Calculation of the costs of efficient provision for some electronic communications services provided at the wholesale level in Romania

MOBILE MODEL DOCUMENTATION

ANCOM

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TERA Consultants
32, rue des Jeûneurs
75002 PARIS
Tél. + 33 (0) 1 55 04 87 10
Fax. +33 (0) 1 53 40 85 15

S.A.S. au capital de 200 000 €
RCS Paris B 394 948 731

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List of acronyms

Table 1 - List of acronyms

2G	Second Generation of mobile telephony
3G	Third Generation of mobile telephony
RON	Romanian leu
BSC	Base Station Controller
BTS	Base Transmitter Station
CAPEX	CAPital EXpenditure
CE	Channel Element
E1	2Mbit/s unit of capacity
EDGE	Enhanced Data rate for GSM Evolution
GSM	Global System for Mobile communications
HLR	Home Location Register
IN	Intelligent Network
Kbps	Kilobits per second
LRAIC	Long Run Average Incremental Cost
LRIC	Long Run Incremental Cost
MB	Megabytes
Mbps	Megabits per second
MEA	Modern Equivalent Asset
MGW	Media GateWay
MSC-S	Mobile Switching Centre Server
Node-B	UMTS equivalent to the BTS
OPEX	OPerational EXpenditure
RNC	Radio Network Controller
SGSN	Subscriber GPRS Serving Node
SIM	Subscriber Interface Module
SMS	Short Message Service
SMSC	SMS centre
STM1	155Mbit/s synchronous transport module
TRX	Transceiver Unit
UMTS	Universal Mobile Telecommunications Systems
VLR	Visitor Location Register
VMS	VoiceMail System
WACC	Weighted Average Cost of Capital

0 Context and objectives

0.1 Disclaimer

This report contains the methodology of the Mobile Model module provided to ANCOM to calculate the cost of a mobile operator. It is based on the materials supplied to us by ANCOM and Romanian operators as well as data available from other public models. We have used reasonable and proper care to cross-check and investigate the material supplied so that the methodology follows as much as possible Romanian specificities. Consequently conclusions drawn in this report may not be suitable in other context.

0.2 Regulatory context

Taking into account the European Commission Recommendation mentioned under Article 15 of the Directive 2002/21/CE, ANCOM reviewed beginning 2012 the different relevant markets in order to identify operators with a significant market power.

Pursuant to these decisions, ANCOM with the assistance of TERA Consultants published the Conceptual Framework in which it is specified how costs should be measured to provide electronic communication services.

ANCOM with the assistance of TERA Consultants has therefore built up a draft bottom-up mobile network model in which the following major characteristics are implemented in accordance with the conceptual framework:

- Network dimensioning is based on a scorched node approach;
- Annuities evolved according to a yearly approach;
- Incremental approach to service costing;
- Two scenarios have been considered:
    1. Four specific operators scenario based on: Vodafone's, Orange's, Cosmote's and RCS&RDS' current mobile networks.
    2. Generic operator scenario where the modeled operator is different from any existing operator and reflects a reasonably efficient Romanian mobile operator with:
        a. a target market share of 20%-25%
        b. a spectrum assignment of 10 Mhz in both 900 Mhz and 1800 Mhz bandwidths, and 15 Mhz in 2100 Mhz bandwidth.

To develop these models, ANCOM held, with the assistance of TERA Consultants, several meetings with the different mobile operators in order to:

- Explain extensive data requests that have been circulated to operators regarding costs, services, network deployments, etc. ; and
- Get a deep understanding of their mobile network.

Following the provision of operators' answers, ANCOM and TERA Consultants first crosschecked the consistency of the information provided with:

- ANCOM statistics data base;
- Benchmarks; and
- TERA's experience.

When some data was not provided by the operators, or when data submitted was inconsistent with other data, the model uses as much as possible data available from other regulators.

Based on this analysis, ANCOM and TERA Consultants built up a "service" module that determines the volume of traffic of the different services to be handled by the operator considered.

This Service Demand Module model has as a starting point real historic demand levels for the period 2006 – 2010 (or 2011 when available), and includes forecasts for the period 2012 – 2020. The results of the service module are described below.

Other data provided by operators form key inputs of mobile model that enables to determine services costs.

The goal of the following document is to describe the assumptions, parameters, procedures and methodologies used in the model. Due to the confidentiality of some data, not all inputs and parameters can be shown. The document is structured as follows:

- Description of the different networks modeled in the mobile model (see section 1);
- Description of the data used for the traffic and the number of users for each service (see section 0);
- Description of the different engineering rules used by the different equipment (see section 3);
- Description of the asset prices and the OPEX (see section 4);
- Description of the additional non-network costs (see section 5);
- Description of the different depreciation methods (see section 6);
- Description of the different allocations made in the model (see section 7);
- Description of some main results (see section 8).

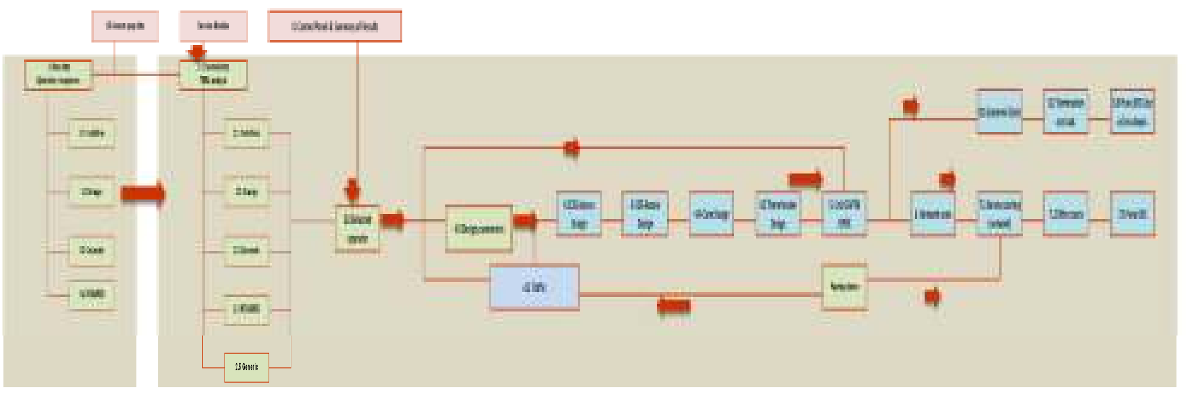
0.3 Steps of the mobile cost model

The purpose of the model is to:

- dimension the modeled mobile network based on current and future service demand;
- to calculate the cost of this dimensioned network with relevant depreciation method;
- to allocate the cost between the different services (and especially the wholesale voice call termination);
- and finally to calculate the long run incremental cost of each service.

The general model approach is summarized in the figure below.

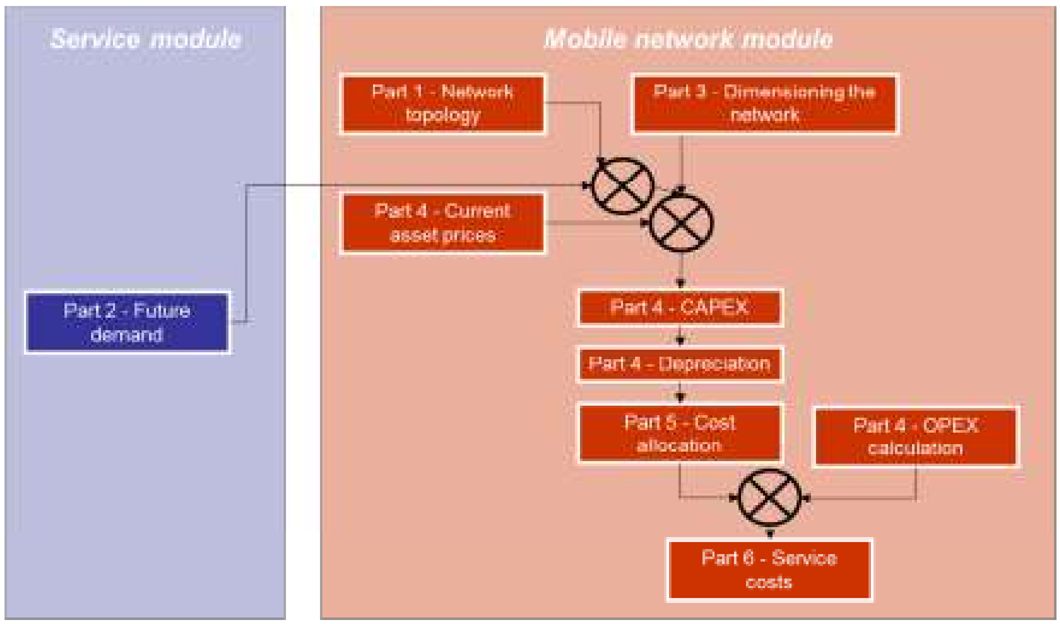
Figure 1 - Overview of the mobile model



Source: TERA Consultants

The different steps of the mobile module are described in the figure below:

Figure 2 - Outline of the mobile network module and the interaction with the service demand module



Source: TERA Consultants

- **Part 1 – Network topology:** The location of nodes along with the required type of equipment (RNC, MSC, servers) will be determined ;
- **Part 2 – Future demand:** For each mobile operator and for each service required, forecasts about the future evolution of traffic will be defined. For the generic operator, assumptions will be made corresponding to the values for the generic operator market share;
- **Part 3 – Dimensioning the network:** This step consists of determining the type and number of assets based on engineering rules that are required at each level of the network to fulfill the demand (the traffic). One important part of this step consists of creating the routing table. For each service, the equipment and links that the service uses are determined;
- **Part 4 – Network costing:** This part consists in calculating the corresponding total cost for the modeled network:
  - Populating the model with the prices of the assets used;
  - Multiplying the number of assets by the price of these assets;
  - Depreciating the CAPEX to annualize the investment cost into annual charges;
  - OPEX are added to the investments' annual charges.

- **Part 5 – Cost allocation:** Costs are allocated to the different services according to the selected allocation key (routing factors' table, required capacity, etc);
- **Part 6 – Service costs:** The cost model calculated for each service its cost per unit.

1 Networks modeled in the mobile cost model

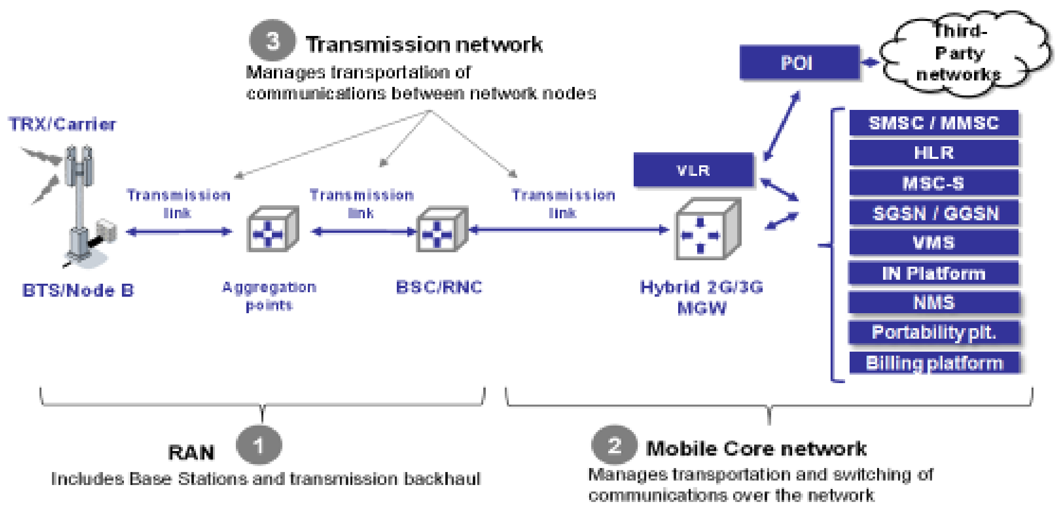
1.1 Scope of the mobile model

In order to determine the unit cost of each mobile service, the model considers all the mobile network components, from the terminal user to the network core equipment, and the transmission technology. For simplicity purpose, the structure of the model can adopt the structure of the mobile network. Hence, each part of the network can be dimensioned separately to determine its cost.

In consequence, the model will address the three main parts of a mobile network, as explained in next sections:

- Radio Access Network (RAN);
- Mobile Core Network;
- Transmission Network.

