenario, considering that the 3G UMTS systems are based on WCDMA. These are soft blocking systems where the number of users is not strictly limited by the amount of hardware in the Node B, as it is the case in 2G, but by the interference generated by their own users, and the users in neighbouring cells. The maximum interference allowed in the system can be measured by a parameter referred to as interference margin, which is used in the calculation of the link budget in the coverage planning process, and also in the calculation of the maximum number of users in the capacity planning process. Note that there is an interdependence between the capacity and coverage planning processes in this case. Figure 2-4 represents the different issues that have an influence in the 3G cell radius dimensioning process.

Figure 2-4: Global scheme for the cell radius dimensioning process in 3G UMTS cells



In the dimensioning process a very relevant parameter is the available bandwidth. Note that UMTS/WCDMA works with 5MHz spectrum blocks. The number of these blocks allocated to the operator determines the type of algorithm the model is going to apply,

1. In case of a single frequency block, the model uses an algorithm which optimizes the deployment of finding the most suitable interference margin that balances radio propagation and coverage.

2. In case of several frequency blocks, and given the interference margin as an input parameter, the model optimizes the use of each site by installing as much equipment as required for the different frequency blocks.

2.1.2.1 Procedure to calculate the cell radius with a single 5 MHz frequency block

The RTR 2G/3G model applies a multiservice optimization algorithm[12] which maximizes the Node B range for a given service and propagation scenario. The algorithm is oriented to the provision of all services with the specified GoS, expressed by a corresponding blocking probability, in the whole area covered by the node B[13].

The complete task of calculating the cell radius can be divided into two sub-problems

- The *outer problem*, which finds the optimum value of the interference margin (MI) to balance the radius by propagation coverage and capacity.
- The *inner problem*, which finds the optimum allocation of capacity to each physical service defined in the scenario.

A general flow diagram of these problems can be seen in Figure 2-5

The outer problem is solved just by making an iterative process to equilibrate the value of the cell radius between the resulting value calculated by propagation studies and the resulting one calculated by capacity studies. This is done by means of increasing the value of the interference margin, Mi, when the cell radius by propagation is higher than by capacity or vice versa.

The inner problem is much more complicated because it implies the use of the traffic concepts and a non-linear process. In order to guarantee that all users of all services are served in the coverage area, the cell radius by capacity will be the most restrictive one among the calculated cell radius per service. It is important to remark that this value depends on capacity/load assignment for each service category considered. A sub-optimal load assignment will lead to large differences in the calculated radius per service and therefore a non-optimal final cell radius by traffic load Rt. Therefore, the problem of finding the optimal cell range by traffic becomes a optimization problem over the load assignment per service.

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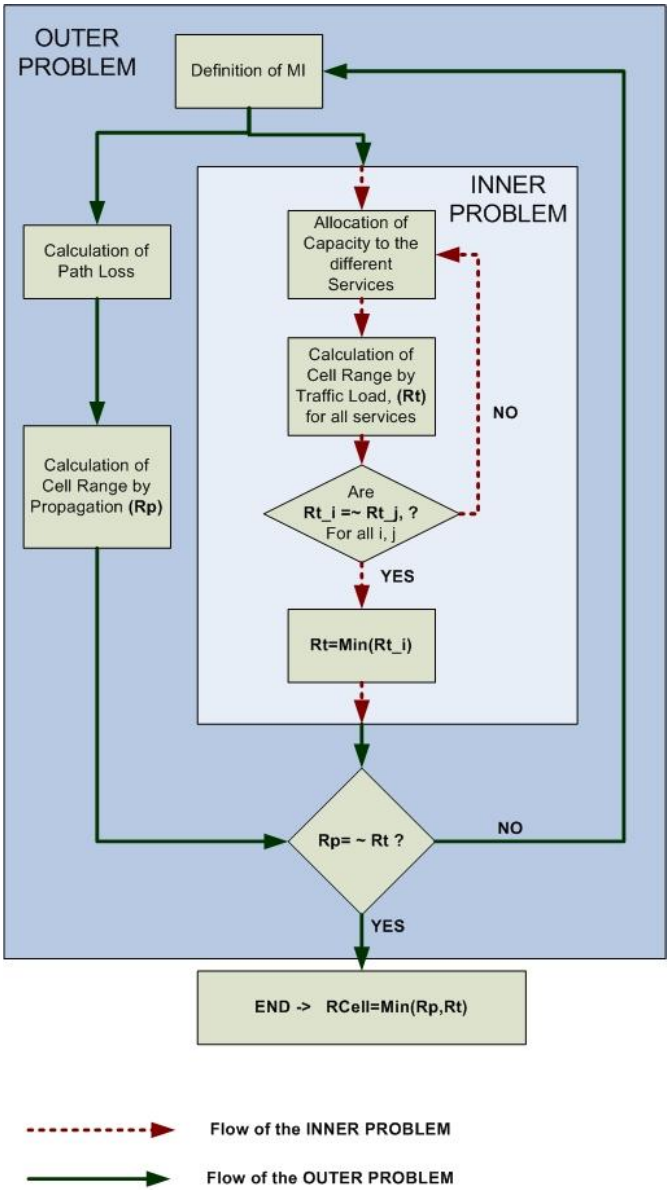
12 A. Portilla-Figueras, S. Salcedo-Sanz, K. Hackbarth, F. López-Ferreras, G. Esteve-Asenisio, "Novel Heuristics for Cell Radius Determination in WCDMA Systems and their Application to Strategic Planning Studies, "Europeen Journal on Wireless Communications, 2009.

13 Note that this leads to a so-called multi service loss model.

Figure 2-5: Flow diagram for the cell radius calculation task



The algorithm in the model calculates the assignment by means of the reduction of the set of services to a unique artificial/equivalent one and performing the dimensioning with this single service. This procedure is based on a concept proposed by Lindberger for multiservice loss network, see [Lindberger-1988] and extended to cover to the singularities of the WCDMA cell design. The artificial service is defined in terms of its equivalent parameters which are calculated, following the Lindberger formulation, on the basis of the traffic, Ai, and the binary rate, Vbi, of each service category i considered in the scenario.

Considering the traffic for this new artificial service, the reduced method calculates a corresponding value of the cell radius, $R_{Reduced}$, assigning all the capacity to the artificial service. From the obtained $R_{Reduced}$, the load factors for each individual service, $L_{Reduced}$ i, can be calculated as follows: from the $R_{Reduced}$, it is possible to calculate the maximum number of users of each service i per sector, and hence the total traffic offered to the system. Using the Erlang formula, with the blocking probability, Pbi, the number of active connections, Naci, of each service i is obtained. Finally the value $L_{Reduced}$ i is calculated by means of the individual load factor of the service, Li, times the number of active connections, Naci.

Considering these values of the load factors, a new solution of the cell radius for each individual service is calculated and its minimum value defines the cell radius.

This process is done for the downlink, which is typically the most restrictive direction in the capacity, and also for the uplink, typically the most restrictive in terms of propagation.

Once the cell radius is calculated, the algorithm checks whether the Node B has enough power to simultaneously serve all users in the coverage area. If that is the case, the cell radius obtained is the final cell radius for the Node B configuration. If that is not the case, the interference margin has to be decreased and the complete process has to start again.

Finally, when the final cell radius of the site/Node B configuration is obtained, the number of sites is calculated similarly as it was done for 2G, dividing the extension of the area under study by the area covered by the site. In the next step the prioritizing factor selects the optimum Node B configuration for the area under study.

In both cases (for a single or for several 5MHz frequency blocks), the model will allow to define a picocell increment factor, similarly to the 2G design to consider possible shadow areas or hot spots.

2.1.2.2 Considerations regarding HSPA deployment

For the deployment of HSPA services the model considers two different possibilities.

- An integrated deployment, using the same frequency bands as UMTS and hence using the remaining transmission power after the provision of UMTS services.

- A separated deployment, where the user selects, from the complete set of 5 MHz frequency blocks, how many of them are reserved for the provision of HSPA services.

Despite the deployment type, the algorithm to calculate the number of required sites (either new or shared infrastructure with existing UMTS) works similarly to the algorithms for GSM and UMTS. In a first step it calculates the area covered by a single site and thereafter the number of sites is calculated by the division of the extension of the area under study by the area covered by the site.

The algorithm to calculate the HSPA cell range, and hence the area covered by the HSPA site works as follows, see Figure 2-6. From the service table 1-18 it is possible to calculate the most suitable set of modulation/code rate/number of multicodes/Inter TTI for the guaranteed binary rate. This set is directly related with an specific Signal to Interference and Noise Ratio at the receiver.

On the other hand, the transmission power of the Node B, either the remaining one after the provision of UMTS services in the integrated deployment, or the complete transmission power in case of a separated one, is also known. From this transmission power, it is required to subtract the power dedicated to the common channels (3. 6 W in a 20 W Node B).

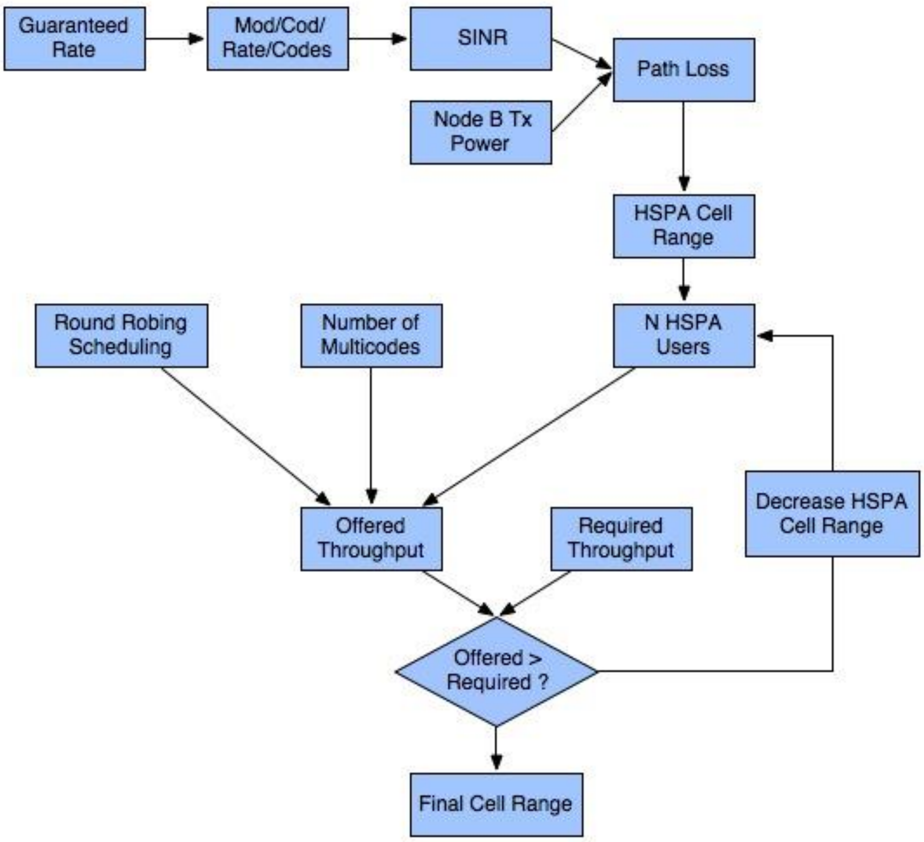
With this value, it is possible to calculate the maximum path loss which guarantees the defined SINR at the edge of the cell. With this value of the path loss and a propagation method, typically Okumura-Hata, it is possible to obtain an initial value for the cell range $R_{HSPA\_0.}$

This value is used, together with the HSPA user density, to calculate the number of HSPA users in the area N_{HSPA}, and therefore the throughput they require B_{HSPA_0}.

Considering that each user has full link utilization, that is, the entire frame is allocated to each user, Round Robin scheduling is used, and using the Number of users $N_{HSPA,}$ and the number of sectors of the Node B under study it is possible to calculate the maximum throughput of the site $\Omega_{HSPA\_Site\_0}$. If this value is equal or higher than BHSPA, the cell range calculated R_{HSPA_0} is the final cell range of the site. If not, the algorithm starts an iterative procedure to reduce the cell radius (5% in each iteration) until the throughput in the *I* iteration $\Omega_{HSPA\_Site\_i}$ is equal or higher thant the B_{HSPA_i}.

Once this value is obtained, the number of sites required to provide HSPA services in the area is calculated. This number is compared with the number of UMTS sites. The maximum value of both will be the final number of sites. Please note that in case of hybrid GSM/UMTS areas, the number of UMTS/HSPA sites is also compared with the number of GSM sites to obtain the final number of locations.

Figure 2-6: HSPA cell range calculation procedure



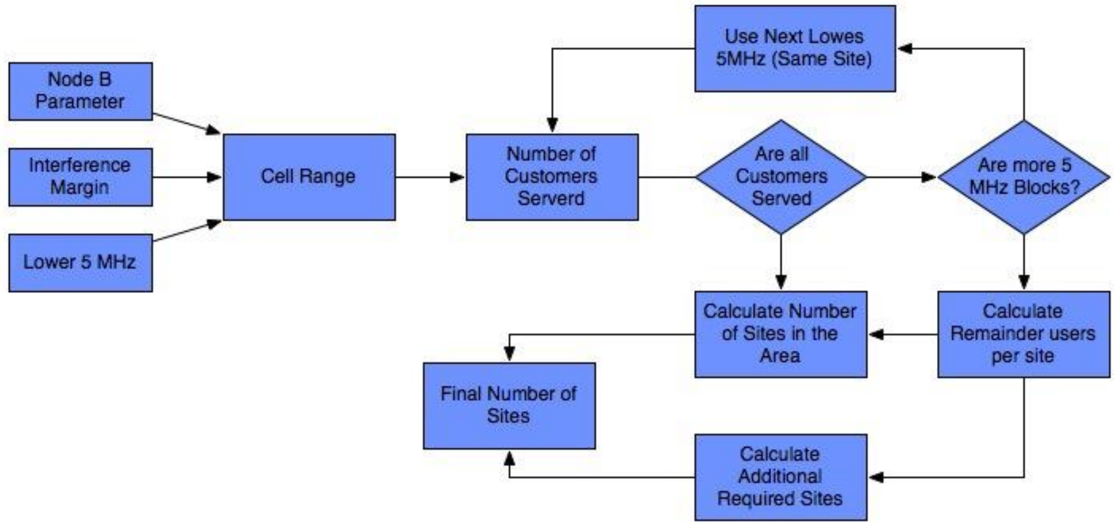
2.1.2.3 Procedure to calculate the cell radius with several 5 MHz frequency blocks,

The advantage of the availability of several (more than 1) 5 MHz frequency blocks for the deployment of WCDMA is, on one hand, the reduction on the interference, and on the other hand, the possibility of using several transmitters on the same site and sector, and therefore providing much more capacity per site. Following this idea, the algorithm in the model works as follows. It starts with the lower 5 MHz block of the lowest frequency band. Using the interference margin specified as input parameter (typically 3 dB), it calculates the cell radius by propagation Rp. With this value the number of users per service *i* Nu_i in the coverage area is calculated. Using a similar procedure as the described above for the single frequency block design, the number of users served by the Node B in the current frequency block is calculated. If there are users not being served, the algorithm will use the next frequency block (in frequency ascending order). This process is repeated until all users of all services are served in the coverage area or until there is no more available spectrum. Note that there could exist some users not being served by the Node B. These users will be handled at the end of the calculation of the number of sites.

The number of sites is calculated by dividing the area under study by the area covered by a single site. As it was said in the paragraph above, there could exist some users not being served per Node B. At this point the algorithm adds as many additional sites as required to cover these unserved users.

Again this process is done for the complete set of Nodes B specified as input parameter. By means of the prioritizing factor, the cost of the solution is obtained and the minimum one is selected.

Figure 2-7: Multiband UMTS calculation algorithm



2.1.3 Considerations about hybrid deployment

When a hybrid cell deployment is required for a specific area of a district, the user demand will be divided using the percentages defined as input parameters for each specific service category. Then with the corresponding traffic demand, one for 2G and one for 3G, the cell deployment is performed independently, obtaining the required number of sites and configurations for 2G and 3G.

As the two technologies share the same site infrastructure, the number of sites required to cover the area under study will be the maximum of the sites for 3G and those for 2G.

The technology with less sites will be deployed in the same sites as the one with the higher number of sites. summarizes the different types of sites the model considers.

Table 2-1: Different types of sites in the model

	GSM/GPRS	GSM/EDGE	UMTS	UMTS/HSPA
GSM	No GSM only cells		Yes	Yes
GSM/GPRS	Yes	No	No	No
GSM/EDGE		Yes	No	No
UMTS			Yes	Yes

2.1.4 Considerations regarding highways and railroads

Highways and tunnels are considered in the model as separate and independent deployments. The model considers that the technology can be either 2G or 3G which will be specified by a corresponding input parameter.

As tunnels and highways have special features, the coverage area is more similar to a line than to a circle and only a subset of Node B- and BTS types will be available for this deployment. The main characteristics of these sites will be:

- Macrocell type: Rural sites (to be deployed near highways and railroads) with large mast to reach large distances
- Large transmission power
- Two sectors.

2.1.5 Signalling traffic in the Iub interface

Signalling traffic in 2G is done in the air interface by means of a dedicated control channel that uses some specific slots in the TDMA frame. Generally speaking it can be assumed that, on the average, the signalling traffic uses one slot of the 8-slotted TDMA frame structure on the air interface.

On the A-bis interfaces between the BTS and the BSC, the E1 structure has one specific slot reserved for signalling, therefore it is implicitely considered in the model.

Signalling on 3G air interface is also done by means of a specific control channel. As 3G is a limited interference system, the decrease of the overall capacity due to the signalling traffic is done by the reduction of the transmission power of the Node B due to these channels.

The Iub interface performs the logical connection functionality between the Node B and the Radio Network Controller (RNC). In this interface it is required to consider the following additional bandwidth due to control and signalling:

- User traffic related overheads. The following protocol specific overheads has to be considered in the Iub interface:
  - Voice 1.5 %
  - Real Time Data (CS or PS) 8.8 %
  - Non Real Time Data 15 %.
- Common transport overhead: In the backhaul the model considers the traffic impacts due to overhead by the activity in the RACH, FACH and PCH transport channels. It assumes a backhaul bandwidth of 130 kbps per Node B.
- Radio Network Control Plane Overheads. The radio network control signalling between RNC and Node B is based on the Node B application part (NBAP). The model considers a bandwidth of 128 Kbps per Node B
- Access Link Control Application Protocol (ALCAP). This protocol is needed to set up the transport bearers (Data Bearer) for the User Plane. It also includes the appropriate Signalling Bearer(s) needed for the ALCAP protocols. The model considers a bandwidth of 128 Kbps per Node B
- Node B Element Management Interface (Itf-B). The Iub interface between Node B and RNC may carry element management information between the Node B and its manager on the Itf-B Management Interface. The model considers a backhaul bandwidth of RItf-B =190 kbps per Node B.

2.2 Aggregation network

The aggregation network covers the network from the BTSs to the BSC for the GSM network part, called BSS, and from the nodes B to the radio network controller (RNC), called UTRAN, for the UMTS network part. These connections form in the logical network a pure star network structure where the required capacities correspond to the capacity requirements resulting from the cell sites.

From the geographical point of view, the RTR 2G/3G model subdivides the aggregation network into two separated parts. This is common practise in the design of 2G/3G mobile networks, see [OPTA-2010], [NSN-2008] because the aggregation in the cell hubs leads to highly loaded links and a corresponding cost reduction due to economy of scale effects and allows for the packet traffic an earlier aggregation via statistical multiplexing[14].

- Connections from the individual cells sites (either GSM, UMTS or both) of a district to a central location (cell hub); and
- Connections of the cell hubs, one for each district, to a corresponding controller location.

The infrastructure of the cell hub location and controller location are shared between GSM and UMTS equipments.

Table 2-2 shows the possible combinations of cell hubs depending on the cell types in the district and Figure 2-8 provides an example, while Table 2-3 shows the possible controller types depending on the type of the cell hubs assigned.

Question 16:	The model considers, that all cell sites of a district are connected to a central point referred to as cell hub, where an aggregator equipment is installed (e.g. an Ethernet switch) and that the cell hub connects to the controller node location. Have you implemented other options? If yes please indicate the type of technology applied.

Table 2-2: Location types in the aggregation network

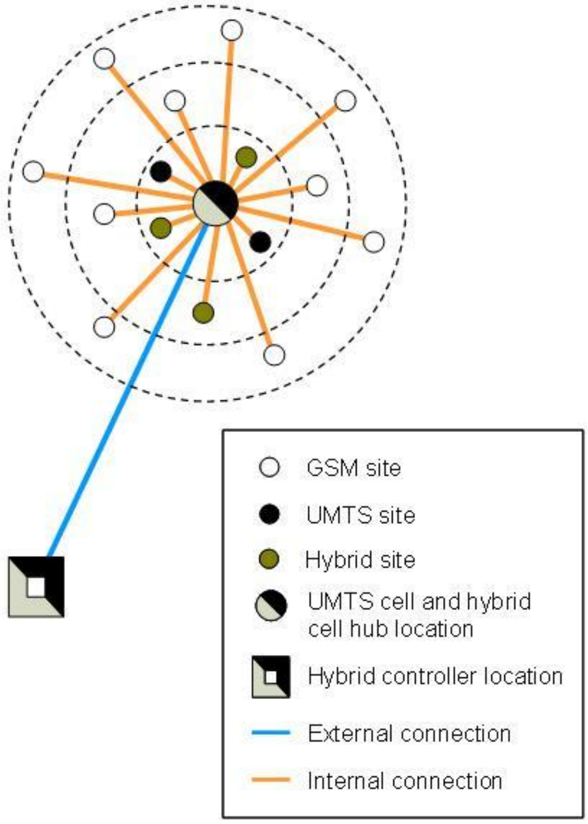
District type	Cell hub type
Only 2G cells	BTS hub
Only 3G cells	Node B hub
Both 2G and 3G cells	Hybrid hub

14 Note that the terminology for the different network parts is not unified and same paper defines as aggregation network only the part between the cell sites and the cell hub and the cell hub to the controller location as backhaul. What in this paper is defined as backhaul for the controller location to the core one is often denominated Metro.

Table 2-3: Controller location types in the aggregation network

Cell hub type	Controller type
Only BTS hubs	BSC location
Only Node B hubs	RNC location
Combination of BTS, Node B and hybrid hubs	Hybrid controller location

Figure 2-8: Example of the network structure of the aggregation network



Concerning the connections from the individual sites – either BTS, UMTS or hybrid sites – to the corresponding cell hub, the RTR 2G/3G model considers that they are implemented by corresponding systems, e.g. short range radio systems, leased lines or own wire transmission over a leased medium (4 wire copper or fibre). For the connections from the cell hub to the controller location, the model considers mainly two possibilities resulting from common best praxis[15] [Nadiv-2010]:

- Leased lines connections provided by an operator which has implemented a corresponding infrastructure,

- Own connections by long range radio systems, or

- Own connections by own wire transmission systems over dark fibre.

In the first case the corresponding physical network is a star topology but in the second case an optimal tree topology or optionally a ring topology[16] has to be provided. The capacities required for the connections from the cell hubs to the corresponding controller nodes correspond to the sums of the capacities installed in the cells situated in the corresponding districts.

Question 17:	What type of transmission systems are you mainly using in the aggregation network (for 2G, 3G and hybrid 2G/3G sites)?

Question 18:	What are your typical network topologies in the aggregation network?

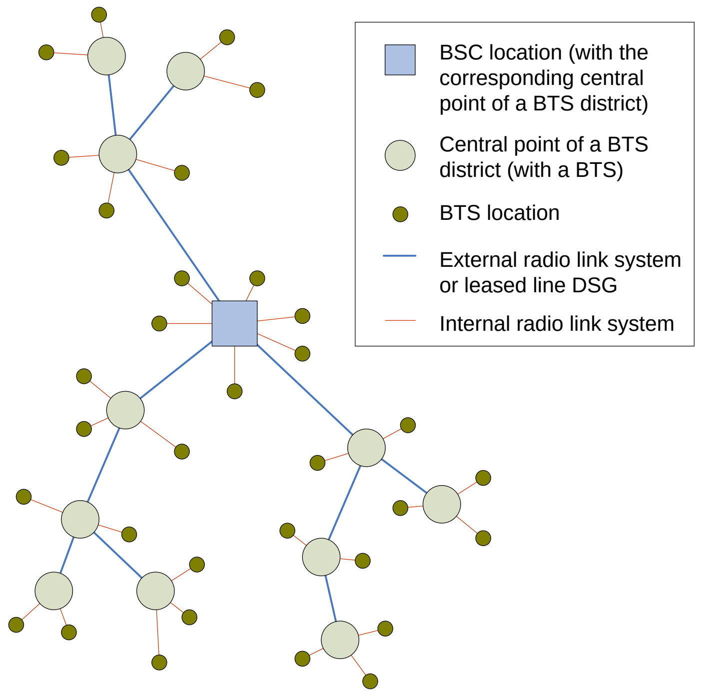
From these considerations results that the model has to solve the following task in the design and dimensioning of the aggregation network:

- Determination of the controller node locations,
- Assignation of the cell hub locations to one of the controller locations,
- Calculation of the required capacities for the internal connections between the individual cells sites and its corresponding cell-hub,
- Calculation of the required capacities for the connections from the cell hub to the controller node locations, and
- Calculation of an optimal tree topology or optimal ring topology for each controller node cluster and capacity routing over the corresponding links resulting in the capacities required for the radio or wire transmission systems.

15 As shown in section 2.2.2 the model provides a scheme for system assignment which allows considering other systems e.g. dark fibre.
16 The algorithm for the calculation of the ring topology is presented in the next section.

The first two tasks involve a classical location problem referred to in the following CLASIG (node classification and assignment) while the last task will be referred to as ARTREE (aggregation network tree) or ARRING. Figure 2-9 shows an example for this tree in the case of a GSM network.

Figure 2-9: Example of an ARTREE corresponding to a controller cluster with its corresponding internal and external links



2.2.1 Algorithm for the CLASIG problem

The RTR 2G/3G model assumes that the total number of controller node locations **ncon**[17] is externally provided but their locations and the assignation of cell hub locations to the relevant controller locations are determined by the model[18]. This leads

17 All input variables which influence to the network design are shown in fat letters.

18 The model does not consider that the locations of the controller nodes could be provided from the outside as a model input. From a methodological point of view this would be extremely difficult. We also believe that from a practical point of view this option would only insignificantly affect the cost estimates. It will be possible to show this with the algorithms of the model by varying the parameters determining the locations of nodes and thereby check the relevant cost influence. Anyway the model user can calibrate this parameter to get a location distribution which provides the best approximation to the reality to controller clusters consisting of controller node locations and their assigned cell hub locations. The model considers that an optimal solution combines two cost drivers:

- Cost for the capacities resulting from the traffic aggregated in the cell hubs which must be routed to the corresponding controller node locations, and

- Length depending costs determined by the geographical distance of the links in each controller cluster.

Hence the CLASIG algorithm selects the cells hub locations which aggregate the highest traffic capacity values as preferred candidates for controller location. This might result solutions where some controller cluster locations are situated next to each other and hence implies very large distances of the connections between the cell hub- and the controller node locations. On the other side, the algorithm might provide a strong equilibrated distribution of the controller node location which results in the so call P-media problem which can be solved by corresponding algorithms resulting from graph theory[19] but might provide a selection of locations with very small traffic loads and corresponding reduced capacity weights and hence large traffic values must be routed from lower locations to the higher ones.

As a consequence the model considers a heuristic algorithm which combines both problems under the control of the model user. The algorithm selects the locations with the largest capacity weights where a minimal distance criterion **dmincon** between the selected nodes is obeyed, where this distance value is an input parameter. The algorithm is supported by numerical and graphical information about the solution and hence the model user can select adequately the minimal distance value leading to an optimal distribution of the controller locations.

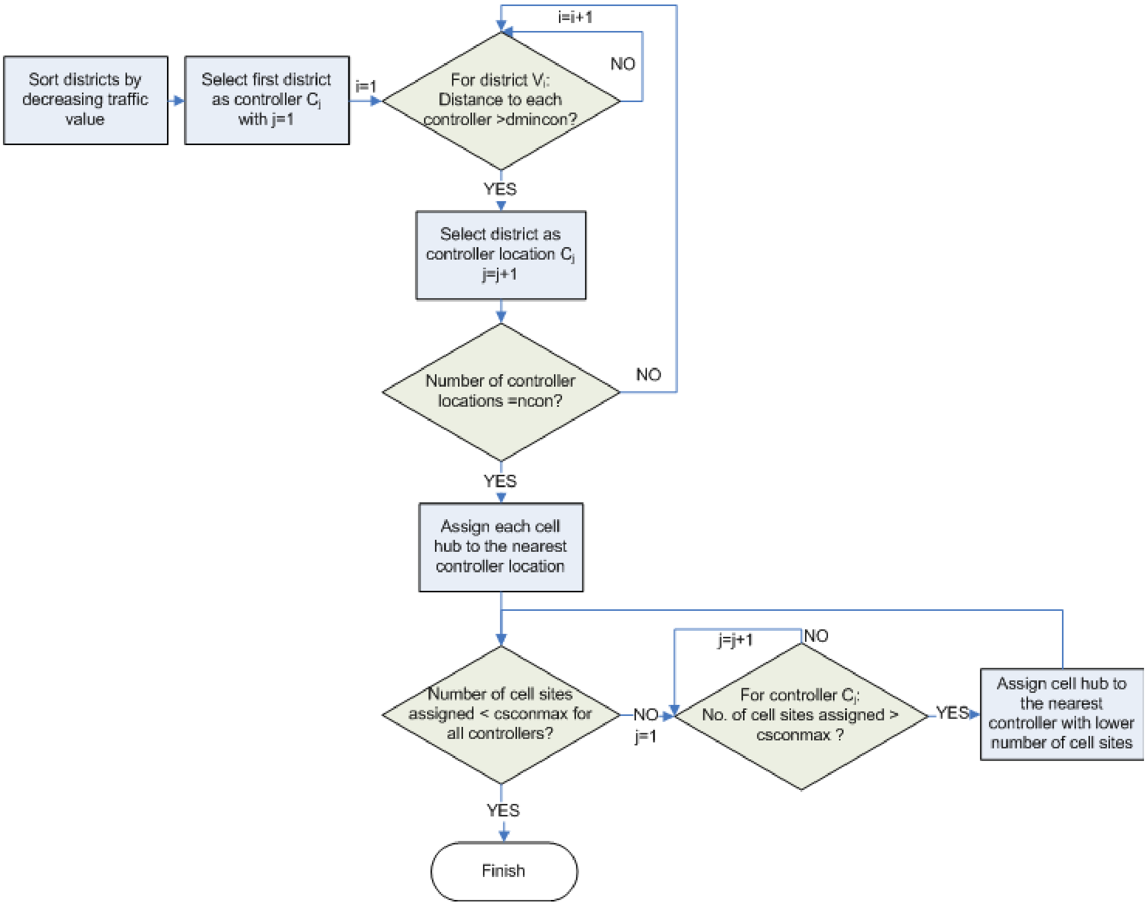
After having selected the controller nodes, the algorithm for the CLASIG problem assigns each cell hub location to the nearest control location. For an equilibrated distribution of the cell hub locations to the controller locations, the algorithm considers a maximal number of cell sites (GSM+UMTS) **csconmax** which can be assigned to one controller node location. This parameter is again provided by the user of the model. In case that the selected number of controller node location is not sufficient to assign all cell sites under the **csconmax** parameter a warning message is given. In this case the model user might increase the number of controller locations.

The algorithm is based on a sorted list for the cell hub locations and selects among the “deepest first search principle” the first **ncon** node from the list which fulfil the distance criteria given by **dmincon**. Concerning the assignation the algorithm assign first each pure cell hub location (which are not collocated to a controller node location) to its

19 E.g. Domschke-Drexl, Logistic: Standorte ed. R. Oldenbourg Verlag Munches-Vienna 3º ed.1990.

nearest controller location and after then reassign cell hub location under the **csconmax** parameter. Figure 2-10 shows a flow diagram of the algorithm.

Figure 2-10: Flow diagram for CLASIG algorithm

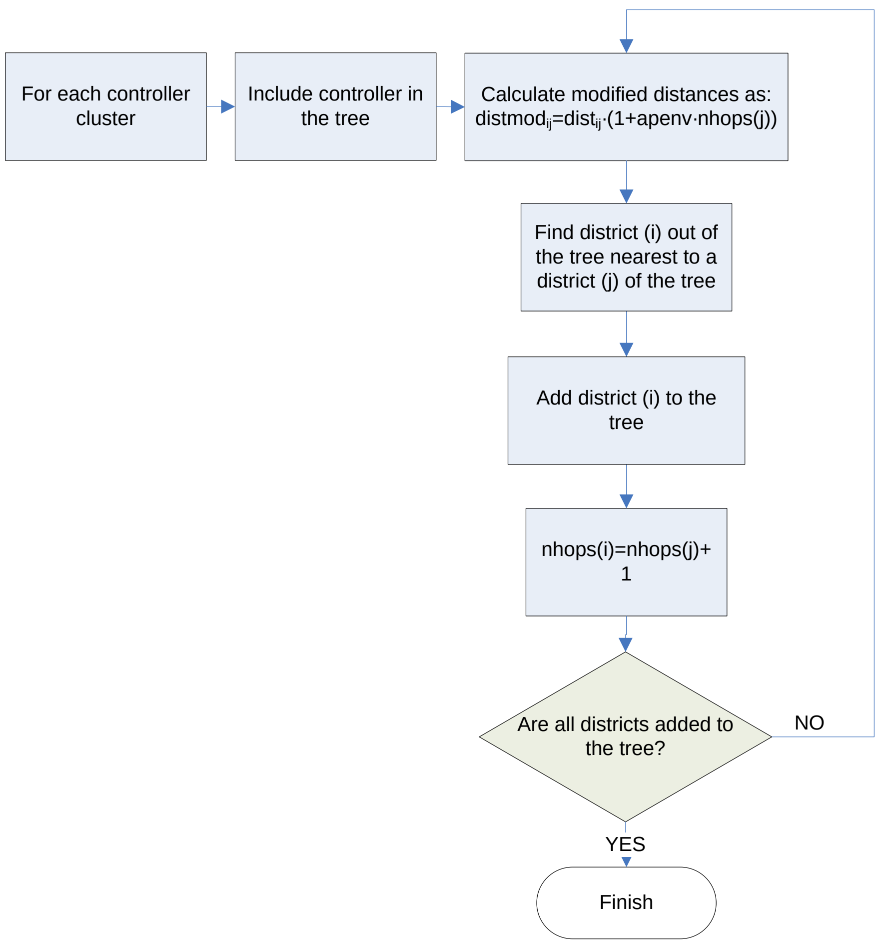


2.2.2 Algorithm for the ARTREE problem

Given a set of N nodes, a tree topology is a connected network topology with N-1 links. In general there exist a large number of different trees. In the case of the ARTREE problem, an optimal-tree topology is the one which minimizes the cost of its implementation. These costs are driven by two main parameters, the capacity required on each link of the tree and the length of a link. The minimum cost network structure when considering the capacity criteria in isolation results in a star topology so that each cell hub node is connected with its corresponding controller node location by routing the required bandwidth demand over only one link. On the other hand the minimum cost outcome considering the length criteria, results in a so-called minimal spanning tree (MST) which is a tree which minimizes the lengths.