Figure 3 - Scope of the mobile model for illustration purpose



Source: TERA Consultants

1.2 Access network

This is the first component of the mobile network, starting from the user terminal to the base station controller and the radio network controller equipment. The Radio Access Network implements a radio access technology connecting the terminal user to the operator’s core network. It involves the following equipment:

- BTS: a Base Transceiver Station (BTS) is the GSM equipment enabling mobile terminals to access a mobile network;
- Node B: the Node B is the UMTS equivalent of the BTS for GSM;

- 2G/3G IBS: an In Building Solution (IBS) is a low power mobile network cell, covering a limited area (hotel, train station, shopping center, etc…);
- TRX: a Transceiver (TRX) is an equipment combining both a transmitter (TX) and a receiver (RX). Such equipment enables sending and receiving wireless signals;
- 3G Transceiver: A 3G Transceiver is a TRX specific to 3G networks;
- Aggregators: is a network equipment which aggregates traffic coming from different base stations. It represents an intermediary step between the base stations and the BSC/RNC equiplent;
- BSC: the Base Station Controller (BSC) handles traffic and signaling between mobile devices and a GSM network;
- RNC: The Radio Network Controller (RNC) is the UMTS equivalent of the BSC for GSM. It controls the Node B connected to it and carries out radio resource management and some of the mobility management functions;

Consistent with realities in the Romanian market, the model uses four access technologies and spectrum bands:

- GSM in 900 MHz band using 2 x 200 KHz channels
- GSM in 1800 MHz banduisng 2 x 200 KHz channels
- UMTS in 2100 MHz band using 2 x 5 MHz channels
- UMTS in 900 MHz band using 2 x 5 MHz channels

1.3 Core network

This is the central part of the operator’s telecommunication network. It provides various services to customers connected through the access network. The model includes a forward-looking network structure implementation assuming hybrid 2G/3G MGWs and MSC-S as described in below sections. According to data gathered from operators and TERA Consultants expertise, the core network described in the model involves the following equipment:

- MGW (hybrid 2G/3G): the Media GateWay translates media streams between different telecommunication networks (2G, 3G, IP, etc…);
- MSC-S (hardware and software): the Mobile Switching Centre Server (MSC-S) is an equipment controlling network switching subsystem elements. It carries out switching and mobility management functions;
- SGSN: the Serving GPRS Support Node (SGSN) is the gateway between the RNC and the core network in a GPRS/EDGE/UMTS network;
- GGSN: the Gateway GPRS Support Node (GGSN) is the gateway between the core network and IP networks to the internet;
- SMSC: the SMS Centre (SMSC) is the network equipment switching SMS traffic;

- MMSC: the Multimedia Message Service Center (MMSC) is the network equipment switching MMS traffic;
- HLR: the Home Location Register (HLR) is a database storing all the subscribers' data;
- VMS: the Voice Message Server offers a service whereby calls received when the mobile is in use, switched off or out of coverage, can be diverted to an answering service which can be personalized by the user;
- VLR: the Visitor Location Register (VLR) is a database attached to a BSS (Base Station Subsystem, which includes base stations, backhaul and BSC/RNC), storing data of the subscribers in its area;
- IN: the Intelligent Network (IN) is a standard network architecture enabling operators to provide value-added services on mobile phones;
- NMS: the Network Monitoring System (NMS) monitors network equipment and notifies administrators and/or operators in case of failures;
- Portability Platform: the Portability Platform allows subscribers to switch between mobile operators, while keeping the same phone number;
- Billing Platform: the Billing Platform gathers subscribers' usage and generates their bills.

1.4 Transmission network

This part of the network ensures the transmission of calls and data between the different network equipment (nodes), either in the access network or in the core network. Transmission network is split into two sub-networks:

- Backhaul: the part of transmission network ensuring transport of calls and data through access network nodes
- Backbone: the part of transmission network ensuring transport of calls and data through core network nodes

Different technologies are used in order to link between network nodes:

- Wireless: Microwave solutions are implemented in the model through equipment allowing the transportation of information with varying bandwidth according to the spectrum of operation:
  - 7 Mhz link: allowing to carry the equivalent of 16 E1
  - 14 Mhz link: allowing to carry the equivalent of 32 E1
  - 28 Mhz link: allowing to carry the equivalent of 64 E1
- Wireline: This can be either of the following solutions:
  - Own Fiber
  - Leased lines

- Dark Fiber[1]

[1] For simplicity reason, the model focuses only on leased lines and own fiber

2 Subscribers, coverage and service demand

The first step to calculate the LRIC unit costs (whether it is LRAIC+ or "pure LRIC"[2]) is to estimate the amount of capacity required to handle the subscribers, coverage requirements and traffic demand in Romania during the study period.

Specifically, the model forecasts the following items for the period 2006-2020:

- Total mobile subscribers and operator specific mobile subscribers (which depends on the market share);
- Territory coverage requirements per geotype;
- Annual demand (with traffic breakdown) for each operator;
- Traffic during the busy hour for each operator.

Mobile subscribers and annual traffic demand information are calculated in the "Service Module" which calculates and forecasts them, relying on data received from the operators, ANCOM, international studies and publicly available databases (such as public models from other countries). Other items are calculated in the "Mobile Module" model and the details of each item are provided in the subsections below.

2.1 List of services

Several services are modeled in the mobile network model, as described in the following table:

Table 2 - List of services

2G Services

	Code	Unit	Service
Category A	2G 01	2G min	On Net calls
	2G 02	2G min	Outgoing Calls to Fixed Line
	2G 03	2G min	Outgoing Calls to Other Mobile
	2G 04	2G min	Outgoing Calls to International
	2G 05	2G min	Other Outgoing Calls
	2G 06	2G min	Outgoing inbound roaming call
	2G 07	2G min	Outgoing outbound roaming call
	2G 08	2G min	Incoming calls from fixed
	2G 09	2G min	Incoming calls from other mobile
	2G 10	2G min	Incoming calls from international
	2G 11	2G min	Incoming inbound roaming call
	2G 12	2G min	incoming outbound roaming call
	2G 13	2G min	Voice Mail Retrieval
Category B	2G 14	2G SMS	SMS on net
	2G 15	2G SMS	SMS outgoing to other network
	2G 16	2G SMS	SMS outgoing to international
	2G 17	2G SMS	SMS incoming from other network
	2G 18	2G SMS	SMS incoming from international
Category C	2G 19	2G MMS	MMS on net
	2G 20	2G MMS	MMS outgoing to other network
	2G 21	2G MMS	MMS outgoing to international
	2G 22	2G MMS	MMS incoming from other network
	2G 23	2G MMS	MMS incoming from international
Cat D	2G 24	2G MB	Data service
Cat E	2G 25	2G vid. min	3G On Net Video Calls
	2G 26	2G vid. min	3G Outgoing Video Calls to Other Mobile
	2G 27	2G vid. min	3G Incoming Video Calls from other mobile

3G Services

Code	Unit	Service
3G 01	3G min	On Net calls
3G 02	3G min	Outgoing Calls to Fixed Line
3G 03	3G min	Outgoing Calls to Other Mobile
3G 04	3G min	Outgoing Calls to International
3G 05	3G min	Other Outgoing Calls
3G 06	3G min	Outgoing inbound roaming call
3G 07	3G min	Outgoing outbound roaming call
3G 08	3G min	Incoming calls from fixed
3G 09	3G min	Incoming calls from other mobile
3G 10	3G min	Incoming calls from international
3G 11	3G min	Incoming inbound roaming call
3G 12	3G min	incoming outbound roaming call
3G 13	3G min	Voice Mail Retrieval
3G 14	3G SMS	SMS on net
3G 15	3G SMS	SMS outgoing to other network
3G 16	3G SMS	SMS outgoing to international
3G 17	3G SMS	SMS incoming from other network
3G 18	3G SMS	SMS incoming from international
3G 19	3G MMS	MMS on net
3G 20	3G MMS	MMS outgoing to other network
3G 21	3G MMS	MMS outgoing to international
3G 22	3G MMS	MMS incoming from other network
3G 23	3G MMS	MMS incoming from international
3G 24	3G MB	Data service
3G 25	3G vid. min	3G On Net Video Calls
3G 26	3G vid. min	3G Outgoing Video Calls to Other Mobile
3G 27	3G vid. min	3G Incoming Video Calls from other mobile

[2] As explained in the Conceptual Framework, the difference between "LRAIC+" and "pure LRIC" consists only in the cost allocation approach

Source: TERA Consultants

- Category A: including voice services;
- Category B: including SMS services;
- Category C: including MMS services;
- Category D: including data services;
- Category E: including video calls services.

In addition to the categories of services above, the model also calculates the cost of user access to services, both in 2G and in 3G.

2.2 Service Demand description

The service demand involves a demographic analysis including the population evolution and the age of the population in order to determine the market subscribers base and its behaviour.

The starting point of the service module is the data provided by ANCOM and the operators:

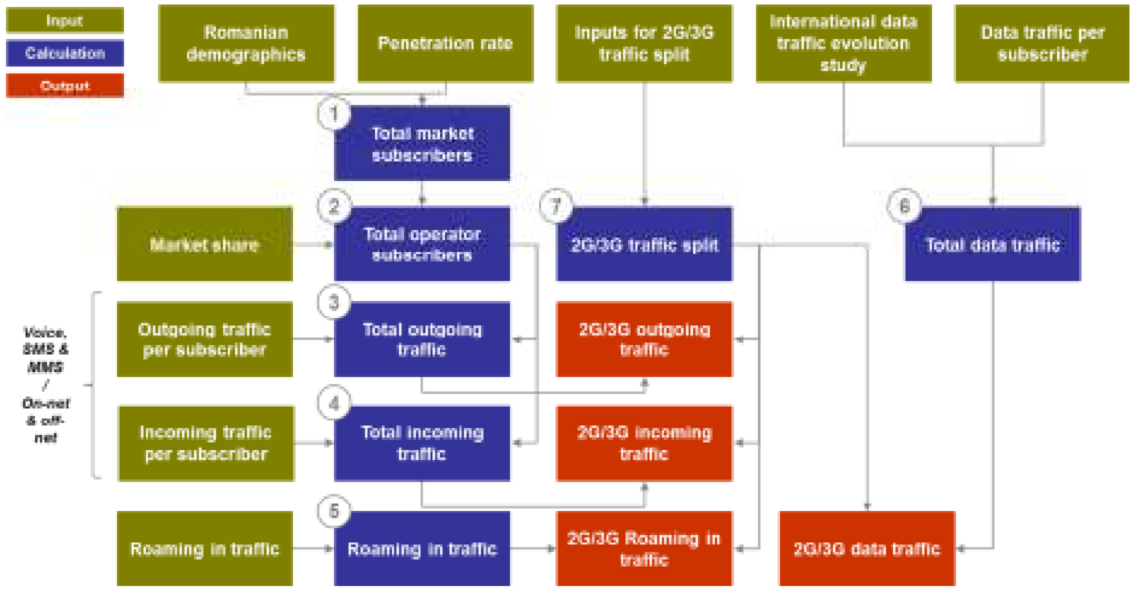
- historical data
- some partial forecasts on the traffic and the subscriber base

The service module relies as much as possible on data provided by ANCOM (up to 2011 when available) and data provided by operators (historic data and forecasts from 2012).

Based on previous demographic data and operators' information, the Mobile part of the Service Demand Module is populated. It analyses the current market status in Romania, calculating average traffic usages per subscriber for different services, and hence deducing the corresponding forecasts, based on population and market shares evolution, as well as on relevant international benchmarks and studies.

Based on these market figures, a forecast of each service to be modeled is performed for all the operators. The resulting traffic demand represents the input of the Mobile Model Module

Figure 4 - Overview of the Service Demand Module structure

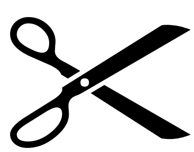


Source: TERA Consultants

2.2.1 Mobile subscribers base

The model forecasts the number of subscribers for each operator based on the forecast of total market number of mobile subscribers and the forecasted market share of operators (according to data received from operators). The latest available subscribers' base information provided by operators corresponds to 2010. Consequently, the model assumes that the calculated market share of operators in 2010 is maintained until 2020.

Figure 5 - Operators' market share evolution



Source: TERA Consultants from ANCOM data

The market share forecasts for each Romanian operator has no effect on the generic operator.

2.2.2 Annual demand (traffic)

The yearly commercial traffic is established for each operator based on past traffic per subscriber trend and subscriber base evolution.

The traffic volume is then split between the different service types:

- Outgoing calls:
    - Mobile to mobile – on-net
    - Mobile to mobile – off-net
    - Mobile to fixed national
    - Mobile to international
    - Mobile to voicemail
    - Other outgoing calls
- Incoming calls (i.e. wholesale voice call termination):
    - Mobile (other) to mobile
    - Fixed national to mobile
    - International to mobile
- Roaming calls, including all types of outbound and inbound roaming calls.

The model also forecasts the volumes of video calls (if any), SMS and MMS, based on subscriber base forecasts and past traffic per subscriber trend. Forecast of data is based on historical data as well as on forecasts from operators until 2015. It is completed and cross-checked with forecast performed by OFCOM[3] and Cisco[4].

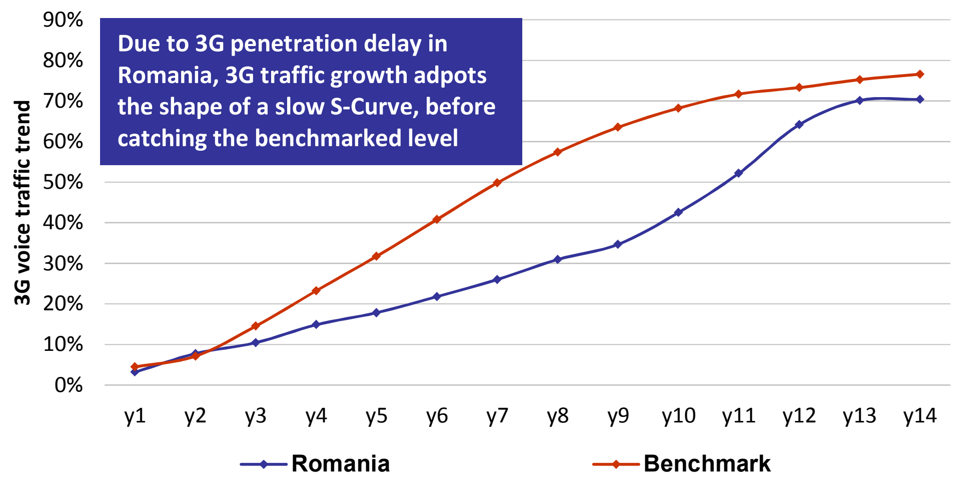
The traffic is then further disaggregated into 2G and 3G traffic volumes, using operators' historical traffics and trends, and forecasts provided by international studies3.