The tree calculation in the RTR 2G/3G model considers both aspects. For this purpose the ARTREE algorithm implements a modified version of the MST. The modification considers that applying a pure MST might result in trees with a great depth, i.e. a high number of links in the paths from the hub locations to the controller location. To limit this depth, an additional parameter or a penalty factor **apenv** is introduced, which increases the length of the links artificially depending of the number of hops between the hubs and the controller node location. The correct value for the penalty factor depends mainly on the geographical topography of the country, system parameters for the radio links like the maximal repeater-less distance and the relation between digital leased line cost and radio link cost. This value is provided as an external parameter and the correct penalty factor will be calibrated for the Austrian case taking into account its topography, the distribution of the cell node locations and the cost relation between an own system implementation or one based on leased lines. Figure 2-11 shows a flow diagram of the algorithm.

Figure 2-11: Flow diagram for ARTREE algorithm



The ARTREE algorithm calculates a star structure for the case of leased lines applying a high penalty factor. Thus the model allows that the user selects between the calculation of the ARTREE by the modified MST or a more cost effective star structure using a corresponding optional external input parameter.

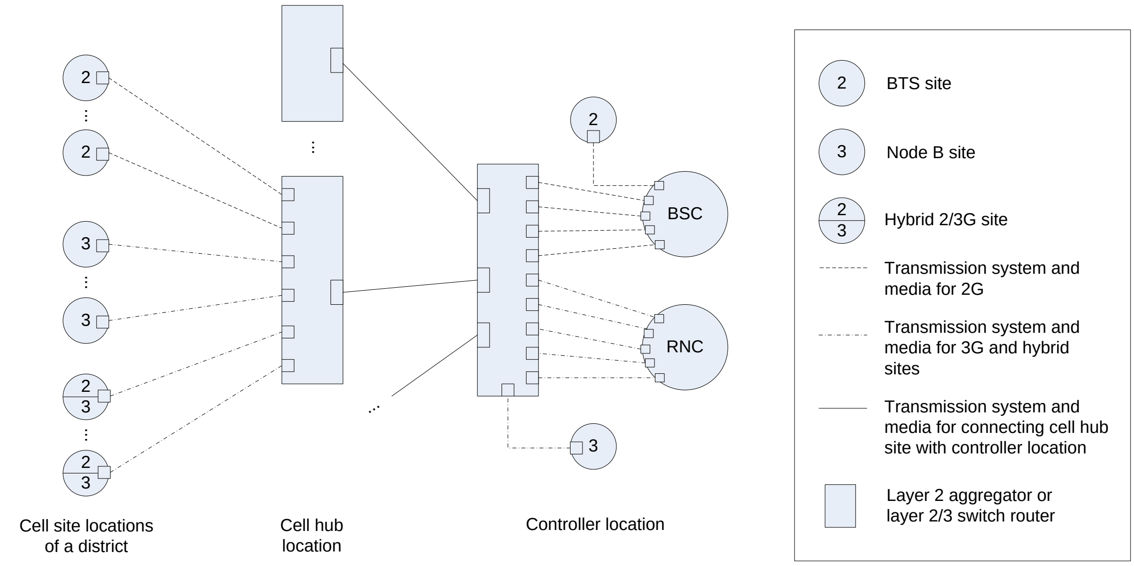
The capacity routing over the tree or star structure and the lengths of the links provides the main parameters for the system assignment where the system assignment procedures are divided into two parts. First the system assignment is completed for the external links. This step is required for the chain of links connecting the cell hubs of the districts to their corresponding control node locations and the second step determines the internal link connections between the individual cell sites in a district to its corresponding cell hub location. All systems are represented by the two characteristic parameters: flow expressed in bandwidth and distance. For the external links the model stores the calculated values (length and flow) for each link. For the internal links the corresponding network topology is approximated by a star one and the model considers mean values for the length taking into account that the cell site location is only approximated in the corresponding ring space areas, seeFigure 2-2. For more details see next subsection.

2.2.3 Dimensioning of the capacities and determining the type and number of systems

Besides the dimensioning of the capacities, also the corresponding equipments need to be determined. It will be shown later on that the model provides the determination of the corresponding equipment by generic characteristic values and hence allows to apply different types of realisation (own infrastructure, e.g. by radio links; partly own infrastructure, e.g. by buying dark fiber; or fully outsourced infrastructure, e.g. by leased lines) and in case of own realisation, the application of different technologies.

The dimensioning of the aggregation network determines the equipment for the corresponding locations which are cell sites, cell hub locations and controller locations and their connections are provided by corresponding transmission systems and medias. Figure 2-12 shows the main building blocks which must be considered.

Figure 2-12: Topology of the 2G/3G aggregation network with its main building blocks



Hence the dimensioning and system assignment is separated into two steps:

- dimensioning and system assignment for the connection from the individual cell sites of a district to the cell hub location
- dimensioning and system assignment for the connections from the cell hub location d=1…D to the corresponding control node location.

These are specified in the next two subsections.

2.2.3.1 Dimensioning and system assignment for the connections between cell sites and cell hub location

From the cell deployment for each district and its corresponding areas the following figures result which are required for the dimensioning for the systems to be installed in the cell site locations, namely for each cell site:

- number of pure 2G cell site locations for urban, suburban and rural areas: $ncsu_{p2G}$, $ncss_{p2G}$, $ncsr_{p2G}$
- number of pure 3G cell site locations for urban, suburban and rural areas: $ncsu_{p3G}$, $ncss_{p3G}$, $ncsr_{p3G}$

- number of hybrid cell site locations for urban, suburban and rural areas: $ncsu_{hyb}$, $ncss_{hyb}$, $ncsr_{hyb}$

- radius for urban, suburban and rural R_u, R_s, R_r

This data allow to calculate an upper bound for the mean length per district separately for GSM star links and Node B star links:

$$mlcsch_{2G} = \frac{ncsu_{2G} \cdot Ru/2 + ncss_{2G} \cdot \left(Ru + \frac{Rs - Ru}{2}\right) + ncsr_{2G} \cdot \left(Rs + \frac{Rr - Rs}{2}\right)}{ncsu_{2G} + ncss_{2G} + ncsr_{2G}}$$

$$mlcsch_{3G} = \frac{ncsu_{3G} \cdot Ru/2 + ncss_{3G} \cdot \left(Ru + \frac{Rs - Ru}{2}\right) + ncsr_{3G} \cdot \left(Rs + \frac{Rr - Rs}{2}\right)}{ncsu_{3G} + ncss_{3G} + ncsr_{3G}}$$

With

$ncsu_{2G}=ncsu_{p2G}+ncsu_{hyb}$	$ncsu_{3G}=ncsu_{p3G}+ncsu_{hyb}$
$ncss_{2G}=ncss_{p2G}+ncss_{hyb}$	$ncss_{3G}=ncss_{p3G}+ncss_{hyb}$
$ncsr_{2G}=ncsr_{p2G}+ncsr_{hyb}$	$ncsr_{3G}=ncsr_{p3G}+ncsr_{hyb.}$

The transmission systems to be provided can be different for the 2G BTS equipment and for the 3G Node B equipment. In the case of hybrid cell sites with with 2G and 3G equipment, the bandwidth demand from both are integrated into one common transmission sytem[20].

Traffic and bandwidth values resulting from cell sites with 2G BTS

The model calculates from the results of the above formulas the traffic and mean bandwidth required from the user for the i=1…$n2G_d$ BTS cell sites from both pure BTS sites and hybrid ones situated in a district.

A_{ci} Traffic for traffic class[21] c in BTS cell site i

$Nslot_c$ Number of slots for traffic class c in BTS cell site i

A_{ai} Normalized traffic[22] in BTS cell site i

20 We estimate that under current technology the E1 group used for connecting the BTS with the BSC is integrated into an Ethernet connection which connects the common cell site with the cell hub.

21 Remember that the traffic class is provided independently whether 2G or 3G technology is applied, see Table 1-12 and the bandwidth requirement must be associated to the corresponding bearer services in case of GSM determined by the number of slots in the TRX, see Table 1-17.

which is summarised by the following set:

$\{A_{ci}$, $nslot_c$ for each traffic class c=1…C, $A_{ti}\}$ for i=1..$n2G_d$

From these figures results the normalized traffic:

$A_{ai} = \Sigma_{c=1…C} A_{ci} * nslot_c$

which describes the total traffic in the BTS site normalized to one slot and hence normalized to voice traffic.[23]

The 2G/3G model considers that the interfaces for 2G BTS equipment are based on E1 signals and for 3G Node B equipment on IP/Ethernet cards. The corresponding interfaces might be already integrated or require an adapter. In case of a hybrid cell sites a small aggregator equipment is required to join the two signals from BTS and Note B equipment on a common transmission system. From the cell deployment and the corresponding BTS types it follows that the maximum number of TRX are nine and hence one E1 provides always sufficient capacity for transporting the traffic of all TRXs with their corresponding slots. Hence the aggregated values in the cell hub for 2G results from the sum over the values from all cell sites for $n2G_d$:

$A_{d2G} = \Sigma_{i=1 … n2Gd} A_{ai}$

$nE1_d = n2G_d$

and at the controller location, where D districts are connected, results:

$A_{co} = \Sigma_{d=1 … D} A_{ad2G}$

$nE1_{co} = \Sigma_{d=1 … D} nE1_d$

Traffic and bandwidth values resulting from cell sites with 3G Node B

The model calculates from the number of users and the total bandwidth resulting from the cell deployment for each Node B the traffic and mean bandwidth for each traffic class c for the j = 1…n3G Node B sites considering both pure Node B sites and hybrid ones, situated in a district d.

22 The traffic is normalized to the traffic which occupies one slot.
23 The model considers voice traffic as normalization unit because the objective of the model is the calculation of the cost for different types of voice services.

For each cell site in district d for the $n3G_d$ locations with 3G Nodes B, the model derives from the values deduced from the 3G cell deployment the following set of values:

{ $u\lambda_{cj}$, $d\lambda_{cj}$, A_{cj} , muB_c, mdB_c for each traffic class c=1…C }[24] for j=1..$n3G_d$

with:

$u\lambda_{cj}$ Upstream packet rate[25] for traffic class c in node-B cell site j,

$d\lambda_{cj}$ Downstream packet rate for traffic class c in node-B cell site j,

A_{cj} Traffic for traffic class c in node-B cell site j,

muB_c Mean upstream bandwidth for traffic class c in node-B cell site j,

mdB_c Mean downstream bandwidth for traffic class c in node-B cell site j.

The 2G/3G model considers that the interface for 3G equipment[26] is based on IP/Ethernet and that the corresponding interface cards are integrated inside the Node B equipment. The model considers QoS parameter for each traffic class expressed by the mean delay from the entrance to the network up to the exit, see Table 1-13. These delays are caused mainly by the transmission systems in the lower levels because the corresponding leased line or installed own systems are dimensioned based on the required bandwidth while the transfer capacities of the aggregation equipment lies in the Gigabit domain and the contribution to the delay is not significant.

For QoS requirements operators mostly consider limits of capacity use defined by a utilization factor which lies in packet networks between 65 and 85 %. Hence the model considers for each network level a prescribed utilisation factor to be provided by the model user. From this follows that the aggregated bandwidth on each transmission link must be multiplied by a global mark-up factor (gMUF) which is the invers value of the ultilisation factor.

For fulfilling the QoS requirements of the different QoS-traffic classes c, the model has to calculate from the corresponding mean-bandwidth value the one for the equivalent-bandwidth, applying a corresponding mark-up Factors (MUF) for each traffic class c. The model calculates the MUF by a generic procedure using a method presented in

---

24 Note that in 3G the packet rates and bandwidth must be considered separately for upstream and for downstream, while in 2G circuit switches the number of slots required must be considered for each direction.

25 Note that the packet rate λ caused by a service is obtained by $\lambda = mB*8/mL$, see Table 1-13.

26 The 2G part of the network does not require QoS evaluation because the corresponding architecture is based on circuit switching of slots aggregated in the 2Mbps E1 groups. Anyway, in case that 2G and 3G traffic is integrated in common transmission links, E1 groups are treated as pseudo wire and the corresponding bandwidth requirement is aggregated with the traffic by an internal traffic class named circuit emulation with much smaller mean delays.

[Garcia-2010]. As the MUFs depend on the mean bandwidth from the different traffic classes and the resulting total bandwidth, the model will provide a corresponding procedure SRMUF(uλ, dλ, A, muB, mdB, gMUF, MUF) applied for dimensioning of each network element and which allows determining the corresponding MUFs. This functional relation is based on queuing theory and it follows that the global MUF decreases with increasing total mean bandwidth and converges for sufficient large bandwidth values to a fixed value **minMUF**, e.g. 1.1. This minMUF considers that in packet networks the capacities of the systems are never fully used for avoiding congestion in case of unforeseen high traffic loads.

To go into more details, the generic procedure “Subroutine Mark-up faktor SRMUF”

SRMUF(uλ, dλ, A, muB, mdB, gMUF, MUF)

calculates the individual Mark-up factors for each traffic class and stores them in the vector MUF based on the follwing input values:

uλ, dλ vectors with upstream- and downstream packet rate for each traffic class

A vector with the aggregated traffic for each traffic class

muB, mdB, vector with the mean bandwidth up- and downstream required for each traffic class

gMUF value for the global mark up factor

and generates as output parameter the vector MUF with the individual mark up factors for each traffic class. .

Applying the SRMUF for each cell site with 3G Node B results the following aggregated values for each 3G cell site j :

(2.1) $$\lambda a_j = u\lambda_j + d\lambda_j$$

$$eBWa_j = \sum_{c=1...C} \max(muB_c, mdB_c) \cdot MUF_c$$

$$Aa_j = \sum_{c=1...C} Ac_j \cdot \frac{\max(muB_c, mdB_c) \cdot MUF_c}{mBW_{voz} \cdot MUF_{c(voice)}}$$

Note that the scheme for the normalized Aa_j traffic is again based on the idea proposed by Lindberg [Lindberg-1988]. using the MUF calculated for the traffic class assigned to voice traffic, typically with c=1, see Table 1-12.

For the cell hub location from the cell sites with 3G Node B the following aggregated values occur:

(2.2) $\lambda_d = \sum_{j=1...n3Gd} \lambda a_j$

$$eBW_d = \sum_{j=1...n3Gd} eBWa_j$$

$$A_{d3G} = \sum_{j=1...n3Gd} Aa_j$$

Traffic, bandwidth and other figures aggregated in a cell hub location

The cell hub connects all cell sites either 2G or 3G or both with an aggregation system, currently a Carrier Ethernet Switch or an IP/Ethernet router[27], see [NSN-2008], [NEC-2010]. The main figures aggregated in the cell hubs are:

(2.3) $teBW_d = eBW_d + n2G_d \cdot BW(E1)$

$$tA_d = A_{d2G} + A_{d3G}$$

$$tnport_d = n2G_d + n3G_d$$

$$n2Gu_d = \sum_i nu_i$$

$$n3Gu_d = \sum_j nu_j$$

Transmission systems and medias between cell site and cell hub location

The RTR 2G/3G model considers a pure star topology for the network part which connects the cell sites of a district with the cell hub location. This is only an approximation of the reality which is justified by the following reasons:

- The model does not determine the exact location of the cell sites because this is out of scope for a network planning tool used for cost determination but considers that they are distributed symmetrically in the different ring areas.
- We know from earlier LRIC cost models that while the estimated locations are not the same as the real ones would be, the differences in length are statistically balanced out and the cost difference is insignificant.
- From earlier studies it follows that the cost contribution of transmission systems between the cell sites and the cell hub is small and the star topology which connects each BTS and each Node B with the cell hub provides an upper bound

27 The model considers, that the type of equipment applied for the LRIC cost calculation is provided by the corresponding parameters, an example for carrier Ethernet is shown in Table 2-6.

for the costs of this part and a fine optimisation will not change significantly the result[28].