Finally, for the generic operator, the traffic is obtained by applying the target market share on the total traffic.

[3] OFCOM – Wholesale mobile voice call termination – 15 march 2011

[4] Cisco forecast and methodology 2011-2016 (may 30th 2012)

Figure 6 - 3G voice traffic evolution over total (2G&3G) voice traffic



Source: TERA Consultants, ANCOM, Operators

2.3 Coverage requirements

The RAN coverage sites are the sites that need to be deployed by an operator to achieve a given level of geographical coverage. There is no traffic constraint consideration. The coverage network is deployed only in order to make a phone call. The model calculates the number of 2G and 3G RAN coverage sites needed based on the inputs of 2G and 3G network coverage per geotype:

- Size (in km²) of each geotype;
- % of territory covered for each geotype (both in 2G and 3G);
- Cell radius in each geotype (depending on the frequency band).

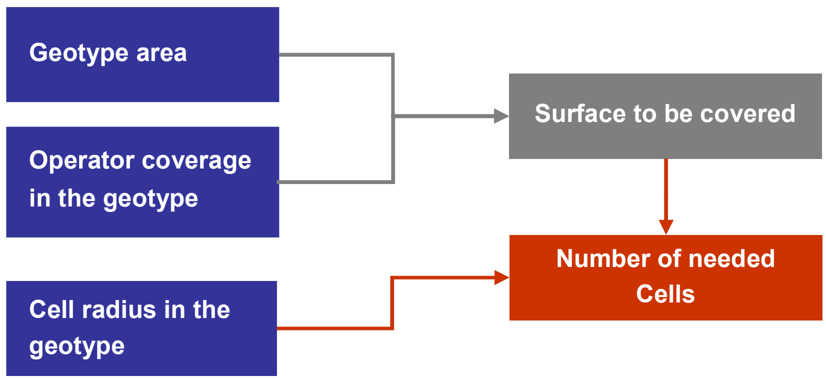
The model determines the % of territory covered in each geotype in accordance with ANCOM figures[5] completed with total population and area coverage when stated by each operator based on the populations' territorial distribution and assuming that operators cover in priority denser areas.

The model forecasts geotypes coverage for each operators according to the national coverage target, which is defined as a parameter for each operator.

The model is populated with cell radii information cross-checked from a benchmark of international practices. The analysis of cell radius versus area density relationship allows extrapolating the appropriate figures for the Romanian geotypes (see section 3.2.1).

[5] Issued from its M7 market analysis rounds 2 and 3

Figure 7 - RAN coverage sites calculation



Source: TERA Consultants,Operators

2.4 Dimensioning Traffic during the busy hour

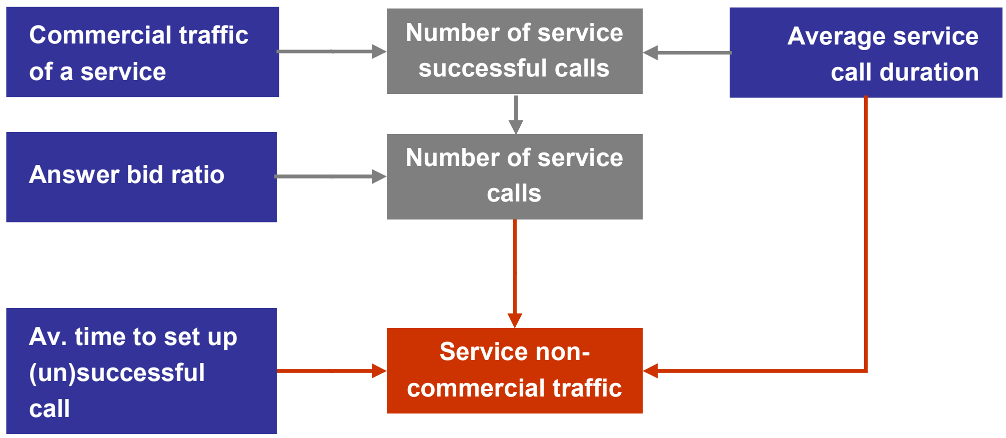
2.4.1 Inclusion of non-commercial traffic

On top of "commercial traffic" (see section 2.2.2), the model has to take into account the "non-commercial traffic" for network dimensioning. "Non-commercial-traffic" includes all the traffic that cannot be billed to a customer such as the time needed to set a circuit between two correspondents and the time during which the correspondent's phone rings. This is essential as even if this traffic cannot be billed to the customers, it represents a strong constraint on the network and has to be included for network dimensioning. The calculation of non-commercial traffic by the model is based on several inputs:

- The average call duration (in seconds): it represents the average length in minutes of a successful call (this parameter is important in converting service volumes to calls).
- The answer bid ratio (or successful call rate, in %): it represents the proportion of calls that are successfully answered by the called party.
- The average time to set up successful (i.e. "answered") and unsuccessful (i.e. "unanswered") calls (in seconds): it represents the additional time for a successful call or unsuccessful call at the beginning and end of the call.

These figures are requested from operators as they are specific to each one of them. Based on thses values, the corresponding values for the generic operator is deduced by averaging them and cross-checked them with an international benchmark. When operators did not provide values, a value derived from the other operators was applied.

Figure 8 - Non-commercial traffic calculation



Source: TERA Consultants, Operators

Calculation example

With the following assumptions:

- T: Total traffic (100 minutes)
- D: Average call duration (2 minutes)
- S: Successful call rate (40%)
- TSC: Average time to set-up successful call (0.2 minute)
- TUC: Average waiting time for unsuccessful call (0.4 minute)

The additional non-commercial traffic is:

- Successful calls = T/D = 50 calls
- Additionnal non-commercial traffic for successful calls = (T/D)*TSC = 10 minutes
- Total calls (successful + unsuccessful) = (T/D)/S = 125 calls
- Unsuccessful calls = (T/D)/S*(1-S) = 75 calls
- Additional non-commercial traffic for unsuccessfull calls = (T/D)/S*(1-S)*TUC = 30 minutes
- Mark-up for non-commercial traffic = 1 + 1/T*[(T/D)*TSC + (T/D)/S*(1-S)*TUC] = 1.4

In other words, 1 minute of commercial traffic generates 1.4 minutes of total traffic (commercial + non-commercial traffic).

Values for the calculation of the non-commercial traffic can be found in Sheet #4.1, table Z22:AD63.

2.4.2 Traffic during the Busy Hour

The network is dimensioned in terms of its traffic carrying capabilities (based on anticipated customer demand levels) over a given period based on busy hour (BH) traffic. Busy hour is the hour of the week with the highest average network usage, averaged using measures over a representative period of one year.

The aim is to determine the amount of traffic passing through each node of the network, and hence the traffic to be handled (dimensioning traffic) during the busy hour. The ratio with each equipment capacity finally gives the number of equipment required during the busy hour.

Equipment capacity is expressed either in Erlangs or in Mbps or in busy hour call attempts (BHCA). The capacity of equipment whose constraints are relating to the number of concurrent calls is usually expressed in Erlangs. Therefore, one Erlang represents the continuous use of one voice path during a period of time (usually one hour). Other equipment are dimensioned in terms of the maximum throughput they can support in the busy hours. Their capacity is then expressed in Mbps. Finally, some equipment are dimensioned in terms of the number of call attempts they handle during the busy hour.

Consequently, all services (including voice, SMS[6], MMS, video calls and data) traffic must be converted to the appropriate unit: Erlangs, Mbps and BHCA.

The modeled network is separated into two main parts: RAN and Core. Transmitted information evolves through these networks with different throughput, due to the different modulation techniques used in each part. Therefore, the dimensioning traffic (Mbps, Erlangs) is not the same in access network and in core network.

Equipment located in the access network (such as BTS, Node B, BSC …) are dimensioned with access dimensioning traffic, while equipment situated in core network (MSC, MGW …) are dimensioned with core dimensioning traffic.

Busy hour traffic is calculated based on busy hour traffic information provided for each cell by operators, and the trend of annual traffic of operators.

As voice services busy hour may differ from data services busy hour, the model does not assume a full overlapping for voice and data BH, and introduces a BH traffic reduction parameter which reflects that non-overlapping. In, fact, if voice and data BH were identical, then the network should be dimensioned in order to support both voice and data busy hour traffics at the same time. In that case the non-overlapping parameter equals 100%. If voice BH differs from data BH, which is more likely to correspond to reality, then the network is dimensioned with lower traffic constraints since the highest constraint on voice does not happen in the same time that the highest constraint on data. In the latter case, the non-overlapping parameter has a lower value than 100%. In the model, that parameter is defined at 80%, and is applied to BH traffic going through each network node.

Finally, the calculated busy hour evolving through the RAN takes into account the amount of traffic offloaded in the IBS (In-Building Solutions). In fact, the model defines two off-load parameters for both 2G and 3G traffics. These parameters are issued from an international benchmark and can be changed in the model (no data was provided by operators). As a consequence, the busy hour traffic to be supported by BTS/Node B equipment is relieved of 2G/3G IBS traffic.

[6] Although SMS traffic does not have a direct impact on radio site dimensioning, it does bear a share of the costs of those radio sites

Conversion rules for both access and core dimensioning traffic detailed in Appendix.

The final values for the traffic conversion can be found in Sheet #4.0, line 73 to 117.

3 Network dimensioning

Based on demand and engineering principles and algorithms, the model determines the number of network elements required. This network dimensioning step calculates the volume of network elements required to support the given level of demand during the busy hour using the chosen technology.

As explained in the scope of the model (section 1.1), the network dimensioning is divided into three main steps:

- Radio access network dimensioning;
- Core network dimensioning;
- Transmission network dimensioning.

Before dimensioning the Radio Access Network, and after calculating the BH traffic for each service, the model calculates first the amount of traffic circulating through each network node. This traffic is function of the BH traffic for each service and how much each service uses each network node (routing factor).

3.1 Routing matrix

The network routing matrix (or routing table) defines how each service uses the network, i.e. how much of each network element is used by the service on average.

The full usage of the network by a network product may be based on the service's volume of minutes or data size or numbers of calls made or any other relevant driver. This information is in a table that lists how much of each network element is used by the product. The "how much" is the effective cost driver and can be numbers of network elements, or relative cost usage (as long as the same cost driver is used for each network element by each product, any driver may be used).

The model considers that the routing factors should be an estimate of the average number of each type of network element used for each service. In the cases where more than one possible route exists (e.g. at the core level), then the average number of network elements used for each route is weighted by the probability that this route can occur.

Each operator provided its routing table, considered as raw data. These routing tables may differ in the list of equipment provided and in the routing factors corresponding to the probability of the route. Hence, the routing tables provided by operators are treated in order to have a global homogeneity between all operators, and to fit to the adopted table format of the model.

The Routing table of the generic operator is given in Appendix 12.4. It is based on the most relevant values for each equipment provided by operators, according to TERA expertise.

The routing matrix for each operator can be found in Sheets #2.x, line 828 to 873

3.2 Radio Access Network dimensioning (Sheets 4.2 for 2G and 4.3 for 3G)

Network dimensioning starts with estimating the radio network required to handle demand (both geographic demand and traffic demand).

In order to achieve a certain level of geographic coverage, the areas covered by a mobile network are divided into smaller areas called cells. Each cell is a unitary network element which includes its own equipment in order to transmit, receive and switch the calls from subscribers located within the borders of its radio coverage area.

The model assumes one main cell type for coverage, that is to say macrocells. For macrocells, the base station antennas are installed on a mast or a pole (in a rural area) or on top of a tall building (rooftop).

The objective of the model is to design a radio network configuration that meets the required level of demand. To do this, the model incorporates the following assumptions:

- A network is rolled out to provide geographical coverage (i.e., there is only a minimum level of traffic) by applying the cell radius and a scorched-node coefficient[7] (SNC).
- Coverage sites are then considered equipped with maximum transceivers configuration, as described in the following sections (3 sectors per BTS and 4 to 6 TRX[8] per sector for 2G dimensioning, according to information provided by operators).
- If coverage sites with that configuration are sufficient to handle the demand traffic, sites configuration is then optimized (less transceivers per site where appropriate)
- In the dual band networks, such as 2G 900-1800 or 3G 900-2100, transceivers for each band are collocated at the same base stations and additional 2G 1800 transceivers (or 3G 900 and 2100 carriers and transceivers) and equipment are added to provide additional traffic capacity. The upper limit on the number of transceivers per base station is determined by either:
    - The physical limit of the number of transceivers, which is a maximum of 4 to 6 transceivers per sector (based on operators data).

[7] Because coverage of an area cannot be performed in an ideal way with a perfect hexagon paving, the use of a SNC reflects the difficulty to display the sites in the best locations and the existence of blocking environments (big buildings) that reduces the coverage.

[8] The number of TRX per sector is the minimum between the maximum number of TRX possible with available spectrum, and the maximum number of TRX that is possible to put in the rack and based on operator's inputs.

    - The number of transceivers and carriers per sector that the spectrum will allow. The model derives this from the spectrum allocations and, for bands that can be used for both 2G and 3G, after allowing for any allocation to either 2G or 3G.

- Once each base station is fully configured with both 2G 900 and 1800 transceivers and 3G 900 and 2100 transceivers and carriers, additional base stations are added to provide additional traffic capacity when needed.

2G and 3G networks for each existing operator are modeled as if it was entering the market now at its current scale and scope of operation with a 2G and 3G network.

3.2.1 Main inputs

3.2.1.1 Spectrum and technology

Operators have frequency bandwidths in GMS 900 Mhz and 1800 Mhz (2G spectrum) and in 3G spectrum (2100 Mhz). Frequency spectrum is divided in coupled channels (duplex) for uplink and downlink.