The capacity of the links which connects a cell site with 2G equipment to the cell hub location is given by one E1 system. The corresponding transmission system is determined by the corresponding cost value to be determined by the model user in the cost model input parameters. The model approximates the cost of this network part by a pure star topology [29].

Question 19:	The model considers that the connection from the cell site with only BTS to the cell hub is provided by a 2 Mbps connection with the same technology for all connections. This can be chosen frorm leased line, microwave mini links, leased four wire copper or own four wire copper. Do you apply other technologies? Please indicate. Do you apply different technologies depending on the area of a district (rural, suburban, urban) ? Please indicate for each area.

The capacity of the links which connect a cell site with 3G equipment to the cell hub is determined by the equivalent bandwidth eBW_{aj} already calculated from the cell hub equipment assignment.

Question 20:	The model considers that the connection from the cell site with UMTS equipment to the cell hub is provided by layer 2 connections. Currently we estimate 100 Mbps Ethernet with the same layer-1 technology for all connections. This can be chosen from leased lines, microwave mini links, leased (dark) fibre or own fibre wire. In case of hybrid cells with GSM and UMTS and additional HSPA the required bandwidth is integrated into one physical connection. Do you apply different technologies? Please indicate. Do you apply different technologies depending on the area of a district (rural, suburban, urban)? Please indicate for each area.

The corresponding transmission system assignment is given by a similar table as in case of the cell hub equipment. Table 2-4 shows an example. Note that the systems in

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28 After having implemented the first version of the model we will check this point again and in case that the assumptions do not hold for the Austrian case we will provide an improvement.

29 From current technology results, that the transmission system might be either a short range 2Mbps radio link or an E1 leased line or a leased two copper wire pair.

the table are listed according to increasing cost and a change of the technologies is considered by modifying the input values of this table, which can be set by the user of the tool. The model provides for each level a separate table and hence the applied technolgy might be different on each level but not any technology mix within a level is considered[30].

The following procedure determines the index for the system:

Index=1;

Do while eBW_{daj}> maxBW(index)

index=index+1

end while

and the number of cell hub aggregator systems and its maximal bandwidth:

$nsys_d$ = nºsys(index)

$BWcellhub_d$ = maxBW(index)

Note that due to the ordering by increasing cost the index provides a point to the system confiugration which fullfills the capacity limitations under the lowest cost. The table considers also the case that two systems with lower capacity migth be cheaper than the next system with higher capacity and due to the free confiugration of the table by the model user the model provides a strong flexibility considering current and future systems. The port cards and, if required, the adapter between the port cards and the interface of the transmission system of leased line are considered in the dimensioning of the aggregation system, see next subsection.

Table 2-4: Example of leased lines or radio link systems for connecting cell-sites with 3G equipment to cell hub location[31]

Index	1	2	3	4	5	6	7	8
System type	1	1	2	2	3	3	4	4
maxBW [Mbps]	2	4	8	16	32	64	140	280
Nº of leased lines of systems	1	2	1	2	1	2	1	2

30 This is in line with best praxis where an operador mainly to assure a reasonable implementaiton of the OAM function will only support a limited number of technologies.

31 From current bandwidth of 3G cell sites follows that systems under the index 6..8 never will be reached

2.2.3.2 Dimensioning and system assignment for the connections from the cell hub location to the corresponding control node location

As already seen, the capacities required for the topology are determined by a corresponding routing of the bandwidth demand aggregated in the cell hubs over the physical topology. The model considers for the aggregation network three types of topologies:

- star
- tree
- ring

Note that the star is a special case of the tree and results from high values for the penalty factor **apenv,** which must be provided by the model user.

In case that the model considers a ring structure as an option the **aring** parameter must be set to 1 (in case of star or tree topology this value must be zero) and either half of the required capacities are routed over the clockwise path to the controller node and the other half part on the counter clockwise path or the total demand is routed over both directions for 100% protection. The model user selects this by determining the **ademp** parameter, Table 2-5 shows the different combinations of parameters in relation with the topology of the aggregation network and its resulting demand protection.

Table 2-5: Parameter values for the topology selection in the aggregation network and flow value calculation on links

Topology	aring	apenv	ademp	Flow on links	Protection
star	0	high[32]	Without influence	Same as in cell hub	0%
tree	0	[1,high)	Without influence	Sum from all cell hub using the link in its path	0%
Ring with reduced protection	1	Without influence	0	Half of the sum over all cell hub flows location in the ring	50%
Ring with full protection	1	Without influence	1	Half of the sum over all cell hub flows location in the ring	100%

Once the required capacities in form of the equivalent bandwidth are determined for each link in the topology, the model determines the type and number of corresponding

32 The definitive value for the Austria case will be determined after having implemented the model.

transmission systems or leased lines. The model provides this system assignment similar as for the systems between cell site and cell hub locations, see Table 2-3.

2.2.3.2.1 Dimensioning and system assignment for a star topology

The results of the formulas expressed under (2.3) in subsection 2.2.3.1 and allows to calculate the required systems to be installed in the cell hub named in the following cell hub aggregator and on the star link connecting the cell hub aggregator with the corresponding equipment on the controller location. For this purpose the RTR 2G/3G model considers again a generic model for the system assignment for both systems in nodes and transmission systems and media.

Dimensioning of the cell hub aggregator

For the cell hub aggregator the model considers a maximum of ten system combinations[33] each of them described by the follwing key values:

- Total capacity of the switch fabric,
- Nº of slots for I/O cards,
- Number of different I/O cards supported by the system,
- For each type of I/O card:
    - max number of ports,
    - line rates of the ports.

Table 2-6 shows an example for an Ethernet switch.

Table 2-6: Example for a cell hub aggregation system[34]

Index	1	2
Ethernet Type	10G	10G
Capacity of the Switching fabric [Gbps]	768	1536
Nº of slots for I/O cards	4	8
Nº of I/O card types	2	2
Nº of ports for I/O card type 1	192	384
Line rate of I/O card type 1	10/100/1G	10/100/2G
Nº of ports for I/O card type 2	32G	64G
Line rate of I/O card type n	10G	10G

33 This value can be reduced or increased if required.
34 Force10 Networks: C-Series (Resilient Switches)

From the formulas (2.3) the model deduces the required values for the different parameters as shown in Table 2-5 and selects the cheapest system for the cell hub aggregator by a similar procedure as in the case of the transmission systems. Based on this consideration, the model determines the cheapest system for the cell hub aggreagtion under a similar procedure as shown for the transmission systems.

Dimensioning for the links of the topology

The capacity on the logical links in the star structure between the cell-hub location and the corresponding controller location is calculated by the sum of the bandwidth requirements of all cell sites connected to the cell hub node. The resulting total mean bandwidth value will be again increased by a corresponding global mark-up factor (gMUF) and the individual mark-up factors for each traffic class are calcualted by the same procedure as explained for the links between the cell sites and the corresponding cell hub location.

For this purpose the model provides, for the flow resulting from routing the capacity demand of the logical links over the physical topology, a set of values on each of the corresponding physical links m. This set is expressed by four vectors which are:

(2.4)

$\underline{u\lambda_m}$ with $u\lambda_c$ downstream frame rate for traffic class c (c=1…C)

$\underline{d\lambda_m}$ with $d\lambda_c$ upstream frame rate for traffic class c (c=1…C)

$\underline{A_m}$ with A_c traffic

$\underline{muBW_m}$ with $muBW_c$ upstream mean bandwidth for traffic class c (c=1…C)

$\underline{mdBW_m}$ with $muBW_c$ downstream mean bandwidth for traffic class c (c=1…C)

$\underline{MUF_m}$ with MUF_c resulting MUF for traffic class c (c=1…C)

The model calculates by a corresponding subroutine SRMUF the MUF values for each QoS-traffic class.

$$SRMUF(\underline{u\lambda_m}, \underline{d\lambda_m}, \underline{A_m}, \underline{muB_m}, \underline{mdB_m}, gMUF, \underline{MUF_m})$$

From this values results for each physical link the following figures which are required for dimensioning purpose

$$eBW_m = \max\{\langle \underline{muB_m}, \underline{MUF_m}\rangle ; \langle \underline{mdB_m}, \underline{MUF_m}\rangle\}$$

$$MUFg_m = eBW_m/\max\{\Sigma_{c=1\ldots C} muBW_c ; \Sigma_{c=1\ldots C} mdBW_c\}$$

with

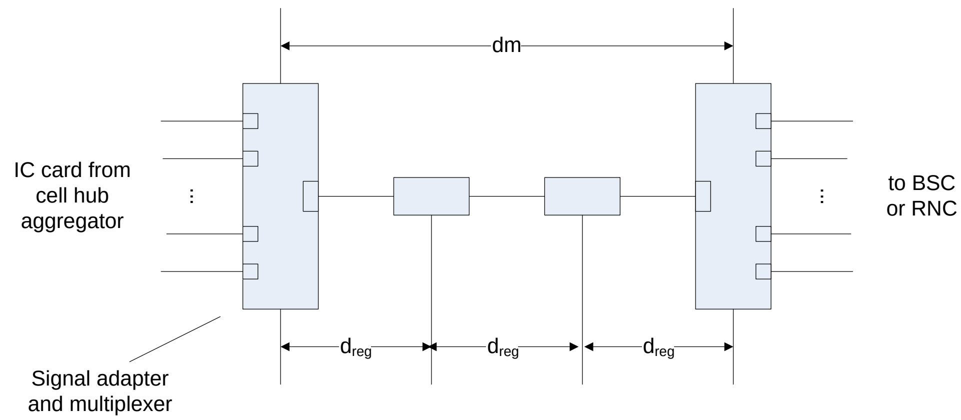
eBW_m equivalent bandwidth to be provides from corresponding transmission systems

$MUFg_m$ global MUF

Transmission systems for a star structure

A star topology results either from leased lines depending on the required bandwidth either on an electrical or optical signal or a proper point-to-point transmission system based on a corresponding transmission medium e.g. dark fibre or radio. Depending on the length of the link a signal regenerator must be introduced. The point-to-point transmission system integrates an element which adapts the bearer signal to the signal required from the transmission system and in case that more than one bearer signal is transported a corresponding multiplexer is used, Figure 2-13 shows these elements.

Figure 2-13: Main elements on the physical link of a star topology for connecting a cell hub location with the corresponding controller node



The system assignment for the point to point system is provided similar as for the systems connecting cell sites with the cell hub location. The main figures resulting from the dimensioning of the cell hub aggregator equipment which dominates the system assignment are:

$nsys_d$ number of cell hub aggregator in district d

$teBW_d$ total equivalent bandwidth to be transported from district d to the controller node

l_d total geographical length of the star link from district d to the controller node

The following procedure results the index for the system:

Index=1;

Do while $teBW_d$> maxBW(index) or $nsys_d$ > maxnrport(index) or $BWcellhub_d$> BWport(index)

index=index+1

end while

The model stores on the link aggregation for each link m=1…Nagrl list the following values for a posterior cost evaluation of the total cost for this network part:

(d1, d2) districts connected by link m

$\underline{A}_m$, $\underline{MUF}_m$ traffic vector and MUF vector over the c=1…C traffic classes

$ntrsys_m$ = nsys(index)

$nreg_m$ = int(l_d /maxlength(index))

$lchcc_d$ =l_m

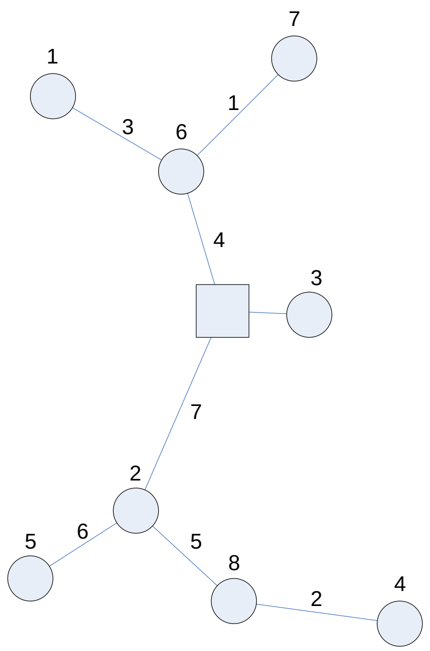
Table 2-7: Example for transmission systems for connecting cell-hub locations to the controller location

index	1	2	3	4	5	6
System type	1	1	2	2	3	3
maxBW [Mbps]	8	16	32	64	140	280
maxnrport	1	2	3	6	2	4
BWport [[Gbps]	0,1	0.1	0.1	0.1	1	1
Max-length [km]	50	50	50	50	50	50
No. of systems	1	2	1	2	1	2

2.2.3.2.2 Dimensioning and system assignment for a tree topology

The ARTREE Algorithm provides for each controller cluster the corresponding tree topology which connects the cell hub of each district to the controller location. The corresponding data structure provides for each cell hub location in the corresponding list of districts indexed by d the next district location on the path to the controller location and in the list of aggregation links indexed by m the corresponding link[35]. Figure 2-14 shows an example where the controller node and its corresponding aggregator has the number 3, odn is the number of the cell hub locations and ndn is the number of the corresponding cell hub locations on the tree while m is the number of the corresponding transmission links[36].

Figure 2-14: Example of an aggregation network with one controller node



odn	1	2	3	4	5	6	7	8
ndn	6	3	0	8	2	3	6	2
m	3	7	0	2	6	4	1	5

35 Note that for the district where the controller is located the index to the next district is zero and the same happens for the link.

36 Note that in the district of the controller node location a cell hub aggregator is collocated which connects the cell site location of this district and hence in the table the index ndn=3 is the destination of the controller node location.

The corresponding routing algorithm maps the demand values aggregated in the cell hub location over the links of the tree and on the cell hub locations of the intermediate nodes where the corresponding traffic passes in transit.[37]

The tree routing algorithm (shown below) results for each district in the corresponding flow values in transit and for each link in the flow values to be satisfied by the transmission systems.

Tree Routing Algorithm:

```
Do over all cell hub location ih=1… nChL
    m=link(ih)
    nextd=ndn(ih)
    Do While nextd>0
        λu(m)= + λuih)
        λd(m)= + λd(m)
        mBWu(m)= + mBWu(ih)
        mBWd(m)= + mBWd(ih)
        λtu(nextd)= + λu(ih)
        λtd(nextd)= + λd(ih)
        m=link(nextd)
        nextd=ndn(nextd)
    end Do While
```

The system configuration for the cell hub aggregator in the cell hub location is provided in a similar way as in the case of the star network but takes into account the additional transit flow. The model uses in both cases the same system types and hence not any difference in the system assignment must be specified.

Concerning the transmission systems, the model supports the same scheme as for the star topology but provides a different table because the transmision technology and/or system types will be different due to the higher values of aggregated bandwidth on the

37 In case of a star structure these values are zero because the star structure does not contain any intermediate node.

tree links and hence allows providing for the star and the tree topology transmission system with different technical characteristics and cost values. Table 2-8 shows an example.

Table 2-8: Example of Radio link transmission systems for connecting cell-hub locations to controller locations applying a tree topology

index	1	2	3	4	5	6
System type	1	1	2	2	2	2
maxBW [Mbps]	32	64	140	280	420	560
maxnrport	3	6	2	4	6	8
BWIC [[Gbps]	0,1	0.1	1	1	1	1
Max-length [km]	50	50	50	50	50	50
no. of systems	1	2	1	2	3	4

2.2.3.2.3 Dimensioning and system assignment for a ring topology

The model provides ring topologies by applying a well known algorithm, see [Lin-1973], which has been applied in earlier cost models, see [ACCC-2007]. Ring topologies are mainly applied under own implementation of the transmission network. Traditionally radio link systems are used for 2G networks based on STM-1 and applying Add-and-Drop multiplexers in cell hub locations with ports of 2 Mbps or Ethernet, see [Ericsson-2010]. The protection provided can be for 50% or 100% of the traffic of all services. Hence results:

Dimensioning by ADM with integrated radio links

First the equivalent bandwidth required on a ring topology is calculated by the following steps.

i. Calculate the total equivalent bandwidth on the ring eqrbw by

   $\mathrm{SRMUF}(\underline{u\lambda_r}\ \underline{d\lambda_r}, \underline{muB}_r, \underline{mdB}_r, \mathrm{minMUF}, \underline{MUF}_r)$

   $\mathrm{eqrBW} = \max\{<\underline{\ muB_r, MUF_r>\ ;\ }<\underline{\ mdB_r\ MUF_r>\}}$

   $\mathrm{MUFg}_r = \mathrm{eqrBW}_r/\max\{\Sigma_{c=1\ldots C}\mathrm{murBW}_c\ ;\ \Sigma_{c=1\ldots C}\mathrm{mdrBW}_c\}$

ii. If protection is only 50% then eqrbw=eqrbw/2

Then the following procedure results the index for the selected system and calculates the total number of systems, the model provides again a table with corresponding systems

i) Index=1;

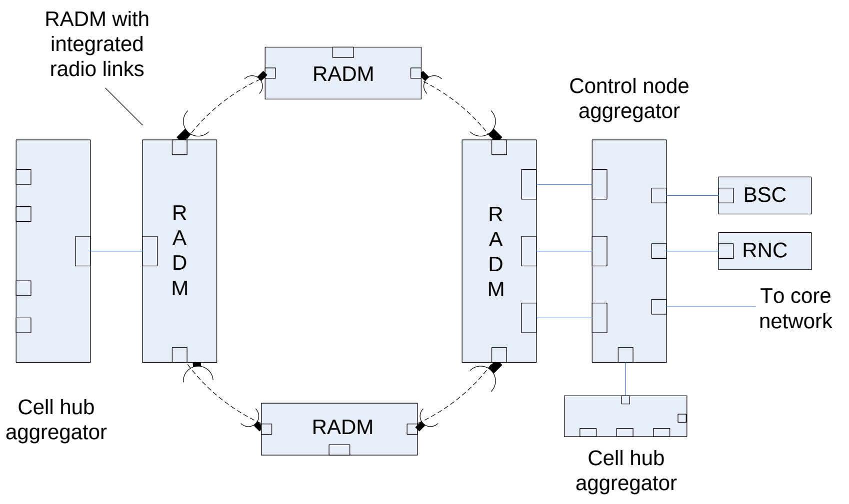
ii) Do while eqrBW> maxBW(index)

index=index+1

end while

The model stores on the aggregation link list the same value as for the star topology.