In terms of functionality, 2G and 3G RAN equipment are quite similar: BTS/Node-B, BSC/RNC; with enhanced capabilities for 3G equipment. In terms of technology, the model considers the HSPA release of 3G (High Speed Packet Access) in combination with 2G. It also includes a forward-looking network structure implementation, as described in the following paragraphs.

Spectrum availability for each operator can vary over time and is to be found in Sheets #2.x, line 368 to 384.

Table 3 - Spectrum allocation in 2012 per frequency band

	unit	Vodafone	Orange	Cosmote	RCS&RDS	Generic
900 MHz	Mhz	12,40	12,40	10,00	-	10,00
1800 Mhz	Mhz	12,40	12,40	12,60	-	10,00
2100 Mhz	Mhz	14,80	14,80	14,80	15,00	15,00

Source: ANCOM, Conceptual framework

As explained in the conceptual framework, the generic operator is considered to have acces to a share of spectrum in each band which corresponds to its retail market share, rounded up to the nearest possible frequency unit.

3.2.1.2 Geotypes

The model distinguishes between different geotypes. Each geotype includes a number of localities that are in a predefined range of population density.

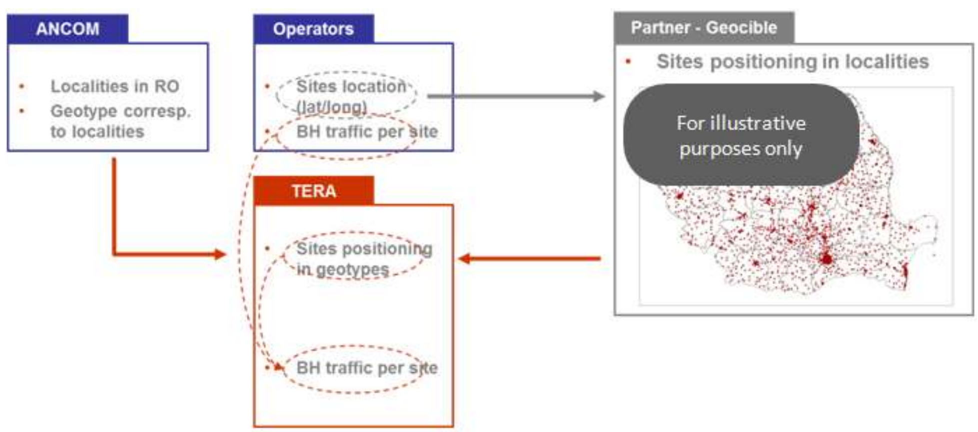
Table 4 - Extract from localities vs. geotypes table

County	Locality Name	Locality- sate aparținătoare	Region	Population January1st 2010	Total surface - km²	density	% pop	% area	geotype ANCOM
B	BUCUREŞTI	BUCUREŞTI	Bucureşti - Ilfov	1 944 451	238	8 174	112,60%	50,72%	0,00%
BR	BRĂILA	BRĂILA	Sud - Est (Dunărea de Jos)	211 161	44	4 808	12,23%	9,36%	0,00%
VS	BÂRLAD	BÂRLAD	Nord - Est (Moldova)	69 049	15	4 742	4,00%	3,10%	0,00%
AG	PITEŞTI	PITEŞTI	Sud (Muntenia)	167 017	41	4 101	9,67%	8,68%	0,00%
BC	BACĂU	BACĂU	Nord - Est (Moldova)	175 867	43	4 072	10,18%	9,21%	0,00%
PH	PLOIEŞTI	PLOIEŞTI	Sud (Muntenia)	227 981	58	3 912	13,20%	12,43%	0,00%
DJ	CRAIOVA	CRAIOVA	Sud - Vest (Oltenia)	299 579	81	3 680	17,35%	17,36%	0,00%
IS	IAŞI	IAŞI	Nord - Est (Moldova)	308 663	94	3 287	17,87%	20,02%	0,00%
HR	BĂLAN	BĂLAN	Centru (Mureşana)	7 496	2	3 217	0,43%	0,50%	0,00%
MS	TÂRGU MUREŞ	TÂRGU MUREŞ	Centru (Mureşana)	144 370	49	2 928	8,36%	10,51%	0,00%
BT	BOTOŞANI	BOTOŞANI	Nord - Est (Moldova)	115 751	41	2 799	6,70%	8,82%	0,00%

Source: ANCOM

Operators provided all location information for their base stations (longitude and latitude). Positioning information allows to determine in which locality is situated each site, and hence the corresponding geotype.

Figure 9 - Site to geotype association in the model



Source: TERA Consultants

Then, the model distributes the total traffic in each geotype according to the traffic during the busy hour per site, as provided by operators

The list of geotypes is defined similar from an operator to another. However this list can evolve easily in order to take into account the specificities of each operator (the model is designed in that purpose). The geotypes are defined as follows for the generic operator:

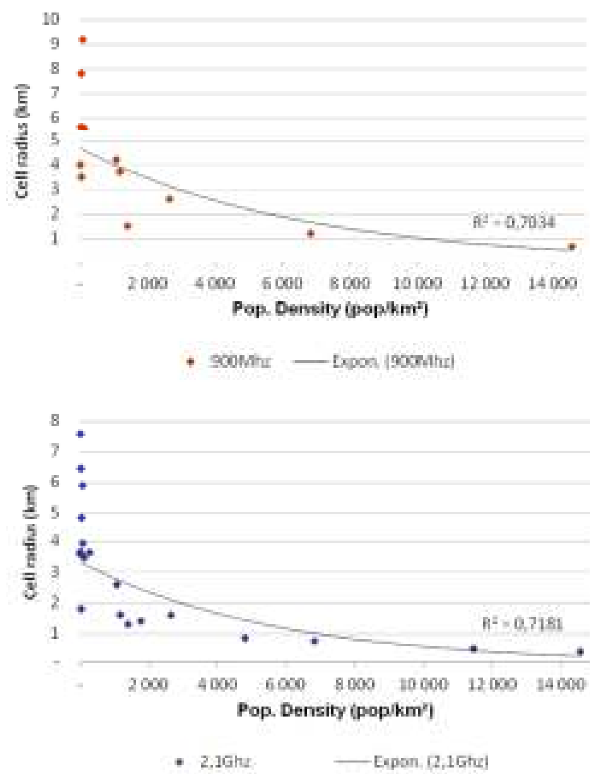
- Dense urban: from 6 500 pop/km²
- Urban: from 3 000 pop/km²
- Suburban: from 300 pop/km²
- Rural: from 1 pop/km²

3.2.1.3 Main engineering inputs

- **Cell radii for each technology and frequency**

  As described in §2.3, the model is populated with cell radii information issued from the operators data which were then cross-checked with a benchmark of international practices (to harmonise the cell radius in each frequency band and in each geotype).

Figure 10 – International benchmark of theoritical cell radius for 900MHz and 2.1 GHz spectrum bands



Source: TERA Consultants, benchmark of models

The analysis of cell radius versus area density relationship allows extrapolating the appropriate figures for the different geotypes, given that the number of sites calculated by the model must be consistent with the current number of sites provided by operators.

Table 5 - Cell radii for the generic operator

Cell Radii	unit	900Mhz	2100Mhz
dense urban	m	628	539
urban	m	1,335	1,000
suburban	m	2,646	2,170
rural	m	7,162	6,759

Source: TERA Consultants, benchmark

Cell radii for each operator can be found in Sheets #2.x, line 238 to 241.

- **Quality of service at the radio interface and in the core network as a percentage blocking probability:**

  The blocking probability is the network design call failure rate in the busy hour. The relevant column of the Erlang B table (see below) is calculated from the blocking probability.

  Call blocking probability can be found in Sheets #2.x, line 878.

- **Number of total channels per 2G TRX**

  Basically 8 channels per TRX as well as the number of channels reserved for signaling. Their difference will be the number of channel allocated to voice.

  The number of channels per TRX, and the corresponding number of maximum simultaneous communications are calculated for the generic operator as average of other operators' values.

  Number of total channels per 2G TRX can be found in Sheets #2.x, line 308 to 327.

- **Number of total channel elements per 3G carriers**

  Pole capacity channels (CE pool) are considered for dimensioning. The size of CE pool is provided by operators and cross-checked with a benchmark of public available models in Europe and Middle East: 64 CE for uplink and 64 CE for downlink per carrier per site for the generic operator.

  Pole capacity can be found in Sheets #2.x, line 337.

- **RNC soft handover percentage**

  This is a characteristic of the 3G network which is related to the fact that each subscriber while making a call may be connected to two or more cell sectors that belong to the same physical cell site.

  RNC soft handover percentage based on operators' submission can be found in Sheets #4.0, line 155.

- **Frequency reuse factor**

  Further detailed in coming paragraphs, it allows determining the frequency reuse pattern. Considering 3 sectors per cell, and hexagonal cell shapes, the frequency reuse factor is assumed to be equal to 12.

- **Spare capacity markup**

  Also known as security markup, it is applied on busy hour traffic, in order to prevent from network saturation. It is requested from operators, and is provided for the different network nodes.

  Spare capacity mark-up can be found in Sheets #2.x, line 214 to 230 for network equipment, and line 694 to 695 for transmission links.

  The values for the generic operator are calculated as average of other operators' values:

Table 6 - Spare capacity markup for network equipment for generic operator

BH Spare Capacity Markup	unit	Value
BTS and Node-B	%	18%
BSC	%	25%
RNC	%	29%
MSC	%	23%
STP	%	45%
HLR	%	23%
VLR	%	23%
VMS	%	13%
SMSC	%	25%
MMSC	%	20%
SGSN	%	20%
GGSN	%	20%
MNP	%	25%
IN	%	22%

Source: TERA Consultants

Table 7 - Spare capacity markup for transmission links for generic operator

Transmission dimensioning	unit	Value
Access links spare capacity	%	28%
Core links spare capacity	%	45%

Source: TERA Consultants

- **Uplink-Downlink traffic ratio**

  3G access dimensioning requires splitting the traffic in uplink and downlink, as the dimensioning rules are different for those two traffics. A ratio of 1:10 between uplink and downlink data traffic is revealed by manufacturers' benchmark[9], and is used in the model.

- **Traffic conversion factors per connection at busy hour, for each bearer in 3G**

  It concerns Packet Switch (PS), and HSPA traffic. It allows deriving Erlang traffic in BH from bit rate traffic. Conversion factors used in the model are benchmarked from public available models in Europe and from manufacturers' data.

Table 8 - Traffic conversion factor from bitrates to Erlangs for each bearer

Traffic per connection @BH	unit	UL	DL
Voice call - CS 12,2	kbps	16	16
Video call - CS 64	kbps	64	64
R99	kbps	25	72
HSPA	kbps	793	171

Source: TERA Consultants

- **Split of 3G busy hour data traffic per Bearer**

  Since each 3G bearer has different resources consumption (cf. next paragraphs), it is necessary to split the 3G traffic on each bearer. As no operator provided this information, TERA Consultants has made an iso-traffic based split assumption (i.e. the traffic is equally splitted between all bearers).

- **Channel Elements (CE) factors**

  The following table indicates the channel element consumption for the different services on different radio bearers (while 64/64 CE are available per carrier in DL/UL). This consumption varies with equipment. It has been assumed the following values, on the base of manufacturers benchmark and operators' data:

[9] Ericsson AB – Channel Element Dimensioning Guideline

Table 9 - Channel Elements factors

3G services CE	unit	CE - UL	CE - DL
R99	CE	3.21	1.93
HSPA	CE	16.50	-

Source: TERA Consultants

The values presented in the table above is the result of the weighted average of CE per bearer with the traffic split on each bearer. The consumption in terms of CE of each bearer is detailed in sheets #2.x, line 341 to 362.

3.2.2 Coverage network dimensioning

3.2.2.1 Dimensioning rules

Based on the size of each geotype, the coverage requirements and the cell radii assumptions, the model derives a minimum coverage network. Specifically, it determines the number of base stations required to provide coverage to each geotype to enable a voice call.

Calculation example

With the following assumptions:

- A: Area to be covered (100 km²)
- R: Radius of a site (2 km)
- SNC: scorched-node coefficient (0.8)

The number of coverage site is:

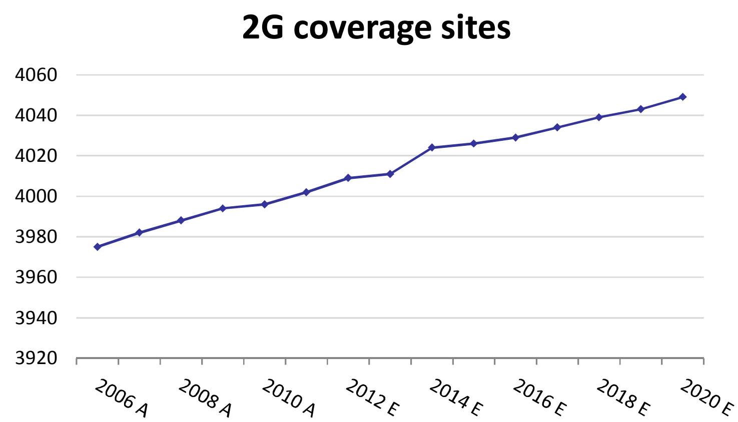
- Number of sites = A / Area of an hexagon = A / [3*3^(1/2)*(R*SNC)²/2] = 13 sites

It is important to note that the costs of the minimum coverage network represents a common cost which is thus distributed to all services in a LRAIC+ cost allocation, but has no impact on voice call termination in case of a “pure LRIC” cost allocation for wholesale voice call termination.

3.2.2.2 Results for the generic operator

3.2.2.2.1 2G radio access network

Figure 11 - Evolution of 2G coverage sites (900 MHz)

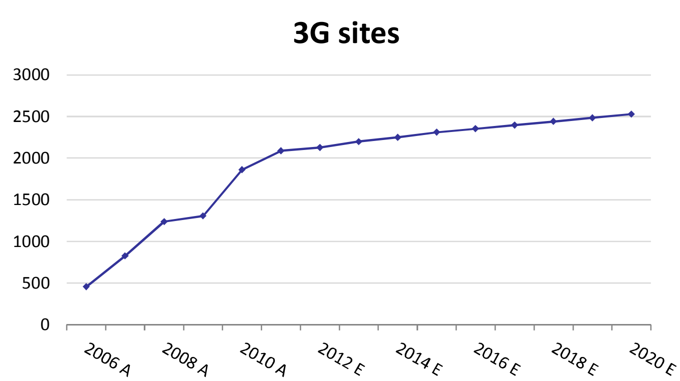


Source: TERA Consultants

Population coverage of generic operator is calculated as average of population coverage of other operators. Then the corresponding territory coverage is deduced based on the populations' territorial distribution, and hence the coverage sites needed.

3.2.2.2.2 3G radio access network

Figure 12 - Evolution of 3G coverage sites



Source: TERA Consultants

Population coverage of generic operator is calculated as average of population coverage of other operators. Then the corresponding territory coverage is deduced, based on the populations' territorial distribution and hence the coverage sites needed.

3.2.3 Traffic network dimensioning

3.2.3.1 Traffic capacity calculation

The traffic capacity required by each base station is determined using the Erlang B table. An Erlang represents the continuous use of one voice path during a period of time (usually one hour). Erlang traffic measurements or estimates can be used to work out how many circuits are required between different parts of a network or between multiple network locations. The traffic capacity (as shown in the Erlang B table) is a function of:

- The number of transceivers deployed in each base station sector;
- The number of traffic channels per transceiver;
- The level of call blocking probability in the radio network (which represents the quality of service an operator wishes to achieve).

The model includes a blocking probability value provided by operators. This value is equal to 2 percent (or P=0.02) for the generic operator, for 2G and 3G networks. This is consistent with the data submitted by operators and general engineering standards.

3.2.3.2 Erlang B table

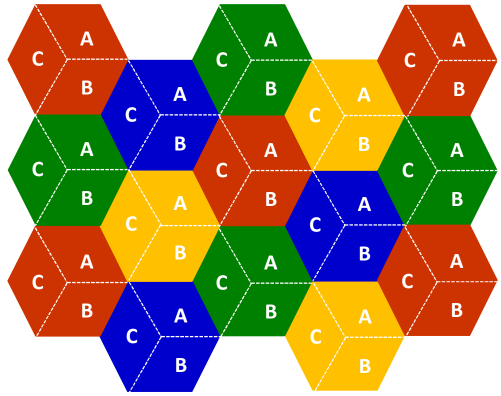
This table provides the amount of traffic for a given blocking probability and number of available channels and is based upon statistical engineering calculations. It is used to convert capacities from circuits to Erlangs or the opposite. For example, it has been used in order to estimate the BTS capacity in Erlangs when the number of channels is known.

3.2.3.3 Frequency reuse patterns

In theory, all cells can use the same carriers. This gives the advantage of allowing more calls to be made at the same time. However, as the spectrum is narrow, this may lead to interferences between the cells. Therefore, a spectrum reuse parameter is introduced. It is function of the number of sectors per site.

The graph below shows an example:

Figure 13 – Frequency reuse pattern of 3x4=12



Source: TERA Consultants

To determine the reuse pattern, the coverage area is represented in a set of contiguous hexagons, to depict base station sites. Each site is split into 3 sectors. The model assumes a frequency reuse pattern of **12**, which allows at least one sector gap between cells that use the same frequency[10]. This is equivalent to a base station frequency reuse of four (assuming three sectors per base station).

The model further assumes that each 2G TRX requires 200 kHz of paired spectrum and provides eight 25 kHz communication channels. For 3G, the model assumes that a carrier requires 5 MHz and can carry 64 communication channels.

3.2.3.4 2G traffic network dimensioning

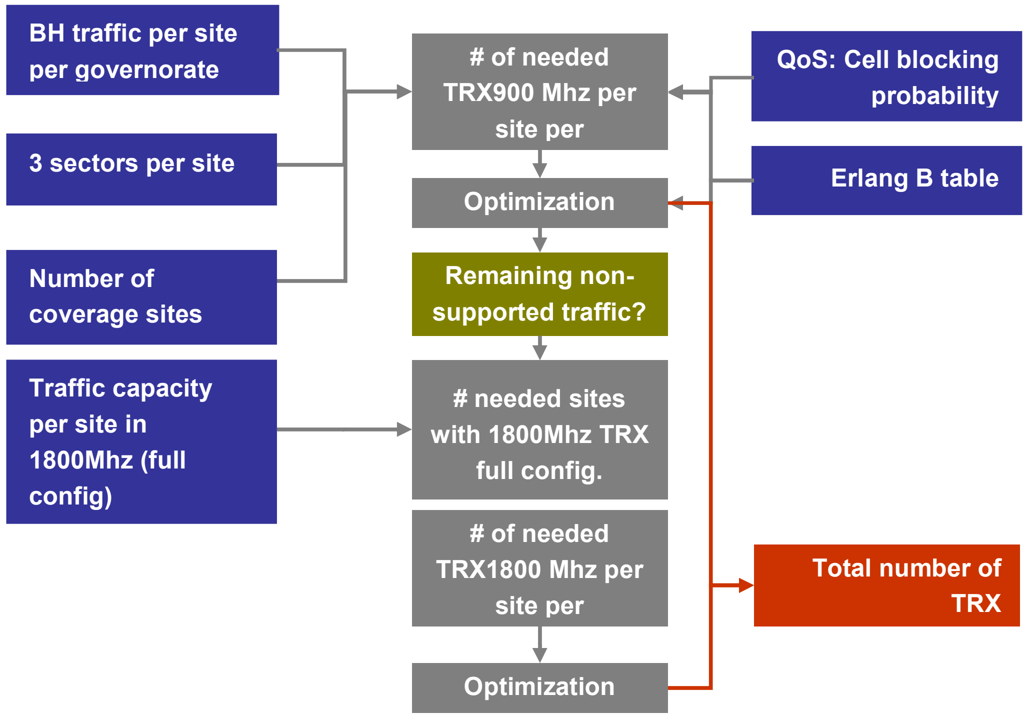
Based on the calculated coverage sites, the first step consists in calculating the number of TRX 900 Mhz to handle the BH Erlang traffic per site per geotype. This first estimate includes limitation in terms of maximum number of TRX per site.

Using Erlang table, the model checks, in a second step, whether the TRX configuration calculated previously can be optimized (through the calculation of the traffic capacity with one less TRX per sector, per site).

Once the configuration is optimized, the model checks whether all the busy hour traffic is handled by the TRX 900 Mhz. If not, the model starts the allocation of TRX 1800 Mhz following the same principle as with TRX 900 Mhz. This step is followed by a configuration optimization step.

[10] In order to ensure quality of service, the norm is to use a four-cell repeating pattern. Each cell has three sectors, so the spectrum reuse factor is 12

Figure 14 - 2G TRX traffic dimensioning



Source: TERA Consultants

3.2.3.5 3G traffic network dimensioning

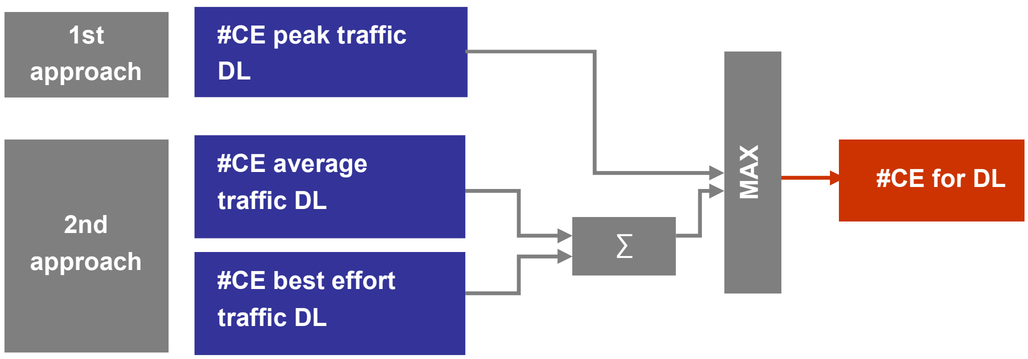
Based on the number of coverage 3G sites needed, the first step consists in calculating the BH traffic per sector per site for each class of service (voice, video call in CS, data in PS, and data in HSPA). While both voice and data was mixed to dimension 2G RAN in terms of traffic, the split between service bearers is necessary in 3G, since each service has a different traffic capacity consumption (also called channel element factor or weight, as described in §3.2.1.3). Because channel elements consumption is different in uplink and downlink, the BH traffic is also split between uplink and downlink, for each class of service.

One way to dimension 3G RAN is to focus on voice dimensioning (Channel Switch traffic) and service quality (GoS). This approach assumes that voice traffic is a priority and hence the dimensioning is based on peak hour voice traffic, and blocking probability parameter for service quality.

The model implements this approach and complements the 3G RAN dimensioning by a second approach involving both of voice and data in their average traffic in BH (packet switch traffic), and hence without quality of service consideration for voice (without Erlang table).

The model considers the maximum number of channel elements (CE) required for each approach. The result is a number of CE per site per governorate. The following figure summarizes the 3G RAN dimensioning process:

Figure 15 - Channel Element calculation algorithm (this figure represents the downlink calculation but a similar calculation applies for uplink dimensioning)



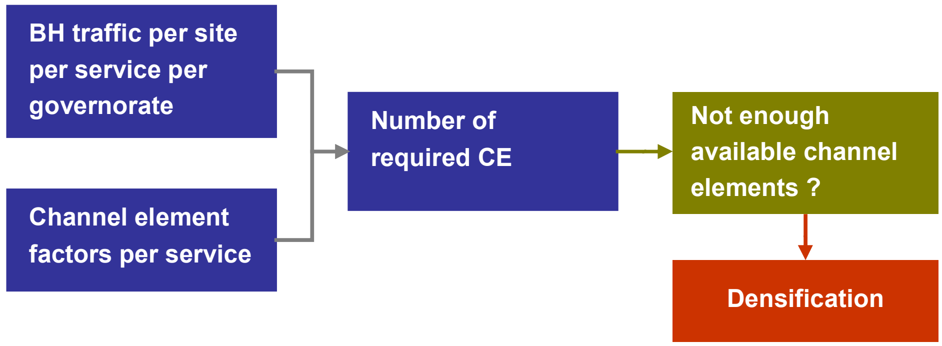
Source: TERA Consultants

The same process is used for UL channel elements calculation. The three main steps of the calculation aim to determine the following intermediary number of channel elements:

- #CE peak: it corresponds to the number of channel elements to handle peak traffic in busy hour. It is function of the number of simultaneous users per site for the service, and the channel element factor for the radio bearer
- #CE average: When conversational and best effort bearers are mixed, the dimensioning has to take the average traffic into consideration. As the conversational traffic has higher priority, the interactive traffic will fill up space when the conversational class traffic is not being used.
- #CE best effort: based on the offered best effort traffic in Erlang for the service.

Once the number of required CE calculated, the models checks whether the number of available carriers fulfills the need in terms of CE (64 CE per 5 Mhz bandwidth carrier for the generic operator). If the number of available channel elements is not sufficient, the model goes through the final step of densification.

Figure 16 - 3G RAN traffic dimensioning



Source: TERA Consultants

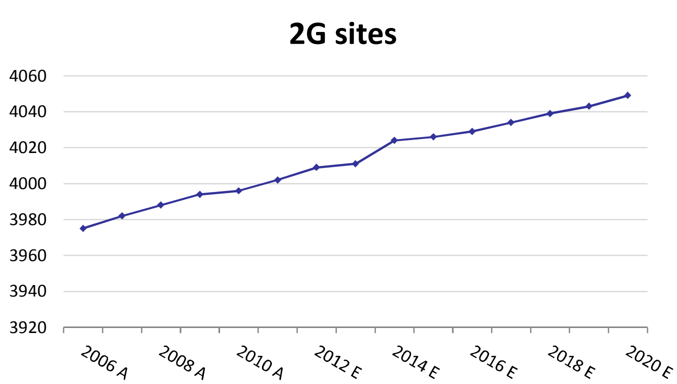
Moreover, the model takes into consideration two additional scenarios, in order to fit to some operators' specificities:

- 900 Mhz spectrum usage in 3G: the model offers the possibility to deduce a carrier from the available 900 Mhz spectrum used for 2G, in order to provide 3G services in that spectrum. This option can be activated either national wide or only in rural geotype. The launch date of 3G services in 900 Mhz is a parameter in the model.
- Dedicated carrier for HSDPA: the model allows to use a dedicated 3G carrier to provide HSDPA services. This option can be activated either national wide or only in urban geotype.