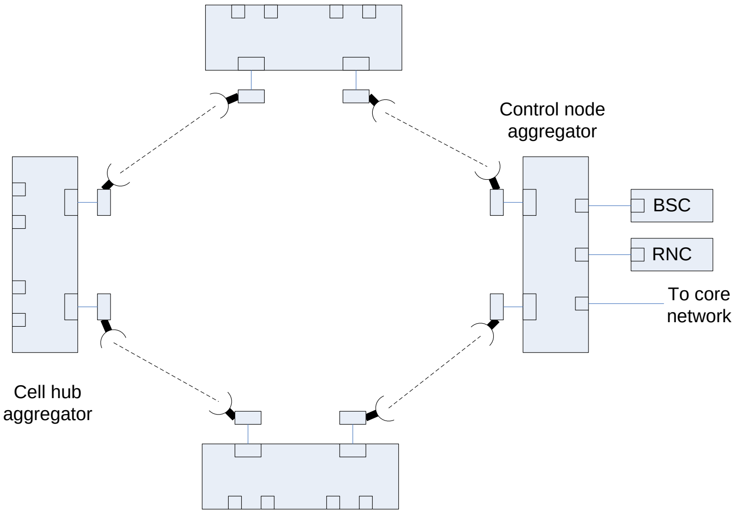
Figure 2-15: Schematic view of a ring topology under radio link based RADM[38]



The model supports as an alternative to the ring topology with a separate layer 1 system the integration of layer 2 with layer 1 in an own ring under the concept of a Metro Ring network. In this case the nodes of the ring are connected by point-to-point radio links as in the case of the tree structure. Note that these Metro Rings currently are working under the "Rapid spanning tree protocoll" RSTP for restoration, see [Navid-2010], [Uhlin-2009]. A 100% protection can be provided by routing of the total bandwidth demand over both, the clockwise direction and on the contra-clockwise one. Hence the total demands on the ring are the sum of the bandwidth from all cell hub locations. Figure 2-16 shows a schematic view.

38 RADM refers to a reconfigurable Add-and-Drop Multiplexer. Currently all ADM are of the RADM type.

Figure 2-16: Schematic view of a Metro Ring



2.3 Backhaul network

The backhaul network connects controller node locations with the highest locations where switching and routing systems are provided, referred to in the following as SwRo locations. The design of this network involves the following tasks:

- Selection of the SwRo locations as a subset of the controller locations,
- Assignation of each controller location to one or two SwRo location resulting in a star structure, and
- Determining the physical topology.

2.3.1 Classification

The RTR-2G/3G model treats the first and second task similar as in the case of the aggregation network, see section 2.2.1. It applies the same algorithm but with an adjustment of the design parameters like minimal distance between the SwRo locations and capacity limitations in the assignment of the number of controller node locations assigned to a SwRo ones. In addition, for resiliency reasons, a controller location can be assigned to two SwRo. This option can be configured by the user of the tool by the input parameter **dswro.** In case that **dswro** =1, each controller location is assigned to two SwRo locations. The protection can again be provided by 50% routing half of the demand over one and the other half over the other connection or by 100% rounting all demand over each connection.

2.3.2 Topology

For determining the physical topology, the model considers the following options:

- Star topology under
    - Implementation by leased lines or
    - Integration of the required bandwidth capacity in the star connections of a physical network for NGN (in case that the mobile operator operates also a fixed network).

The first case means that the physical network also has a star topology where the required bandwidths on the star links determine the number and types of leased lines.

When the backhaul locations are connected to two core node locations (double star), this is carried out in the physcial network in the same way as above.

The second case leads again to a star topology where capacity units are provided through the physical network infrastructure of the NGN operator; e.g. STM-N groups from the SDH or OC-N from the OTN standards.

- Ring topology with the option of 50% or 100% protection under
    - Own radio links or
    - Leased wavelength or leased dark fibre.

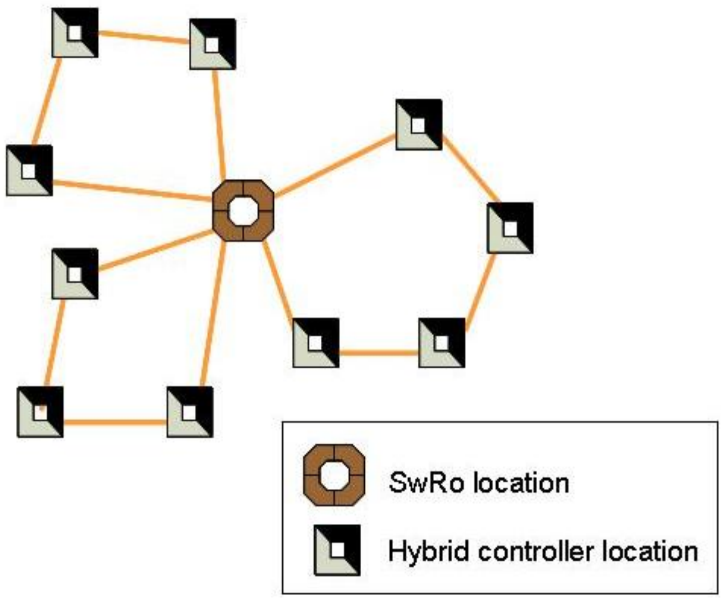
The model considers for the ring topology those connections which minimize the length-depended costs and calculates therefore a ring topology which minimizes the total length. The corresponding algorithm is based again on the algorithm for the travelling salesman problem (TSP), see [Lin-1973]. The model considers additionally that the number of locations in the ring might be limited for reasons of network resilience. The algorithm used for this is known as the “Shamrock"[39] algorithm**.** It consists of two steps:

- Determining the sub-cluster of controller locations to be in the same ring, and
- Calculation of the ring topology for each sub-cluster.

39 Shamrock is the national symbol of Ireland and corresponds to a cloverleaf.

Figure 2-17 shows an example for a backhaul network composed of three rings considering four controller locations as maximum value for each ring[40].

Figure 2-17: Example for a backhaul network topology



Question 21:	What type of topology do you have implemented in the backhaul part of your mobile network?

Algorithm for calculating the Shamrock topology

The algorithm is applied to each cluster, and is composed by two main steps:

1. Calculation of the sub-clusters. Figure 2-18 illustrates a flow diagram of how the subclusters are determined.

2. Calculation of the rings for all sub-clusters. For the calculation of the rings, the model uses a well know heuristic algorithm, see [Lin 1973] already applied in cost models for 2G mobile networks, see [ACCC-2007].[41]

40 We consider as a first approach for the case of own realisation under ring topologies only rings which support one core node. The case of supporting two core nodes requires deeper studies, but we estimate that the support at two core nodes causes large ring lengths which limit its realisation. In case of a star topology, a support at two core node locations (double star) does not generate problems and will be included as an option.

Figure 2-18[42]: Flow diagram of sub-clustering algorithm

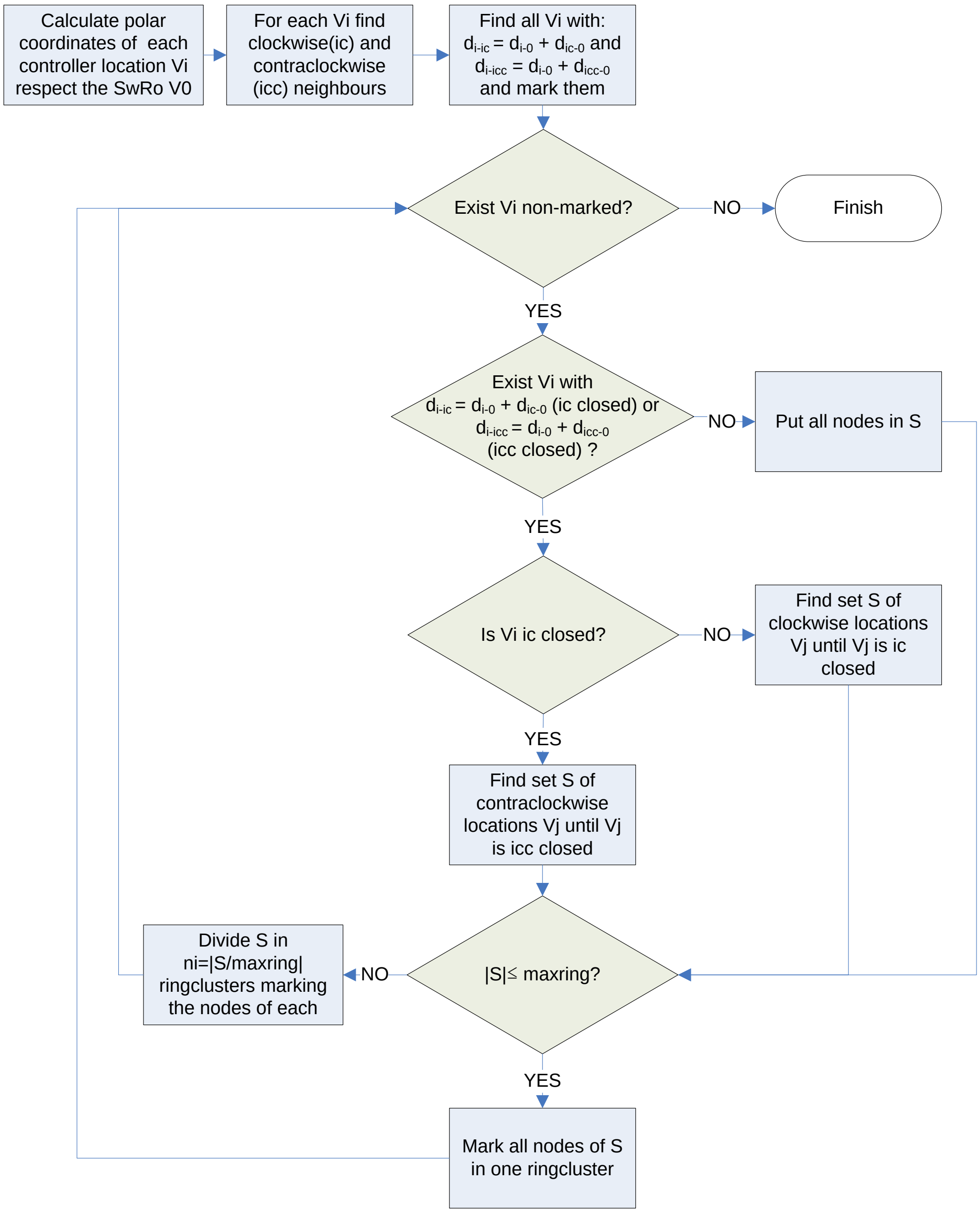


Figure 2-19 and Table 2-9 illustrate an example how the algorithm calculates the parameter values of Table 2-9, considering a maximum of four access locations per ring (maxring=4), in a region with two obstacles (i.e. mountains).

41 The corresponding flow diagram will be included in the final description of the model.

42 The algorithm considers that each node Vi has two neighbours: a clockwise one, Vic, and a contraclockwise one, Vicc, and that a direct connection from Vi to Vic or vice versa is closed when the corresponding real distance is equal to the sum of both distances to the central node so that the shortest path goes over the central node location.

Figure 2-19: a) Example of cluster in a region with two mountains, b) solution provided by the algorithm for a maximum of four access locations per sub-cluster[43]

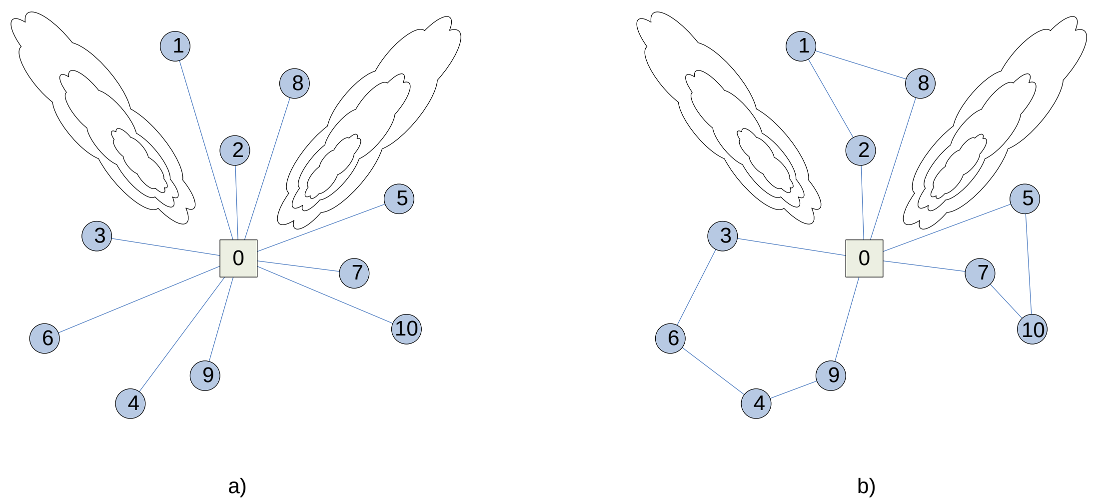


Table 2-9: Parameters values for the example illustrated in Figure 2-19

i	1	2	3	4	5	6	7	8	9	10
ic	2	8	1	6	7	3	10	5	4	9
icc	3	1	6	9	8	4	5	2	10	7
ic closed	N	N	Y	N	N	N	N	Y	N	N
icc closed	Y	N	N	N	Y	N	N	N	N	N
ring cluster index	1	1	2	2	3	2	3	1	2	3

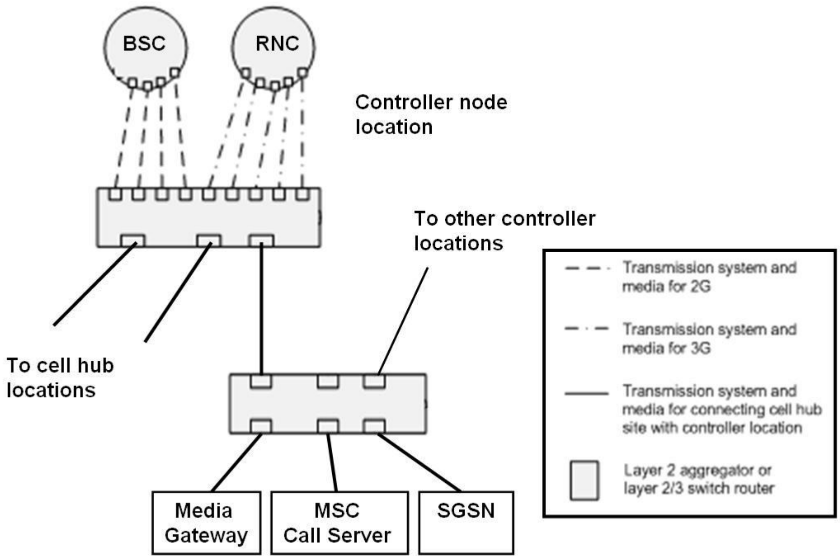
2.3.3 Dimensioning of the backhaul network

The dimensioning of the backhaul network covers the control node aggregator, the cell controller equipment, BSC for 2G and RNC for 3G and the transmission systems connecting the controller node locations with the corresponding core node locations.

43 Note that the clockwise or contraclockwise nodes order applied for forming the subclusters in one ring is not applied for the proper ring calculation, see in the example the subcluster of nodes v7,v5,v10 or v1,v2,v8.

The model considers the same scheme as applied in the dimensioning of the aggregation network part using corresponding tables which contains the traffic flows for the dimensioning.

Figure 2-20: Topology of the 2G/3G backhaul network with its main building blocks



From the traffic flows aggregated in the cell hubs and transported over the links connecting the cell hubs with the controller, one obtains the traffic flow required for the dimensioning of the controller units. Note that the traffic resulting from HSPA services is not evaluated from the RNC but is routed transparently over the aggregation equipment from the link of the cell hub locations to the links of the core node locations.

Question 22:	The model considers that the traffic resulting from HSPA is routed also over the complete hierarchy up to the core (SwRo) node location and is switched in the intermediate location (cell hub and controller node locations) by the corresponding aggregation equipment. Do you implement other options? If yes, please indicate the type of technology you apply.

2.3.3.1 Dimensioning of the BSC and RNC

From the figures aggregated in the cell hubs and on the links connection the cell hub locations with the controller one receives the figures required for the dimensioning of the controller units.