3.2.3.6 Results for the generic operators

3.2.3.6.1 2G sites

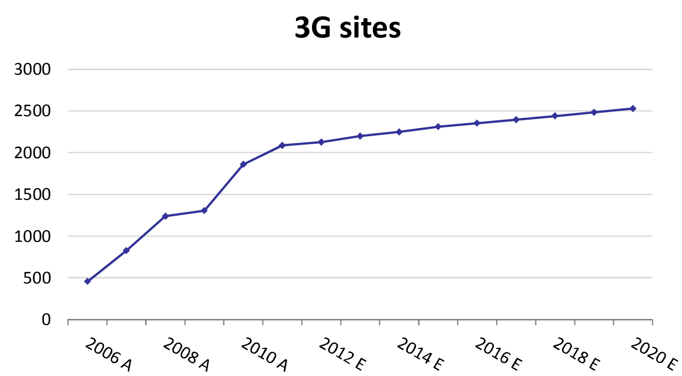
Figure 17 - Evolution of total 2G sites (900Mhz and 1800 MHz)



Source: Tera Consultants

3.2.3.6.2 3G sites

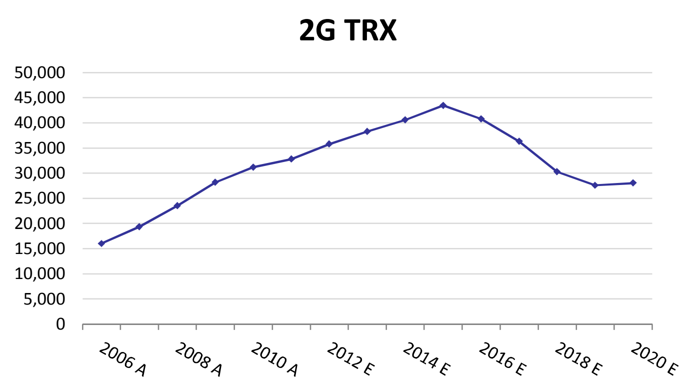
Figure 18 - Evolution of total 3G sites



Source: Tera Consultants

3.2.3.6.3 2G TRX

Figure 19 - Evolution of 2G TRX

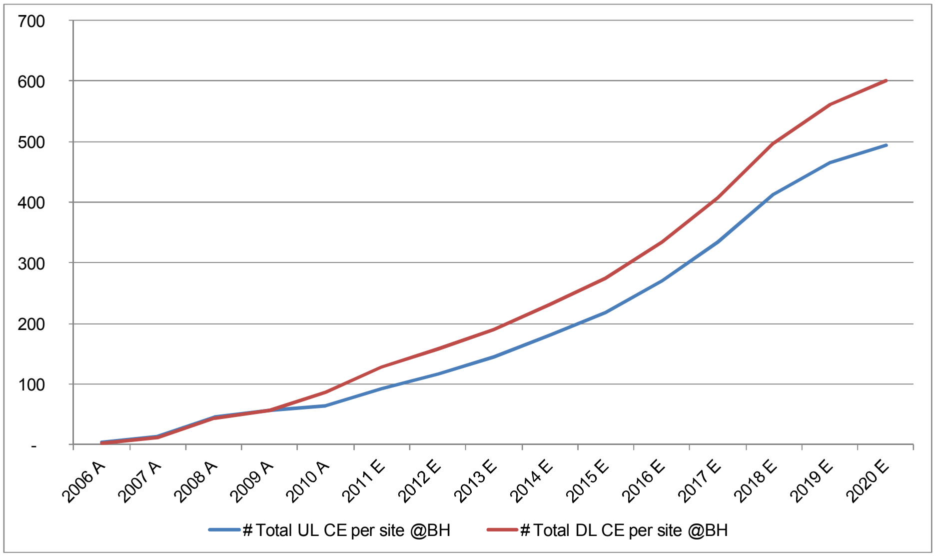


Source: Tera Consultants

Decrease in the number of TRX from 2016 corresponds to the fall of 2G voice traffic per user, while it increases in the same time for 3G traffic.

3.2.3.6.4 3G Channel elements

Figure 20 - Number of DL and UL Channel Elements per site @BH for generic operator



Source: Mobile Model

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Considering the above 2G/3G sites dimensioning results, it appears that the coverage provided by operators is sufficient to deliver the traffic demand, which in turn leads to a low number of densification sites.

Although these results may be correct, it is nonetheless expected from the operators to provide comments on this matter and if needed to fine tune the inputs in order to better reflect their RAN structure (coverage vs. densification):

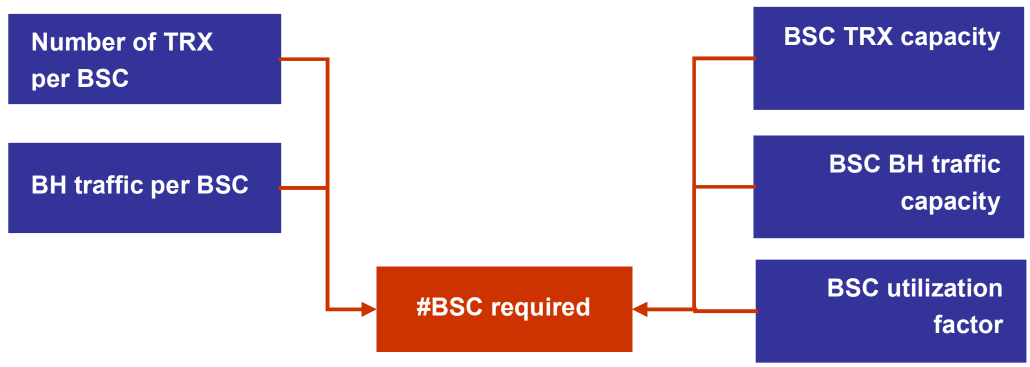
- Traffic evolution
- Population and surface coverage
- Cell radii
- RAN dimensioning rules

3.3 BSC and RNC equipment dimensioning (Sheets #4.2 for BSC and #4.3 for RNC)

3.3.1 BSC dimensioning rules

As indicated by operators, BSC equipment are dimensioned based on the number of TRX per BSC and the BH traffic per BSC. Both of these requirements should be met, and the maximum number of BSC estimated for each requirement is then multiplied by a utilization factor, in order to calculate the number of needed BSC equipment.

Figure 21 - BSC dimensioning



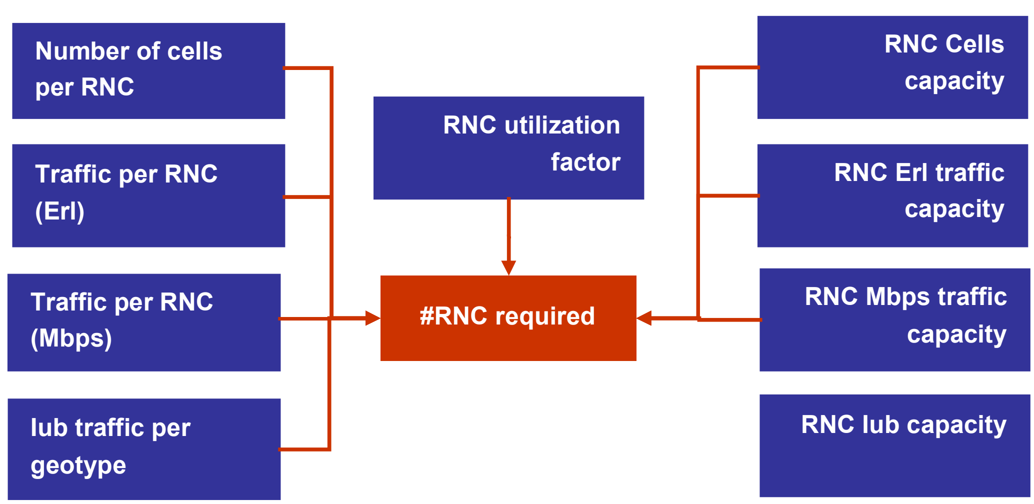
Source: TERA Consultants

The BSC dimensioning parameters are values provided by operators and can be found in Sheets #2.x, line 595.

3.3.2 RNC dimensioning rules

As indicated by operators, RNC equipment are dimensioned based on the number of cells per RNC, the traffic capacity in Erlangs and in Mbps per RNC, and Iub capacity per RNC (the Iub is an internal interface connecting the RNC with the Node B). These requirements should be met, and the maximum number of RNC estimated for each requirement is then multiplied by a utilization factor, in order to calculate the number of needed RNC equipment.

Figure 22 - RNC dimensioning



Source: TERA Consultants

The Iub interface is located between an RNC and a Node B. It allows the RNC to control, through the Node B, a number of cells and to add or remove radio links in those cells.

The RNC dimensioning parameters can be found in Sheets #2.x, line 598.

3.4 Core network dimensioning (Sheet #4.4)

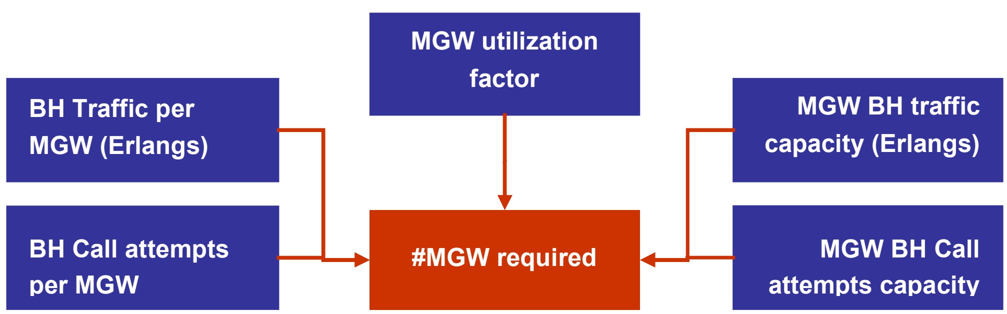
The parameters to dimension the network equipment can be found in Sheet #2.x, line 603 to 615

3.4.1 MGW and MSC-S dimensioning rules

The model assumes hybrid 2G/3G MGWs and MSC-S as it represents a forward-looking solution for operators.

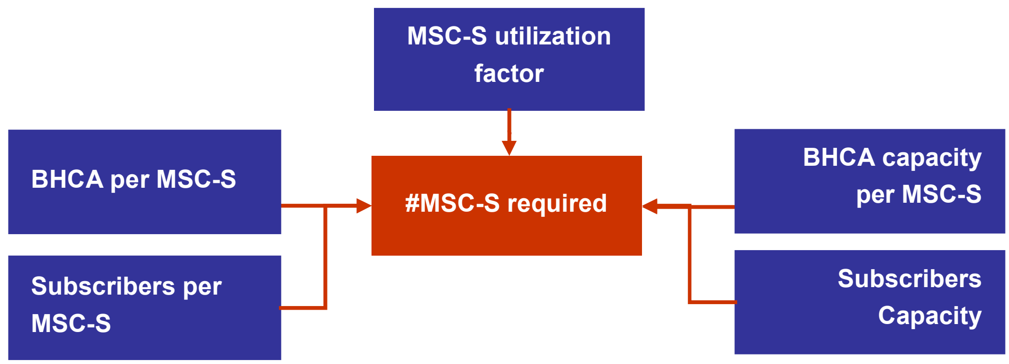
The number of MGWs is determined by its capacity in terms of BH traffic in Erlangs and BH call attempts. In the same time, the number of MSC-S is determined by the BH call attempts, and the number of subscribers. Capacity information is derived from data provided by operators and international benchmarks.

Figure 23 - MGW dimensioning



Source: TERA Consultants

Figure 24 - MSC-S dimensioning



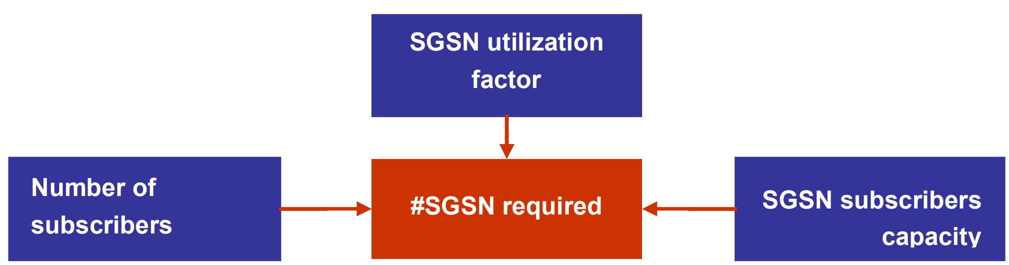
Source: TERA Consultants

3.4.2 SGSN/GGSN dimensioning rules

The number of SGSN is determined by its capacity in terms of subscribers.

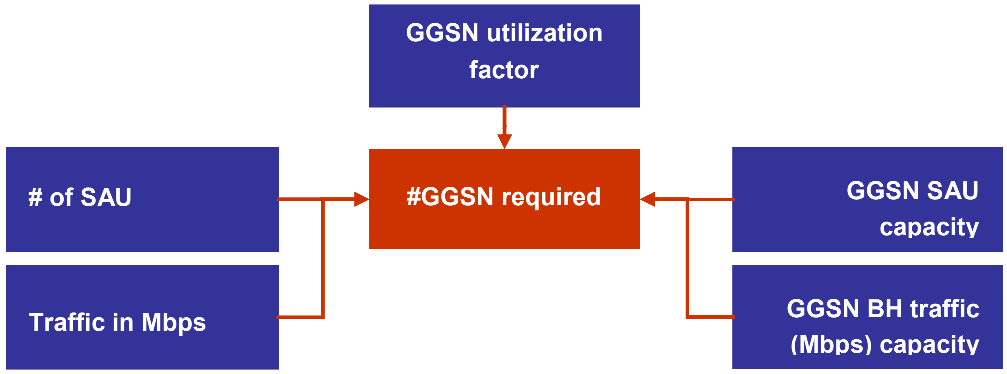
The number of GGSN is determined by its capacity in terms of BH traffic in (Mbps), and simultaneous attached users (SAU).