The model considers that the cell controller systems BSC for 2G are dimensioned by one or a combination of the following values:

- Nº of BTS aggregated to an BSC
- aggregated number of users from the corresponding cells $tn2Gu_{cc}$
- number of active connections in units of slots $tnasl2G_{cc}$

Table 2-10 shows an example for BSC dimensioning assuming the operator install only one type of BSC. Note that the four parameter values for the capacity driver are strongly correlated and hence in some from the data sheets of an equipment provider only a subset of values can deduced. In this case the missing value can be set to a high one and is hence ignored in the BSC dimensioning.

Table 2-10: Example for the BSC dimensioning for GSM/GPRS traffic[44]

index	1	2	3
BSC Type	1	1	1
Max no. of BTS	200	400	600
Max. no. of users	$8.6*10^5$	$17.2*10^5$	$25.8*10^5$
Max. no. of active connections in slot units	$1.44*10^4$	$2.88*10^4$	$4.32*10^4$
No. of BSC equipment	1	2	3

44 This example considers that up to 200 BTS can be connected to one BSC and that one BSC, that each BTS can provide up to 9 TRX and that the mean BH traffic per use in nº of slots is 0,01 Erlang

Concerning the dimensioning of the RNC the model applies the same scheme as for BSC in 2G but consider one or any combination of the following values[45]:

- Number of the Nodes B aggregated to a corresponding RNC,
- Aggregated number of users for the corresponding cells $tn3Gu_{cc}$,
- Number of active sessions, $tnase3G_{cc}$, resulting from all users over the corresponding 3G cell sites associated to the controller node loaction,
- Mean bandwidth resulting from the active section and managed from the RNC $tmBW_{cc}$

2.3.3.2 Dimensioning of the controller node aggregator

The controller node aggregation system in the controller node location is provided in a similar way as in the case of the cell hub aggregation system where the two characteristic values maxBW and maxnrport are provided by the same table as for the cell hub aggregator, see Table 2-8.

```
Index=1;
Do while teBW_cc > maxBW(index) and tnport_d(index) >maxnrport
        index=index+1
end while
```

2.3.3.3 Dimensioning of the links from the controller node location to the core one

Concerning the dimensioning of the capacity for the links of the logical structure, the 2G/3G model considers that all GSM/UMTS bearer traffic for circuit switched services, mainly voice, is directed to the media gateway situated in the corresponding SwRo location while the signalling traffic is directed to the MSC call server. The signalling part of the all data packet traffic is routed to the so called packet control unit to the service GPRS support node (SGSN) while the bearer traffic is routed directly to the SGSN[46]. Figure 2-21 shows the corresponding functional blocks complementing the general

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45 This scheme allows to consider all of these parameters or only a subset one e.g. when only the number of Node B aggregated to a RNS is relevant for dimensioning the model user has to set the other parameters to high values. The influence of these parameters to the RNC equipment and a corresponding table with an example like for BSC in Table 2-10 requires additional studies and will be provided in the final version of the model description.

46 The model does not consider the dimensioning of these units because they do not share any circuit switched traffic and hence its cost does not have any influence on the cost of the voice service.

network architecture shown in Figure 1-1. Note that in a pure GSM network the RNC function blocks are not required while in contrast in a pure UMTS network the BTS, TRAU and PCU are not required.

For determining the transmission systems for either a star or a ring topology, the same tasks and corresponding algorithms are applied as in the dimensioning and system assignment for the aggregation network, see subsection 2.2.3, which results in the following tasks:

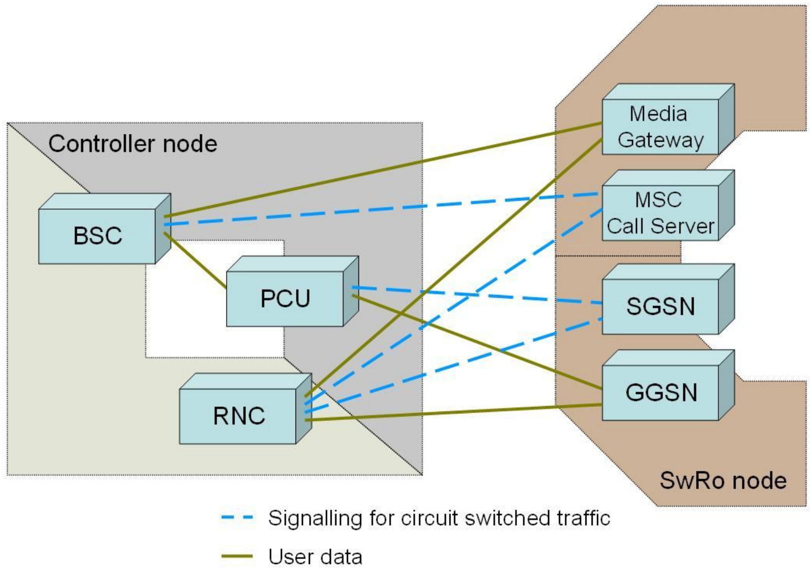
For the star or double star topology:

- Determine the total bandwidth aggregated on each star or double star link and increase this bandwidth by multiplying it with the global mark-up factor assigned by the model user for this network level;
- Calculate the MUF and the equivalent bandwidth for the traffic of each traffic class;
- Provide the dimensioning of the star links considering a dimensioning table with the corresponding parameter values like in the dimensioning of the links in the lower level.

For the ring topology:

- Determine the total bandwidth aggregated on the ring links depending on the option whether the traffic is protected by 50% or 100%;
- Determine the corresponding transmission systems in the same was as discussed in subsection 2.2.3.2.3.

Figure 2-21: Logical connections between the functional blocks of the controller node locations and the one of the SwRo node location[47].



Finally we indicate that the RTR 2G/3G model considers the special case where the number of controller node locations is the same as that of the SwRo node location. In this case the equipment for the controller function is installed in the same locations as the systems for the switching and routing functions and the connections between them are purely internal. Hence no logical structure and physical topology must be provided. We estimate that in this case the dual homed option is not applied because its main objective is the protection against failures in the links. The risk of failure in the equipment is strongly lower than the one for transmission links, and protection against it can be provided by doubling the equipment. We consider the failure of the break down of all equipment in a location, e.g. due to earthquake, as out of the scope of the model[48].

2.4 Core network

The dimensioning of the core network part considers the functional units in the core node locations and the structure and topology of the core network. Note, that for the

47 We consider, that the adaption of the voice coding for GSM or UMTS to the PCM scheme the PSTN/ISDN, in the classical 2G GSM network provided by the TRAU, is provided by the Media Gateway in the core node location.

48 This modelling approach does not exclude that special protection measures for large business users are implemented. Such measures usually generate specific incremental costs, which are imposed to the respective users in their specific contracts.

purpose of a cost model for voice traffic regulation only those functional elements must be dimensioned which have an influence to the cost of voice[49]. The model considers for the design and dimensioning of the core node elements always the functional elements according to Release 4, independent of the UMTS/GSM mix even in the singular case of a pure GSM/GPRS network without any UMTS cell site.

The dimensioning of the core network must be treated differently for the GSM and UMTS circuit switched services traffic part, on the one hand, and the GPRS-UMTS data part, on the other hand. This is due to the fact that the model expresses the corresponding GSM/UMTS circuit switched traffic by fixed units expressed in GSM by the use of slot units, for voice traffic one unit[50], contained in the TRX frame. In the core network part, circuits are emulated and hence all functional units must be considered by a loss system expressed by the classical Erlang loss formula[51].

In contrast, GPRS and UMTS data traffic comes in packet streams and hence a corresponding network design is generally based for each service on the packet rate and the corresponding mean bandwidth value expressed by the product of mean value of the packet rate times the packet length. As already indicated, it follows from queuing theory that the capacities of corresponding packet routing or frame switching systems cannot be fully used but only partly, (expressed in the model by the corresponding global mark-up factor for the core network links) to avoid long queuing delay and congestion. Differently from the loss system design in the GSM part, congestion in packet based systems is critical for the system administrator and must be avoided under all circumstances. In classical packet systems, e.g. the 'improved best effort Internet' known as NGI, congestion avoidance is provided by a combination of different traffic engineering methods as over-engineering, traffic classification and priorisation, random packet deletion, etc.

The RTR 2G/3G model will not consider a dimensioning of these functional elements which integrate only traffic from packet service categories based on packet transport and, as shown, the circuit switched voice traffic does not share these elements with this traffic. Anyway, in case that VoIP traffic is considered for costing purposes, the corresponding mark-up factors which transform mean bandwidth values into equivalent bandwidth values should be calculated for these network elements which are involved in packet voice traffic. Similarly, as already shown before, the multiplication of the mean bandwidth required for each packet transported service with the mark-up factor provides

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49 An exception is when Voice over IP services between mobile end user and user connected to best effort Internet e.g. Skype is considered as a service to be regulated.

50 An exception is the traffic resulting from SMS services which is routed over the capacities reserved for signalling traffic. The GSM part of the RTR 2/3G model, however, considers the SMS traffic demand by equivalent slots amount.

51 Note that in the core part for voice traffic, a similar codification for both GSM and UMTS voice traffic is applied, namely AMR (UMTS) or G.722 (GSM) with 12.65 Kbps in the air interface, hence not any differentiation between GSM and UMTS is required.

the equivalent bandwidth which is one of the drivers for the assignment of the switching and routing systems as also for the multiplexing and transmission systems in the physical network part.

The equipment is similar to the aggregation equipment in lower level node locations but requires traffic routing functions and hence corresponding IP/MPLS routers. These routers aggregate and distribute the traffic from all considered service categories. The model bases the dimensioning on tables with the characteristic values of the router where the drivers are similar to those for the aggregation equipment[52].

2.4.1 Design of the core systems for the GSM and UMTS circuit switched traffic

The core network locations (already determined in the backhaul network) with their corresponding softswitch-systems (media gateway) are the first points where traffic aggregation for GSM circuit switched services applies. This is mainly important for the circuit switched services because the required bandwidth is dimensioned by the Erlang loss formula. It is well known that these capacities are reduced under traffic aggregation. The effect is apparent from the example in the marked part of Table 2-11 showing that the bandwidth requirement per GSM circuit switched traffic unit is reduced neither in the cell hubs nor in the BSC of the controller locations due to the fact that they do not provide traffic aggregation[53]. In contrast the bandwidth reduction in the SwRo node implemented by the media gateway is significant.

In UMTS things are different due to the fact that the dimensiong in the fixed network part is based on packet and not on circuit aggregation and hence the aggregation occurs at all network levels depending on the occupation degree in the equipment and transmission systems. This occupation degree is a parameter applied by the operator to avoid congestion and as already discussed the model considers this parameter as a global mark-up factor gMUF in form of an input parameter for each network level. The resulting individual mark-up factors for each traffic class are calculated by the model. The calculation scheme is therefore more complicated and cannot easyly be provided by an EXCEL example. Corresponding results will be presented after the first implementation of the model.

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52 Examples for corresponding parameter values under consideration of currently equipments will be included in the document which provides the final description of the implemented model.

53 This does not apply for UMTS voice traffic in the aggregation and backhaul parts because its dimensioning is provided by a waiting system and not by a loss system. Therefore stochastical multiplexing applies and the real bandwidth per traffic unit is calculated from the mean bandwidth required per traffic unit multiplied with the corresponding mark-up factor.

Table 2-11: Example for the traffic and bandwidth requirement from GSM traffic in the different nodes of the 2G/3G network[54]

BW calculation for GSM part in different nodes of the Hierarchy			
Allowed loss for GSM traffic in BH	0.01	number of GSM cells site per cell hub	10
No. of users in an GSM cell site	115	BH traffic in cell hub	57.5
BH traffic in slots per user	0.05	GSM BW requ. per cellhub	2560
No. of slots per TRX	6	nr of cell hubs per BSC	10
BW requirement per TRX kbps	128	BH traffic in BSC	575
BW requirement per GSM cell site kbps	256	BW requ. per BSC node	25600
No. of BSC nodes per core node	10	BW per traffic unit BTS cell site	44.5217
Circuit switched traffic per core node	5750	BW per traffic unit cell hub	44.5217
Corresponding number of circuit units	5755	BW per traffic unit BSC node	44.5217
BW required per Media Gateway node	122773	BW per traffic unit in core node	21.3518

The two main elements for circuit switched traffic are the media gateway and the MSC call server. The model considers that the media gateway is installed in each SwRo location while the MSC call servicer is installed only in a limited number depending on an input parameter given by the model user[55]. The driver for determining the media gateway system are the BH traffic and the corresponding number of required circuits, while the dimensioning of the MSC call server depends on the BH calling rate. Hence the total circuit switched traffic required in the BH must be calculated where this traffic is divided into on-net, off-net outgoing and off-net incoming traffic.

Hence, the model has to determine for the circuit switched on-net traffic and for the off-net incoming traffic a corresponding traffic matrix which provides the traffic values routed between the different SwRo locations while the off-net outgoing traffic is routed to the geographically nearest SwRo location which provides interconnection to the PSTN/ISDN[56]. The number of locations with PoI facilities to the PSTN/ISDN is configurable by an input parameter and the model situates the corresponding

54 Note that this table was created by a small EXCEL program for demonstration purpose and hence provides only an example to illustrate the concept, the green marked figures are given input for the example and the yellow marked are the main results from which the conclusions are derivates. The main figure is the number of circuit units in a core node resulting from the circuit switched traffic inn the core node. This figure is calculated assuming a blocking probability of 1% and the results show that due to the strong traffic aggregation the Erlang loss formula is in the linear domain where 1 Erlang corresponds early to one circuit.

55 The MSC call server can serve a high number of calls such that normally one call servicer will be sufficient. Anyway for reasons of network availability at least two MSC call server are installed either in the same location or in two different one

56 From a practical point of view most GSM Mobile Networks provide interconnection to the PTSN/ISDN at all core net locations and hence the traffic is routed internally to the corresponding interfaces, one for the proper 64kbps circuits of the PSTN/ISDN and one for the signalling base on the CCSSnº7.

equipment in the locations with the highest traffic aggregation. For the off-net voice traffic the model has to install the the corresponding interface cards in the media gateway or, if required, in a session border gateway.

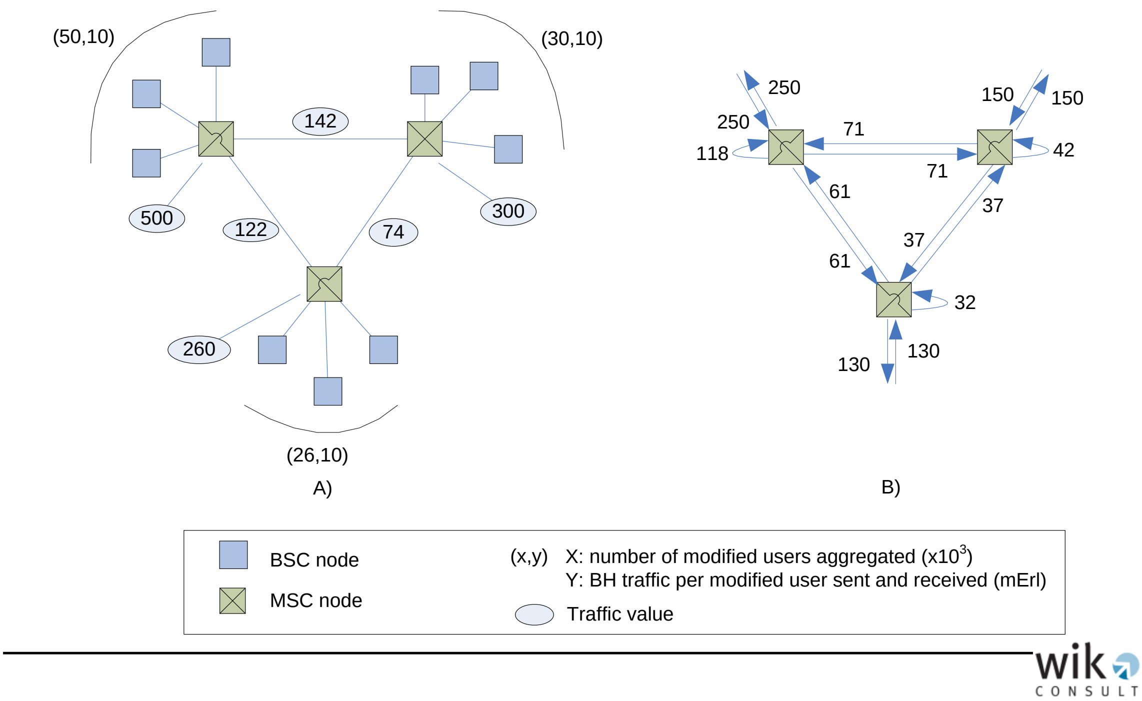
Question 23:	The model considers that the Media Gateway provides the interconnection to PSTN/ISDN. Do you provide additionally interconnection at a Media Gateway to an IP network for supporting voice termination for VoIP?