Figure 25 - SGSN dimensioning



Source: TERA Consultants

Figure 26 - GGSN dimensioning



Source: TERA Consultants

3.4.3 SMSC/MMSC dimensioning rules

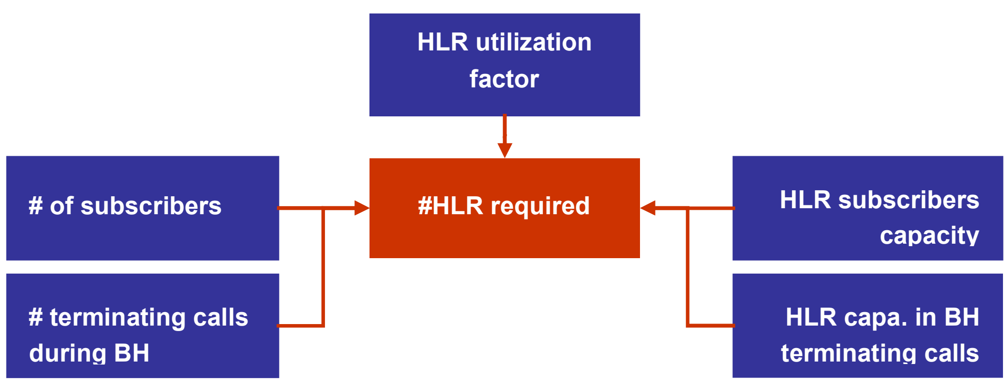
The number of SMSC is determined by its capacity in terms of SMS at the busy hour. The number of MMSC is determined by its capacity in terms of MMS at the busy hour.

3.4.4 HLR/VLR dimensioning rules

The number of HLR is determined by its capacity in terms of subscribers and terminating calls during the busy hour.

The number of VLR is determined by its capacity in terms of subscribers.

Figure 27 - HLR dimensioning

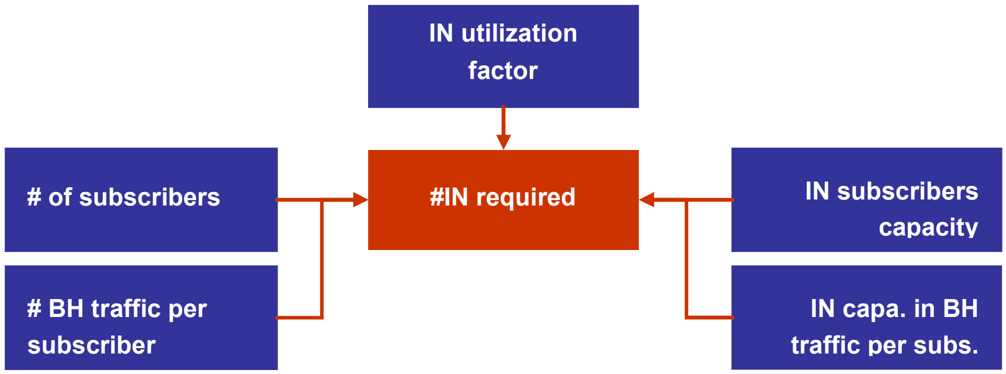


Source: TERA Consultants

3.4.5 IN dimensioning rules

The number of IN is determined by its capacity in terms of subscribers and BH traffic per subscriber.

Figure 28 - IN dimensioning



Source: TERA Consultants

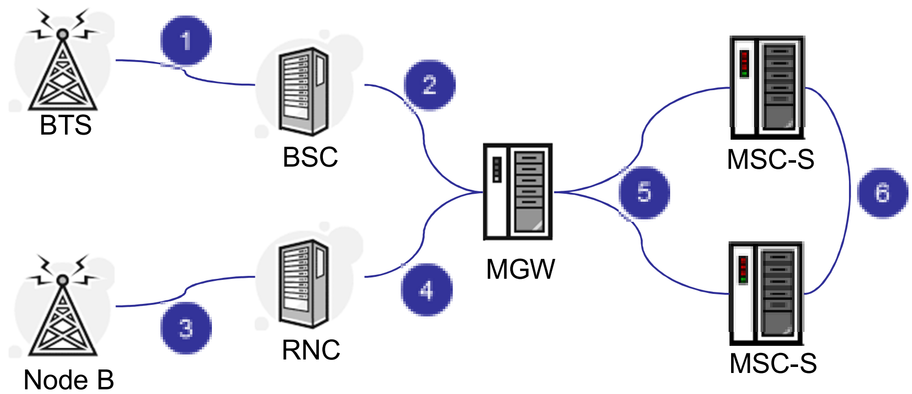
3.5 Transmission network dimensioning (Sheet #4.5)

The model dimensions the transmission network based on the traffic requirements as well as management limitations. The transmission network includes the following links:

- BTS-BSC 1
- BSC-MGW 2
- Node B-RNC 3
- RNC-MGW 4
- MGW-MSCs 5
- Inter MSCs links 6

The logical description of the transmission network is in the figure below.

Figure 29 – Transmission network logical structure



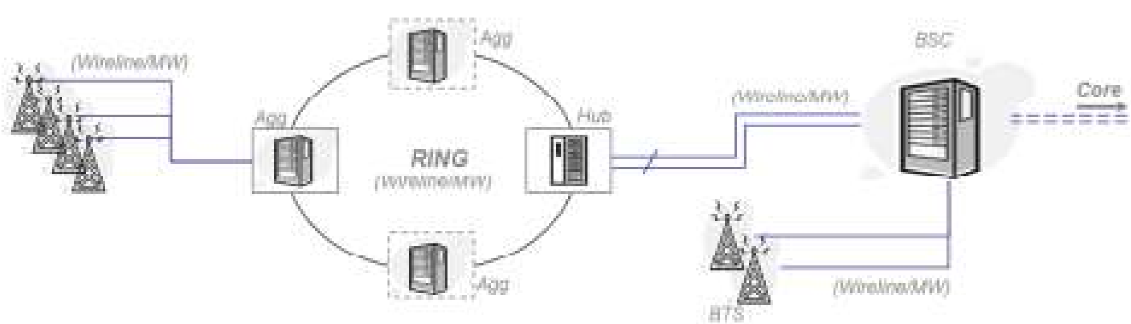
Source: TERA Consultants

The physical description of the netwok includes additional nodes, such as aggregators, rings and hubs.

In the transmission network, the base stations/NodeBs can be directly linked to BSC/RNC or indirectly through aggregation rings. The backhaul links can be either wireline or wireless depending on the description of the transmission network provided by each operator. The backhaul is considered 50% wireless and 50% leased lines for the generic operator (this applies for macrocells, since only wireline links are used for IBS). This option appears to be an efficient one, with the most advantageous evolution of transmission costs in the time (expressed as % of total network cost), and already adopted in Romania and in other countries.

The model considers a standard architecture for the transmission network that is intended to fit to the structures provided by the operators, as described in the figure below which details the backhaul (access transmission network):

Figure 30 - Access Transmission network physical structure



Source: TERA Consultants

Transmission network dimensioning is based on several steps :

- **Step 1:** Transmission network dimensioning is driven by the traffic that needs to be carried over the transmission network as well as the network topology. The latter defines the minimum number of links required, the type of links and the link length. For example, the number of backhaul links cannot be less than the number of base stations. Their positioning in the network determines the links length. Finally the site sharing/collocation aspects have been considered for backhaul dimensioning.

- **Step 2:** Based on traffic limitations, radio design parameters, link capacities and utilization level, the number of E1 links required for each part of the transmission network is estimated.
  The relationship between each site configuration and the number of E1 links output of the site is function of their equipment and traffic characteristics and is given by the following table:

Table 10 - Site configuration vs. E1 links number relationship for generic operator

Transmission links

Site conf --> output #E1	unit	# E1 links
1/1/1	#	1
2/2/2	#	1
3/3/3	#	1
4/4/4	#	2
5/5/5	#	2
6/6/6	#	2
7/7/7	#	3
8/8/8	#	3
9/9/9	#	3
10/10/10	#	4
11/11/11	#	4
12/12/12	#	4

Source: TERA Consultants expertise

Calculation example

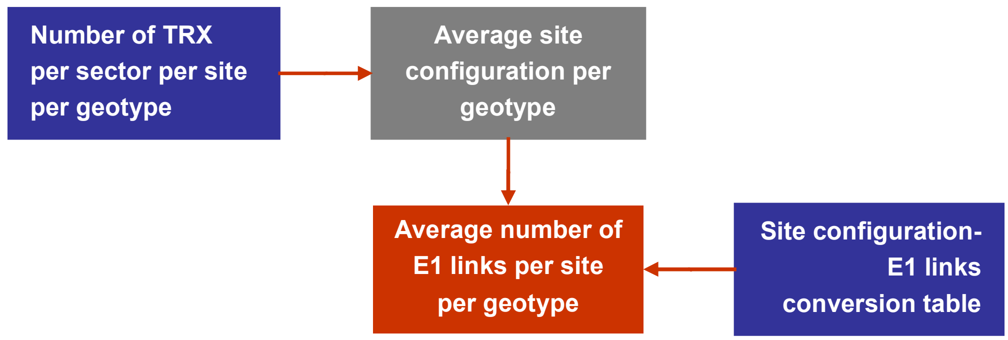
With the following assumptions:

- 900Mhz : 4/4/4 configuration
- 1800Mhz: 4/4/4 configuration

The number of E1 liks is:

- 3 E1 links corresponding to 4/4/4 + 4/4/4 = 8/8/8 configuration.

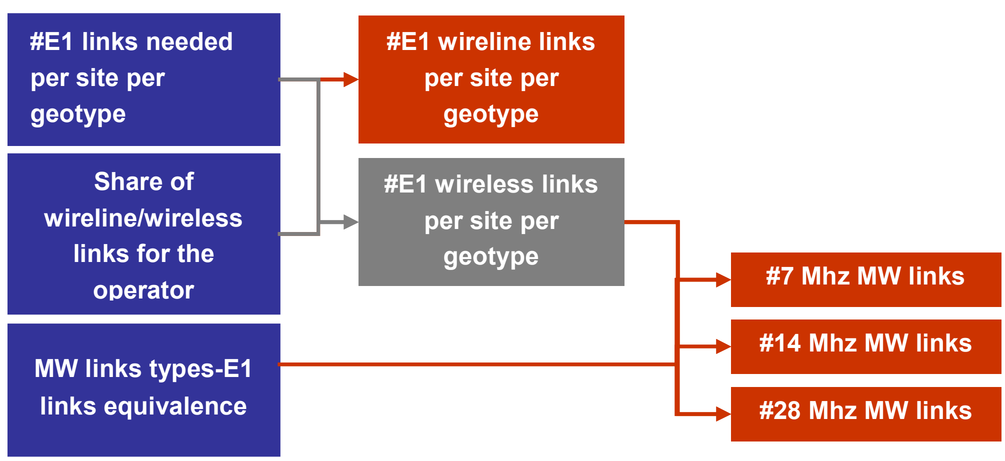
Figure 31 - Average number of E1 links per site per geotype



Source: TERA Consultants

- **Step 3:** Based on the share of microwaves, leased lines and fibre links, transmission links per transmission type are split between those different types of links. This share is calculated based on operator's response to data request. The same ratio between wireline and wireless links given per each operator is kept to model its backhaul links. In case of wireless links, the model assigns the appropriate MW frequency link to each base station, according to the need of E1 links of each base station.

Figure 32 - Number of Wireless/Wireline E1 links determination



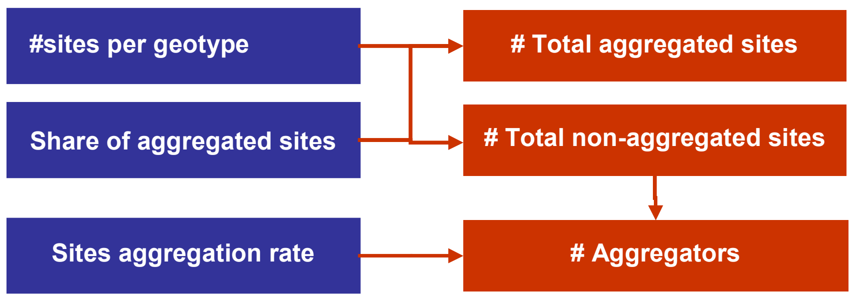
Source: TERA Consultants

- **Step 4:** In this step of the backhaul dimensioning, the model considers the presence of links aggregators. This is done in accordance with each operator topology. The aggregators represent an intermediary step between the BTS/Node B equipment and the BSC/RNC equipment. The aggregators are themselves aggregated in aggregation hubs within aggregation rings. Each aggregation hub is linked to a BSC/RNC.

The model allows to define the share of sites aggregated in rings, and the share of sites directly linked to BSC/RNC. It also allows to define the aggregation rate, which represents the number of sites aggregated per aggregator.

Access links can be either wireline or wireless links. Aggregation rings can also be wireline or wireless (wireless links are doubled as well as wireline/wireless links from hubs to BSC/RNC).