For the calculation of the traffic relations in the different directions inside of the core network and to and from the interconnection facilities, the model calculates the corresponding traffic matrix based on the circuit switched traffic weights in SwRo locations and considers that the on-net traffic is the sum of the originated and received traffic. Figure 2-20 shows an example for the on-net traffic distribution, where three locations generate 500, 300 and 260 Erlangs of on-net traffic respectively. In the case of the location generating 500 Erlangs and assuming that incoming traffic is similar to the outgoing one[57], 250 Erlang of outgoing traffic are distributed over the different locations depending on their weigths. In this case, 71 Erlangs will be routed to one locations, 61 to the other one and 188 Erlangs will be kept inside the proper location.

The core network treats the UMTS circuit switched services traffic similarly as the circuit switched data for GSM, given that, as already mentioned, both use in the core network virtual connections on MPLS tunnels applying a similar bandwidth for voice connections either from UMTS or GSM units, e.g. AMR-WB (G.722.2). .

57 The symmetry between incoming and outgoing traffic does not disturb the cost calculation because the costing of the network elements is based on the sum of both off-net in and off-net out traffic. Only in the case where PSTN/ISDN interconnection in a subset of the core net location is considered would the asymmetry affect the traffic load on the core links. From earlier studies we conclude that the number of core network locations is small and therefore in general interconnection with the PSTN/ISDN at all core network locations is provided.

Figure 2-22: Example for the traffic distribution and routing for on-net traffic: A) Traffic pattern after routing, B) Traffic distribution pattern[58] .



2.4.2 Design of the core systems for the GPRS/UMTS data traffic

The total data traffic consists of both the data from the GPRS/EDGE integrated in the BTS network and of UMTS/HSPA data. Data traffic requires connections from a[59]:

- GPRS/UMTS/HSPA user to an application server situated at one of the own SwRo locations
- GPRS/UMTS/HSPA user to an application server situated in a different network

The data traffic with destinations to an application server inside the network is routed to the geographical nearest SwRo location where a corresponding server is installed, typically at the core node with the highest traffic load. The model considers an input parameter for determining the number of application server locations. These servers will be situated at the SwRo locations with highest traffic load. Note also that the model considers the capacity of the data traffic on the network links but does not provide a

58 Remember that the modified users consist of the extended user number taking into account the user movement, see section 1.3.
59 There have not been identified services that require a connection between two GPRS/UMTS/HSPA users (without using an intermediate server).

dimensioning of the servers themselves as they do not influence the cost for call termination.

Question 24:	In which locations of your network do you usually place application servers?

The data traffic with destination to an application server outside the network is routed to the geographical nearest SwRo location where a corresponding PoI is installed. The number of PoIs to other networks is configurable by an input parameter, these PoIs will be situated at the SwRo locations with highest traffic load because this is the preferred choice from a costing point of view. .

Question 25:	How many POIs do you operate in your mobile network and where are they located?

2.4.3 Logical and physical core network design

The model considers that in Austria the number of core network locations will be limited and hence the network structure for the logical network is provided as fully meshed consisting of N*(N-1) direct connections where N is the number of core locations. From this follows that on-net traffic and off-net incoming traffic is routed at most over two core locations and its corresponding direct connections between them.

Concerning the physical layer the model assumes that connections are implemented by one of the following options:

- Digital leased lines or pseudo-wire connections, e.g. circuit emulation over IP/MPLS,
- Provided from the SDH infrastructure of a fixed network operator, or
- By own transmission equipments using leased dark fibre.

In the first two cases, the model considers for the physical topology a fully meshed network composed of N*(N-1)/2 links considering that the capacities for physical links are symmetrical in both direction. The third case is implemented in form of a ring topology with exactly N links. The model considers for the dimensioning of the core links again the global mark-up factor gMUF provided from the model user for this network part and calculates the individual mark-up factors for each service class by the same procedure as applied in the aggregation and backhaul network parts.

Concerning the system assignment to the physical links the model considers for the first two cases the same scheme as discussed in subsection 2.2.3. For the third case, the model assumes the application of RADM or ROADM equipment and a 100% protection of the ring capacities, hence the required bandwidth of the links of the ring results from the sum of the maximal values between each of the asymmetrical logical connections.

The assignation of the required N equipments of RADM or ROADM[60] type is provided by the same scheme as shown in subsection 2.2.3, while the number of fibre pairs is derived from the number of RADM/ROADM in each core node location.

2.4.4 Design of additional core network units

Such additional core network units are the:

- Gateway- and Support GPRS service node,
- Different types of server such as SMS, MMS, WEB etc., and
- Registers for the control plan (EIR, VLR, HLR).

The model does not consider the design and dimensioning of data equipment and interfaces with other networks because these equipments do not influence the cost calculation for call termination, the same is true for the different types of servers. In contrast the model has to consider the registers for the control plan. The number of EIR and HLR locations is determined by the user of the model by an input parameter. The model assumes that the EIRs[61] and the HLRs are situated at a subset of the core network locations, mainly the one with the highest traffic load, and the driver for the number of registers is the number of mobile users in the network. For reasons of network availability there are at least two registers where each of them can handle the total control traffic demand.

Question 26:	The model considers that the number of users is the main driver for dimensioning the HLR. As a consequence in a pure LRIC model the HLR cost does not influence the (marginal) cost for voice call termination. What is the driver you apply for dimensioning the HLR ?

60 RADM will be applied when the demand between the core node location is expressed by electrical signals mainly from SDH (STM-N) and OADM when these signals are optical ones

61 In the case that an operator does not install the EIR the corresponding cost value is put to zero

The model considers that at each SwRo location a VLR is installed normally as part of the MSC and that the driver for dimensioning is the number of users concentrated at the core node.[62]

Question 27:	The model considers that the VLR is an integrated part of the MSC call server and hence the driver for dimensioning it is, like for the MSC server, the number of BH call attempts. As a consequence the cost of the VLR influence to the pure LRIC cost calculation for the cost of voice call termination. What driver do you apply for dimensioning the MSC call server and for the integrated VLR ?

2.5 Summary for topology and transmission technology and redundancy concepts

This section summarises the different options considered by the model for:

- Topologies,
- Transmission systems and node equipments, and the
- Redundancy concept.

2.5.1 Topologies, transmission systems and node equipments considered by the model

The model considers four basic topologies and implements corresponding algorithms for their optimal design. The use of the topologies depends on the network levels they connect and the applied transmission equipment. The following

62 This results from the assumptions that the number of users from other core net cluster visiting the considered core net cluster is the same as the number of users from the core net cluster visiting others one.

Table 2-12 summarises the possible uses of the three topologies at the various network levels together with the corresponding systems.

Table 2-12: Topologies supported by the model in relation with the network level and transmission technology

Connection	Topology	Leased line	Mircowave Systems	Dark fibre	Four-wire copper
cell site – cell hub node	star	x	x	x	x
	tree	--	--	--	--
	ring	--	--	--	--
	meshed	--	--	--	--
cell hub – controller node	star	x	--	--	--
	tree	--	x	x	--
	ring	--	x	x	--
	meshed	--	--	--	--
controller node - core node	star	x	--	--	--
	tree	--	--	--	--
	ring	--	x	x	--
	meshed	--	--	--	--
Core node - core node	star	--	--	--	--
	tree	--	--	--	--
	ring	--	--	x	--
	meshed	x	--	x	--

The model considers a generic scheme based on the driver which determines the type of system to be used; for point-to-point transmission systems these drivers are:

- maximal bandwidth of the system
- maximal number of ports,
- types and number of ports (which determines the bandwidth of the port), and
- maximal length of the link without signal regenerator.

The same scheme is applied for transmission systems based on ring topologies where the maximal bandwidth refers to the capacity of the ring. Table 2-13 shows as an illustrative example the values of these drivers for the systems of the SDH/ NG-SDH technology[63].

63 Next Generation SDH is the extension of the synchronous digital hierarchy to include Ethernet Signals from 10, 100, 1G, 10G.

Table 2-13: Parameter values for the transmission systems of the SDH or NG-SDH hierarchy

	Parameter values	STM-1	STM-4	STM-16	STM-64	STM-256
	Bandwidth	149	599	2,396	9,584	38,338
Point-to-point transmission link	Port types	E1, E3, 10/100E	STM-1, 100E	STM-1, 4 100/1GE	STM-1, 4 100/1G, 10G	STM-1, 4 100/1G, 10G
ADM	Port types	E1,E3, 10E	STM-1, 100E	STM-1, 100E	STM-1, 4 1GE	STM-1, 4 1GE, 10GE
OADM	Port types	---	---		STM-1, 4, 1GE	STM-1, 4 1GE, 10GE

The model provides tables for each option of transmission type and network level where the type of system is selected. These tables are ordered by the level of cost, and as in general the costs are related to the maximal bandwidth, this order is according to increasing bandwidth, e.g. the cost of the leased line for the connections between the cell hub and the controller node might be ordered from E1 over E3, STM-1 and 100E to STM-1. Table 2-14 shows an example for the transmission systems in relation with the network level[64].

Table 2-14: Example of transmission systems or leased lines applied in the different network levels

	Leased line	RF Systems with Bandwidth	Dark fibre	Four-wire copper
cell site - cell hub node	E1, E3, STM-1 100E	2, 34, 155, 10, 100	1GE over fibre	100E over Cu
cell hub - controller node	E3, E4, STM-1	34, 155, 10, 100	1GE over fibre	----
controller node - core node	STM-1, STM-4	100, 155	1GE or 10GE over fibre	---
Core node - core node	STM-1,4,16	---	ADM or OADM	---

64 This is only an example of transmission systems for which we estimate that they are currently used, the optimal combination of systems must be determined after the implementation of the model.

The equipment installed in the node locations of the different levels is differentiated into two types, i.e.

- General equipment for aggregation, distribution and routing, and
- Equipment for the specific functions of the node level,

as shown in Table 2-15.

Table 2-15: Equipment in relation with the network node type and dimensioned by the model[65]

Network level	General equipment	Specific equipment
Cell site	Layer 2 aggregator (100E)	BTS, Node B, HSPA
Cell hub node	Layer 2 aggregator (100E)	---
Controller node	Layer 2 aggregator (100E)	BSC, RNC
Core node	Layer 2/3 aggregator and router (IP/MPSL router)	Media Gateway, MSC call server, HLS, VLR, EIR,

2.5.2 Redundancy concept considered by the model

Redundancy is required for maintaining a minimal degree of network availability in case of overload or breakdown of equipment or transmission line. The model considers the following means which the user can select optionally:

- Reducing the utilisation degree of the equipment by an over-dimensioning of the global capacities required for the transmission links,
- Installation of at least two equipments from the same type even in case this is not required in terms of capacity,
- Connecting of a lower layer location to two different upper locations (double star), and
- Providing meshed or ring topologies.

The over-dimensioning applies to the different connections between the nodes of the 2G/3G hierarchy and is determined by global mark-up factors gMUF separately for each network level. We estimate, that these mark-up factors are higher for lower level and

65 Remember that the model considers for the dimensioning only this equipment which shares voice traffic.

smaller for higher levels because the transmission systems can be higher loaded by increasing bandwidth provided from the transmission system without causing congestion. From experience we know that operators apply utilisation factors between 0.65 and 0.85 leading to global mark-up factors from 1.18 up to 1.54. Note that in 2G/3G mobile networks the downstream bandwidth requirement is higher for most data services than the upstream one. Hence in case of congestion even under a correct selection of the mark-up factors increasing delay and/or packet loss can happen already in higher level parts and we estimate that the mark-up factors for the lower level must not be significantly higher than those for the upper levels and in the lowest level even less. The following table shows an example for the mark-up factors in the different network levels, but the definitive values for Austria will be calibrated when the model is applied. Note that with the provision of redundancy in the transmission systems a corresponding redundancy is reached in the common aggregation and routing units.

Table 2-16: Example for the global mark-up factors for providing redundancy on the transmission links

Connection type	gMUF
cell site – cell hub node	1.2
cell hub – controller node	1.25
controller node - core node	1.2
Core node - core node	1.15

Concerning the redundancy means provided for specific equipments the model provides the corresponding options through means listed in Table 2-17.

Table 2-17: Means to achieve redundancy for the node equipments in relation with the network level

Network level	Means to achieve Redundancy
Cell site	Not any
Cell hub	Not any
Controller node	At least two BSCs and RNCs, double star connection to the core node locations for controller node locations which are not collocated in the core node location
Core nodes	At least two HLRs, MSC call servers (at the same location or in different ones)

Concerning the network topologies, if follows from Table 2-13 that the model allows the provision of ring topologies upwards from the cell-hub locations through the core network part assuring a 50% or 100% restoration of the lost capacities in case of the interruption of one of the transmission links or corresponding equipments. Under the provision of leased lines in a topology, the availability can be increased by contracting a leased line implemented under SDH technology with a higher value of availability and a restoration guarantee in a predefined time limit, e.g. 50 ms.

Table 2-18: Example for the global mark-up factors for providing redundancy on the transmission links

<table>
<tr><th>Connection type</th><th>Star leased line</th><th>Star proper system</th><th>Ring</th></tr>
<tr><td>cell site – cell hub node</td><td rowspan="3">By leased line with restoration in a time limit</td><td>Not any</td><td>Not applied</td></tr>
<tr><td>cell hub – controller node</td><td>N/A</td><td rowspan="3">50% or 100%</td></tr>
<tr><td>controller node - core node</td><td>N/A</td></tr>
<tr><td>Core node - core node</td><td>N/A</td><td>N/A</td></tr>
</table>

Note that for the cell sites and the connections from cell sites to the cell hub node the model does not apply any specific redundancy means. This follows from cost considerations because this network part causes the highest capex and opex and additional redundancy means would cause additional cost which are not justified in terms of the increased availability at the low level[66].

66 Note that in regulatory procedures for the PSTN/ISDN redundancy in the Subscriber Access has never been considered.

3 Ermittlung der Kosten

Da dieser Bereich von deutschsprachigen Mitgliedern des Teams vertreten wird und die englischsprachigen Mitglieder hier keinen Input zu leisten brauchen, wird dieser Teil in Deutsch gehalten. Im Übrigen basiert er im Wesentlichen auf dem entsprechenden Teil des Angebots, da dort der Ansatz bereits so detailliert wie für die Grobspezifikation erforderlich dargestellt worden ist. Er wird hier der Vollständigkeit halber mit nur geringen Änderungen wiedergegeben

3.1 Voraussetzungen

Der Startpunkt für die Kostenberechnung ist die Liste der Systeme und Anlagen und ihrer jeweiligen Anzahl, die von den Netzplanungsmodulen bestimmt worden sind. Netzkosten bestehen aus den annualisierten Capex und den Opex. Im Fall der Verwendung von LARIC würde hierauf auch ein Aufschlag für Gemeinkosten erfolgen, was aber bei Verwendung von pure LRIC für die Terminierung im Mobilfunknetz nicht erforderlich ist. Für den Fall, dass Teile der Kapazität gemietet werden, was vorrangig für Übertragungswege in Frage kommt, kommt anstelle von Capex und Opex ein entsprechender Mietbetrag zur Geltung. In den folgenden Abschnitten werden wir unsere Ansätze zur Bestimmung dieser Kosten beschreiben, wie auch die Zuordnung des entsprechenden Kostenanteils zu Terminierung.

Neben der Liste der Systeme und Anlagen wird von den Netzplanungsmodulen auch das Volumen für Terminierung übernommen, damit von den Kosten auf Basis pure LRIC für das gesamte Segment der Terminierung ausgehend auch die pure LRIC pro Minute dieses Dienstes berechnet werden können.

Zusätzliche Inputs, die für die Kostenermittlung benötigt werden, und ihre Quellen sind wie folgt:

- Mietleistungspreise – Werden von RTR zur Verfügung gestellt;
- Preise der Anlagen und Systeme – Werden von den Unternehmen erfragt, bzw. es wird auf die Datenbank des WIK zurückgegriffen;
- Lebensdauern der Systeme und Anlagen – Stehen aus der Datenbank des WIK zur Verfügung;
- Der Wert des WACC zur Ermittlung der annualisierten Capex – Wird von RTR zur Verfügung gestellt; und
- Informationen zu Opex – Wird von den Unternehmen erfragt, bzw. es wird auf die Datenbank des WIK zurückgegriffen.

3.2 Annualisierte Capex

Der erste Schritt zur Ermittlung der annualisierten Capex in einem BU-Modell besteht darin, den Investitionswert der Anlagen des vom Netzplanungsmodul bestimmten Netzes zu bestimmen. Dadurch dass diese Bewertung mit den gegenwärtigen Preisen der Anlagen vorgenommen wird, stellt das Ergebnis den Wert eines vollkommen neuen Netzes dar. Dies ist konsistent mit der konzeptionellen Überlegung, wonach die Kosten des Netzes denen entsprechen sollen, die von einem neu in den Markt tretenden Anbieter aufgebracht werden müssen.

Abgeleitet von diesen Investitionswerten der einzelnen Anlagen sind jährliche Beträge zu ihrer Amortisation zu bestimmen, wobei diese Beträge sowohl die Abschreibungen als auch die Zinsen für die Bereitstellung des Kapitals abdecken müssen. In BU-Modellen ist es üblich, dafür den Annuitätsansatz zu benutzen, bei dem Abschreibungen und Zinsen in einem Berechnungsschritt bestimmt werden. Von diesem Ansatz werden wir in diesem Abschnitt bei der Darstellung unserer konzeptionellen Überlegungen zur Ermittlung der Capex auch ausgehen. Im nächsten Abschnitt werden wir dann darauf eingehen, wie Abschreibungen und Zinsen als getrennte Größen berechnet werden können.

Der konzeptionelle Ansatz zur Bestimmung der annualisierten Capex beinhaltet folgende Überlegungen:

(1) In Übereinstimmung mit ökonomischer Abschreibung müssen die in einem Jahr zur Anrechnung gebrachten Capex einer Anlage dem Wertverlust während dieses Jahres entsprechen.

(2) Dieser Wertverlust wird durch den in dem betreffenden Jahr erbrachten Anteil an der gesamten erwarteten Ausbringung der Anlage bestimmt. Die zweite Komponente in diesem Wert, d. h. der Wert je Leistungseinheit, entspricht den durch das Modell zu berechnenden Kosten, die durch die Parametrisierung (ursprünglicher Investitionsbetrag und Lebensdauer der Anlage, Zinssatz) vorbestimmt sind.

(3) Es wird von der regulatorischen Vorgabe ausgegangen, dass aus Gründen der Nichtdiskriminierung die Kosten einer jeden Leistungseinheit, unabhängig zu welchem Zeitpunkt diese erbracht wird, in einem ökonomischen Sinne gleich sein sollen.

Diese Überlegungen bedeuten, dass die Capex, die für eine Anlage in einem gegebenen Jahr zur Anrechnung gebracht werden, proportional zu dem von ihr erbrachten Leistungsvolumen stehen müssen. Dabei ist dann auch zu beachten, dass Volumina der Ausbringungsmengen in der Regel von Jahr zu Jahr variieren, ferner, dass sich die Preise der Anlagen während der Lebensdauer der Anlagen verändern, so dass der zum jeweiligen zukünftigen Zeitpunkt geltende Investitionswert des Netzes sich ändert. Beide Entwicklungen sind mit zu berücksichtigen, wenn insbesondere der Überlegung unter (3) Rechnung getragen werden soll. Im Folgenden werden wir zeigen, dass diese Anforderungen mit dem Annuitätsansatz erfüllt werden können. Nach unserer Einschätzung muss im Rahmen eines BU-Kostenmodells jeder Ansatz, der den Überlegungen unter (1) bis (3) gerecht werden soll, mit der unten entwickelten Annuitätsformel kompatibel sein. Wir werden diese Formel zunächst in der einfachen Version vorstellen, in der von unveränderten jährlichen Ausbringungsmengen und unveränderten Preisen der Anlagen ausgegangen wird, und dann den Fall betrachten, in dem zukünftiges Wachstum und Änderungen in den Preisen der Anlagen mit einfließen.

Formal gehen wird dabei wie folgt vor. Wir bezeichnen mit I den Wert der betreffenden Anlage zum Zeitpunkt der Investition und mit A den jährlichen Betrag, der zur Amortisation von I erwirtschaftet werden muss. Ferner, lassen wir i für den Zinssatz stehen, definieren $q = 1/(1+i)$ und bezeichnen mit n die Länge der wirtschaftlichen Lebensdauer der Anlage. Die folgende Relation muss dann gelten, um sicher zu stellen, dass das eingesetzte Kapital einschließlich zu zahlender Zinsen erwirtschaftet wird:

$$I \quad = \quad A * [q + q^2 + \ldots + q^n] \,.$$

Unterstellt wird dabei, dass der Restwert der Anlage zum Zeitpunkt n vernachlässigbar gering ist. Aus der obigen Formel folgt, dass

$$A \quad = \quad c * I \,,$$

wobei

$$c \quad = \quad 1 / [q + q^2 + \ldots + q^n] \quad ,$$

oder nach algebraischer Umformung,

$$c \quad = \quad (1/q) * [1 - q] / [1 - q^n] \;\; .$$

Für diese Berechnung müssen der Zinssatz (gewöhnlich in der Form des Weighted Average Cost of Capital, oder WACC) und die erwartete Lebensdauer der betreffenden Anlage bekannt sein. Hervorzuheben ist, dass in dieser Ableitung die Amortisationsbeträge A über die Zeit hinweg gleich bleiben, da annahmegemäß in dieser einfachen Version Mengen und Preise der Anlagen während der n Perioden unverändert bleiben.

Während der wirtschaftlichen Lebensdauer einer Anlage ändern sich in der Regel mindestens zwei Parameter, die einen starken Einfluss auf die Kostenbestimmung haben: die jährlichen Ausbringungsmengen der Anlage, die gewöhnlich wachsen, und der Preis der Anlage, der sich in die eine oder andere Richtung verändern kann. Diese erwarteten Änderungen sind bei der Preissetzung in Betracht zu ziehen, da ein zukünftiger potentieller Wettbewerber, dessen Preissetzung zu antizipieren ist, von diesen dann geänderten Bedingungen ausgehen wird. In der Annuitätsformel können diese Entwicklungen berücksichtigt werden, indem die Formel für q wie folgt spezifiziert wird:

$$q = [(1+g)*(1+\Delta p)]/(1+i)$$

wobei

g = prognostizierte durchschnittliche Wachstumsrate des Leistungsvolumens der Anlage während der wirtschaftlichen Lebensdauer der Anlage, und

Δp = durchschnittliche erwartete Veränderungsrate im Preis der Anlage (als Modern Equivalent Asset) während der wirtschaftlichen Lebensdauer der Anlage.

Werden entsprechende Werte für q in die Gleichung

$$I = A * [q + q^2 + \dots + q^n]$$

eingefügt, ergeben sich Amortisationsbeträge A für die sukzessiven Jahre, die ceteris paribus von Jahr zu Jahr um (1+g) größer sind als die im Jahr zuvor, entsprechend dem prognostizierten Wachstum der Leistungsmenge. Auf diese Art und Weise wird gewährleistet, dass jeder zukünftigen Einheit an Leistungsmenge derselbe Betrag an Abschreibung zugeschrieben wird als einer gegenwärtig erbrachten Einheit. Einem analogen Argument folgend, stellt der Faktor Δp sicher, dass zu jedem Zeitpunkt der Abschreibungsbetrag proportional zum Wert der Anlage erfolgt. Bei sowohl $g > 0$ wie $\Delta p > 0$ werden den zukünftigen Perioden größere Amortisationsbeträge zugerechnet als der gegenwärtigen. Falls $g > 0$ aber $\Delta p < 0$, was für bestimmte Anlagen insbesondere neuerer Technologie durchaus der Fall ist, hängt die Entwicklung von A über die Zeit hinweg von den genauen Werten der beiden Parameter g und Δp ab, d. h. $(1+g)*(1+\Delta p)$ kann größer oder kleiner als 1 sein.

Bezüglich des für die Verzinsung des eingesetzten Kapitals anzusetzenden Zinssatzes werden in der Aufforderung zur Angebotslegung keine Anforderungen gestellt. Wir gehen deshalb davon aus, dass dieser Wert von der RTR zur Verfügung gestellt wird.

Der hier beschriebene das Wachstum des Outputs und die Entwicklung der Preise der Anlagen in Betracht ziehende Ansatz entspricht der ökonomischen Abschreibung, da die Abschreibungsbeträge dergestalt bestimmt werden, dass sie in jeder Periode dem Wertverlust der Anlage entsprechen. Gleichzeitig entspricht er auch dem Gebot, Grundlage für eine nicht-diskriminierende Preisbildung zu sein. Dieser letzte Aspekt ergibt sich daraus, dass die Zinslast auf der Basis eines durchschnittlich eingesetzten Kapitals berechnet wird, was die Voraussetzung dafür ist, dass die Kosten der Anlage einschließlich Zinsen in jedem Jahr proportional zu der Ausbringungsmenge und zum Wert der Anlage bestimmt werden.

3.3 Abschreibungen und Verzinsung als getrennte Größen

Die Ausführungen im vorangegangenen Abschnitt behandeln den von uns als für ein BU-Modell am ehesten geeigneten konzeptionellen Ansatz zur Bestimmung von Capex. Er wird im Modell als die Option implementiert, bei der der Kapitaldienst bestehend aus Abschreibungen und Zinsen in einem Berechnungsschritt ermittelt wird. Das Modell wird auch die Option anbieten, mit der Abschreibungen und Zinsen getrennt ausgewiesen werden können.

Welcher konzeptionelle Ansatz dabei anzusetzen ist, ist dann von der RTR vorzugeben. Die Formel, die dazu im Modell implementiert wird, kann beliebig danach bestimmt werden, ob z.B. lineare oder ökonomische Abschreibung angesetzt, oder die Berechnung der Zinslast auf der Basis des Restwertes einer Anlage oder entsprechend dem durchschnittlich gebundenen Kapital vorgenommen werden soll. Auch bei Anwendung des Annuitätsprinzips können Abschreibungen und Zinsen getrennt ausgewiesen werden. Entsprechend der Parametrisierung der Annuitätsformel (siehe obigen Abschnitt) ist dann zunächst für die betreffende Periode die Abschreibung zu bestimmen und dann die Zinsbelastung als Differenz zwischen Abschreibung und dem Annuitätsbetrag. Bei Verwendung der einfachen Annuitätsformel wäre die lineare Abschreibung zu verwenden, bei einer Parametrisierung, die prognostiziertes zukünftiges Wachstum und erwartete Preisänderungen berücksichtigt, wäre entsprechend ökonomische Abschreibung zu bestimmen. Es würde sich dabei zeigen, dass wegen der dem Annuitätsansatz zu Grunde liegenden Konzeption die Abschreibungs- und die Zinsbeträge von Periode zu Periode in einem konstanten Verhältnis zueinander stehen.

Generell betrachten wir den Ausweis von Abschreibungen und Zinsen entweder als getrennte Größen oder als in einer Zahl zusammengeführt als eine Wahl bezüglich der Darstellungsform und nicht als eine Wahl zwischen konzeptionellen Ansätzen. Wie erwähnt, werden in dem für die RTR zu entwickelnde Modell beide Optionen implementiert. Welche Konzeption bei der Bestimmung von Abschreibungen und Zinsen implementiert werden soll, wird Entscheidung der RTR sein.

3.4 Opex

Dieser Typ von Kosten wird in BU-Kostenmodellen in der Regel nicht in Abhängigkeit von den sie verursachenden Aktivitäten modelliert, weil die dazu benötigten Informationen nicht vorliegen. Es ist deshalb üblich, Opex in der Form von Prozentaufschlägen auf die Investitionswerte der Anlagen zu bestimmen. Für die Bestimmung dieser Prozentaufschläge kann auf vorliegende Erfahrungswerte aus anderen Projekten des WIK zurück gegriffen werden. In diesem Projekt erwarten wir jedoch, dass Informationen aus den Rechenwerken der Mobilfunkunternehmen in Österreich zur

Verfügung stehen werden, aus denen spezifische Werte für die Prozentaufschläge für die verschiedenen Anlagetypen abgeleitet werden können.

Opex wird somit in den zu erstellenden BU-Modellen entsprechend folgender Gleichung ermittelt:

$O_i \quad = \quad ocf_i \, I_i$

wobei

O_i = Opex für den Anlagetyp *i*,

I_i. = Gesamte Investition in den Anlagetyp *i*,

ocf_i = Faktor, der Opex als Anteil am Investitionswert des Anlagetyps I bestimmt, und

i = Index über alle Anlagetypen.

3.5 Besondere Aspekte der Kostenbestimmung

Zu den besonderen Aspekten gehören die Kosten von extern beschafften Kapazitäten (hier insbesondere Mietleitungen) und die Berücksichtigung von gemeinsamer Nutzung von Infrastruktur durch das modellierte Netz sowie von anderen Trägern:

- Bei extern beschafften Kapazitäten werden die dafür zu entrichtenden Mietbeträge, die auf den konkreten österreichischen Mietleitungstarifen basieren, anstelle der sonst anzusetzenden Capex and Opex eingesetzt.

- Falls Anlagen der Infrastruktur (z.B. Türme) mit einem anderen Träger gemeinsam genutzt werden, werden dem modellierten Netz die Kosten der Anlagen nur anteilig zugerechnet. Die dabei anzusetzenden Anteile sind entsprechend den gegebenen Nutzungsverhältnissen abzuleiten, wobei auch auf Erfahrungswerte zurückgegriffen werden kann

3.6 Bestimmung der Gesamtkosten und Kosten für einen Dienst

Da Struktur und Umfang des Netzes von der Nachfrage bestimmt wird, die während der Spitzenlastzeit befriedigt werden muss, werden die Gesamtkosten des Netzes von der Nachfrage zu diesem Zeitpunkt verursacht. Die Verteilung dieser Kosten auf die Mengen, die während der gesamten relevanten Zeit nachgefragt werden, kann unterschiedlich erfolgen. Es kann eine strikte proportionale Verteilung entsprechend der Nachfrageverursachung während der Spitzenlastzeit vorgenommen werden, oder die Kosten werden den verschiedenen Diensten entsprechend Kriterien zugeordnet, die eher durch Preissetzungsüberlegungen bestimmt werden. Die Vorgehensweise zu dieser Fragestellung ist mit RTR abzustimmen.

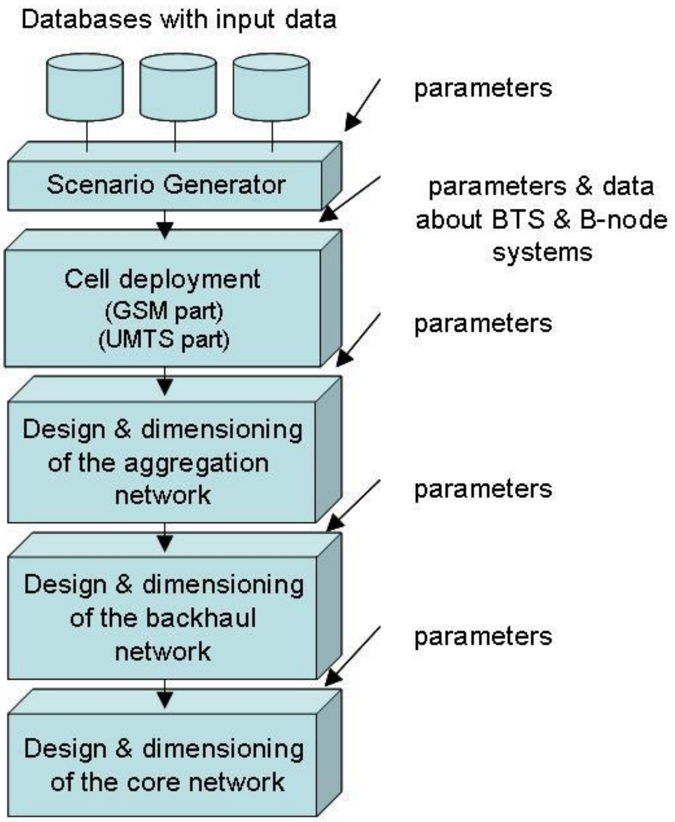
Im Pure LRIC-Ansatz, der für die Kosten der Terminierung im Mobilfunknetz anzusetzen ist, wird bei der Bestimmung der Kosten von Terminierung von den Gesamtkosten ausgegangen, die durch Aufsummierung von annualisierten Capex und von Opex über alle Anlagen entstehen, die jeweils zweimal zu bestimmen sind, einmal mit und einmal ohne Bereitstellung von Terminierung. Die Differenz zwischen diesen beiden Gesamtkosten sind dann die Kosten dieses Dienstes; die Kosten pro Minute ergeben sich, wenn diese Differenz durch das Volumen an Terminierung dividiert wird. Da die relevante Kostendifferenz durch das zusätzliche durch Terminierung verursachte Volumen während der Spitzenlastzeit verursacht wird, entspricht diese Vorgehensweise der proportionalen Verteilung der Kosten.

4 General Aspects for the RTR 2G/3G model

The model is provided in form of a software tool where all algorithms for network design are implemented by a high level program language (C++) and compiled under the Microsoft Visual Net concept in form of separate modules for each of the block of functions. The C++ functional modules and their corresponding compiled DLLs establish a direct communication with an MS Excel based core program (EXCEL-CP) which provides all the additional functionalities associated with an advanced user program interface with data analysis and management capabilities.

The tool will be implemented as a combination of both concepts (an MS Excel-CP and the DLL functions). The MS Excel-CP will be subdivided into five functional modules corresponding to the different network parts of the 2G/3G network architecture. Figure 4-1 shows the different modules and their linear relationships. After the implementation of the model, flow diagrams with more detail about the data flow betweeen the different modules will by provided in a corresponding document.

Figure 4-1: Structure of the functional modules for the network dimensiong of the RTR 2G/3G model [67]



Each module requires individual scenarios with complete sets of associated parameters and data files. These sets are partly inputs from preceding modules while the rest are parameters required by the concrete module scenario. The MS Excel-CP solves all the interrelations between the DLL modules, managing the results from the previous modules and introducing the new parameters specifically related to the current module scenario. After having finished the calculations, all data which drive the corresponding cost calculation are provided to the cost calculation module. The calculations in the MS Excel-CP are linear, there are no loops or iterations and hence can be programmed in MS Excel without any problems.

67 The cost module is not explicitly indicated because we consider that it is implemented - at least in its main part - in a worksheet of the MS Excel file corresponding to a scenario.

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