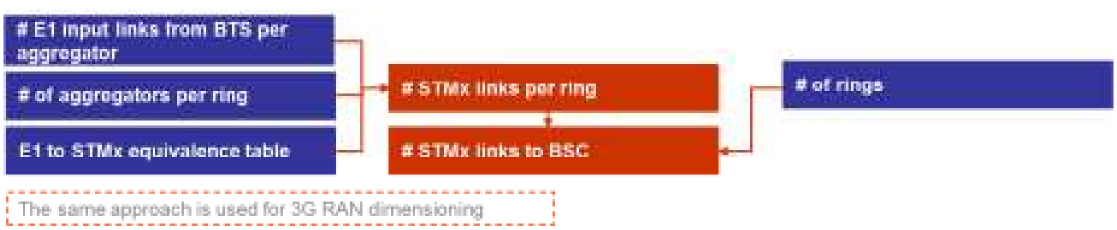
Figure 33 - Usage of share of aggregated sites and sites aggregation rate



Source: TERA Consultants

- **Step 5:** The number and type of links output of each aggregator (the ring link dimensioning) is function of the number of input links of each aggregator and the number of aggregators in the ring. This way, the model dimensions the number of output links to BSC and to RNC

Figure 34 - Calculation of the number of links per ring and to the BSC



Source: TERA Consultants

Step 6: Concerning core network links: BSC-MGW, RNC-MGW, MGW-MSCs and inter MSCs links, the BH traffic (Mbps) per equipment is used to dimension the links, according to their traffic capacity. The model also considers additional parameters to express spare capacity in core links as well as links redundancy. These parameters are provided by operators and can be changed in the model.

4 Unit costs and OPEX

Once the model has calculated the required quantity of network elements, it calculates the associated capital expenditures by applying modern equivalent asset (MEA) unit costs. It then calculates the corresponding annuity by including the WACC, the price trend and the economic lifetime, and it adds the OPEX.

4.1 Network element unit CAPEX (Sheet #5)

The asset unit CAPEX (i.e., prices paid for equipment added to cost of installation) represents the evolution of MEA values. A full list of these CAPEX is contained in the model and is displayed in the appendix 12.5. The unit CAPEX for each network element for the generic operator was derived based on data received from the operators and data incorporated in mobile LRIC models for other countries.

The model derives the final CAPEX unit cost estimates by taking, for each operator, the provided value considering the price trend of equipment. These CAPEX inputs and price trends are expressed in nominal terms and in Euros. The model is itself expressed in Euros.

Network sites CAPEX is calculated for the sites owned in acquisition, or for the rented sites considering administrative and development costs. The model assumes that all the sites of the generic operator are rented (with administrative and development costs to prepare the sites), and its costs are deduced from the costs observed for other operators (usually an averaging method is applied). For collocated sites, especially for core network collocated sites, the CAPEX per collocated element is calculated by dividing the provided CAPEX of a collocated site by the number of collocated elements.

As for the transmission equipment unit costs, the values are derived from the data submitted by operators (the values for the generic are obtained through an averaging approach).

4.2 Network element OPEX

The principle of OPEX calculation in the model is based on the determination of markups applied to CAPEX for each network component. This approach is standard practice in bottom-up modelling.

The markup is obtained either provided by operator or issued from international benchmark of practices, where operator figures were not available.

Sites OPEX include rental fees when sites are not owned in acquisition, and maintenance fees[11]. This information is provided by operators. In accordance with operators data, all the base station sites of the generic operator are owned in rental in

[11] The model assumes that the maintenance fees are already included in the CAPEX markup previously defined, and hence put to zero in the model.

the perspective of an efficient operator. Moreover, the model assumes that 2G/3G sites are collocated when possible, as well as 2G/3G IBS. For core equipment, the model considers that BSC, RNC and MGW are collocated when possible, as well as other core sites which are collocated in MGW and MSC-S. It is assumed that the generic operator owns all the sites in rental (as for an efficient operator).

For microwave transmission equipment, OPEX used correspond to the values provided by operator: aggregated OPEX or annual recurring fees.

The model also includes in network OPEX the spectrum fees (annual recurring fees), that are considered as joint network costs applied to the RAN, and depending on the number of carriers.

4.3 Total Network annual cost

Total annual costs are calculated by summing annual capital costs with operating and maintenance costs.

5 Additional costs (non-network costs)

In addition to previously calculated network costs, other cost items are considered for LRAIC+ calculation. These costs are added in order to complete the perimeter of costs to be allocated to network. The model includes the following costs:

- Interconnection staff costs;
- Licence costs;
- subscribers acces costs;
- Business overheads.

5.1 Interconnection specific costs

These specific costs are directly induced by interconnection service. They consist of the cost of interconnect billing and staff allocated specifically to interconnection.

As per the reference interconnection offers of the operators, some of the interconnection specific costs are already recovered through the provision of ancillary interconnection services, whose costs are being modeled in distinct a POI cost model.

Interconnection staff cost has been directly provided by operators.

Generic operator's values correspond to the average of other operators' responses.

To avoid double counting between interconnect specific costs and costs which are recovered through the ancillary services, the model considers an input parameter of 50% that represents the share of interconnection staff cost allocated to regulated termination. This parameter can be changed.

5.2 Licence costs

Spectrum license costs (one-off) are also included in the total costs for LRAIC+ calculation. They are considered as un-attributable common costs, recoverable from the entire business. They are provided by ANCOM and consist of the initial license fee valued based on the results of a recent licence auction in Romania.

It is assumed for the generic operator a spectrum allocation resulting of an auction. Considering the bandwidths, it is made the following assumptions:

- 900 Mhz: 10 Mhz,
- 1800 Mhz: 10 Mhz
- 2100 Mhz: 15 Mhz,

considering this to be representative for a generic mobile operator acting on the Romanian market. The parameters to define the spectrum allocation can be found in Sheet #2.x, line 368 to 384.

These spectrum assumptions are valued according to ANCOM at 160 M€ for the generic operator (133 M€ for 2G and 27 M€ for 3G).

These costs[12] are allocated as business overheads. The model applies a markup to the network costs (calculated as percentage of licence fee total costs in the sum of network costs and retail costs) resulting in licence fees unit costs.

5.3 Subscriber access

Alongside the calculation of unit traffic termination cost, the model calculates an additional per subscriber cost based on SIM cards evolution. The cost of SIM Cards is benchmarked from international models, and depreciated on its economic life[13]. The resulting unit cost per subscriber is not applicable on unit traffic (minute, sms or MB) but equals to a cost per subscriber per month. It is calculated for 2G and 3G SIM cards.

On top of the cost of SIM cards, the model provides the possibility to allocate network equipment costs that are subscriber-driven to a subscriber access cost. The allocation keys are based either on a proportionality rule (subscriber-driven vs. traffic-driven) or on a EPMU rule.

5.4 Business overheads

The business overheads are considered in the model as a markup applied to the total of the network costs. The business overheads to be taken into account must be only those relevant to network. The model defines a markup to derive the network component of business overheads from the total network cost.

This markup is obtained from the three following parameters provided by operators[14]:

- Network costs;
- Retail costs;
- Un-attributable costs.

The markup represents the percentage of un-attributable costs in the sum of network costs and retail costs and is applied to the network unit cost.

The model assumes that generic operator business overheads correspond to the average business overheads of four operators.

---

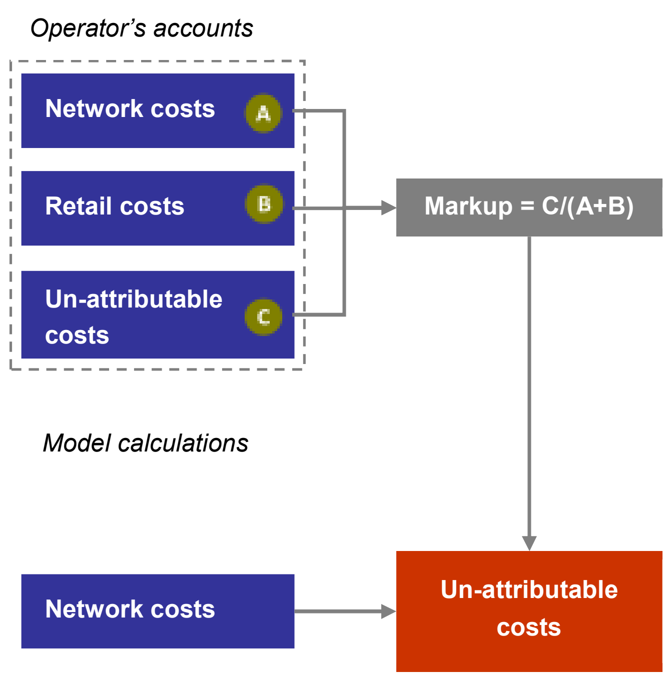
[12] Source: ANCOM

[13] 4 years, issued from benchmark

[14] Total costs of operators consist of the provided information contained in the operators' accounts : network costs, un-attributable costs, and retail costs

Data retrieved from operators corresponds to the year 2010. Consequently, historic and forecast business overhead costs values are assumed to evolve in accordance with network OPEX costs.

Figure 35 - Business overheads calculation



Source: TERA Consultants

5.5 Conversion rules for non-network costs

Allocation of additional costs between services is done through the total annual traffic distribution (there is no busy hour dimensioning aspect for these additional costs). This is why conversion rules must be applied to compare the annual traffic of each service (voice, SMS, MMS, Data). Each service traffic is converted into 2G minutes traffic based on various conversion factors calculated according to each service rate and unit size, as provided by operators. Conversion factors are presented in Appendix 12.3.

5.6 Final result

The final cost is the sum of network cost, interconnection specific cost, license cost and business overheads.

6 Depreciation

There is a very large number of approaches to depreciate an investment, but NRAs in Europe mainly use economic depreciation when implementing bottom-up model rather than accounting depreciation with straight line annuities.

Economic depreciation calculates annuities that evolve with expected incomes generated by the asset over the asset's useful life. Economic depreciation is defined simply as the period-by-period change in the market value of an asset. The market value of an asset is equal to the present value of the income that the asset is expected to generate over the remainder of its useful life.

The most appropriate methods for depreciation of investments are:

- Tilted Annuity
- Adjusted Tilted Annuity

As it is stated in the Conceptual Framework, "ANCOM intends to calculate depreciation for the mobile and fixed core models either with the economic depreciation approach or with the tilted annuity approach, depending on the outputs of the discussions with operators because these depreciation methods provide appropriate economic signals".

In consequence, in the model, annuities are calculated in tilted annuities depreciation, by assuming in the formula that the first annual cost recovery is happening one year after the investment is made.

Under the tilted annuity approach, cost recovery for an asset is a function of the replacement cost of the asset, the expected annual price trend of the asset, the expected economic life of the asset and the WACC. It is considered in the model a WACC of 10.5%.

Figure 36 - Tilted annuity method

$$A_t = I \times \frac{(\omega - p)}{1 - \left(\frac{1+p}{1+\omega}\right)^n} \times (1+\omega)^{payment\_term}$$

Where:

- A_t is the annuity of year t;
- I is the investment;

- ω is the cost of capital;
- t is the year considered;
- n is the asset life;
- p is the tilt (price trend of the asset in the long term);
- Payment_term is the difference in time between the investment is paid and the first payment is received. When this parameter is set at 0, the formula already includes 6 months of payment terms (equivalent to one year between the first annual cost recovery and investment is made).

The model also calculates the economic depreciation (Sheets #8.1 and 8.2).

The aim of this approach is to calculate the yearly incremental cost of the network, during the period 2006 – 2030[15].

The first step is to determine the incremental quantity of equipment, sites, and transmission links each year. This calculation is based on the network dimensioning results obtained in the previous paragraphs, and takes into account the economic life of equipment to determine the number of equipment renewed each year.

Once the incremental number of network equipment, sites and transmission links is known, the next step is to deduce the corresponding incremental network cost, multiplying the incremental number of units by the unit CAPEX and unit OPEX.

The total network cost (total cost for each network equipment) is then allocated to the services in order to determine a constant economic cost for each service. Example:

Total cost of BTS allocation to service 1:

$$\sum_i \frac{BTScost_i \times UsageService1_i}{(1+\omega)^i} = \sum_i \frac{VolumeService1_i \times p_{BTS|service1}}{(1+\omega)^i}$$

Where:

$BTScost_i$: Total annual cost of BTS equipment in the year i
UsageService1i : % usage of service1 of BTS equipment in the year i
VolumeService1 : annual volume of service1 in the year i
ω : the WACC
pBTS|service1 : the component of the constant economic cost of service1 which is related to BTS which is the aim of the calculation

[15] Extension of 2006-2020 period to 2030 allows to englobe all the equipment with their economic lives for the economic depreciation calculation. After 2020 the traffic is maintained as is until 2030.

The quantity of usage of each equipment is determined for each service. These values have been previously calculated for LRAIC cost (Cf. section 7.1.1). Values after 2020 are maintained until 2030[16].

Once the component of constant economic cost of each service is calculated for all the equipment, the sum of these components is done in order to get the total constant economic cost of each service.

[16] As the model considers that additional traffic represents the traffic corresponding to 4G (LTE)

7 Cost allocation

Once the total costs and additional costs are calculated, the next step is to allocate them in order to deduce the cost of the targeted service. The allocation may differ according to the selected approach: either in LRAIC+, or in Pure LRIC. The model proposes to choose between these methods in the control panel.

7.1 LRAIC+ cost allocation approach

7.1.1 Total annual costs allocation

Knowing the annual total cost of each network element, the aim is to determine the percentage of usage of each element by each service.

The model is based on the 'Required Capacity Allocation' approach. It belongs to '*Proportionality Rules*'. Costs are allocated according to the capacities required for each service supported by the network. In the case of telecommunication networks, costs can be allocated on the basis of the busy hour bandwidth.[17]

For example: If an on-net call represents 10% of the total traffic usage of BTS, 10% of total traffic usage of BSC, 5% of total traffic usage of MSCs, and 5% of total traffic usage of MGW, then to total annual cost allocated to this equipment represents: 10% of the annual cost of BTS, 10% of annual cost of BSC, 5% of annual cost of MSCs, and 5% of total annual cost of MGW.

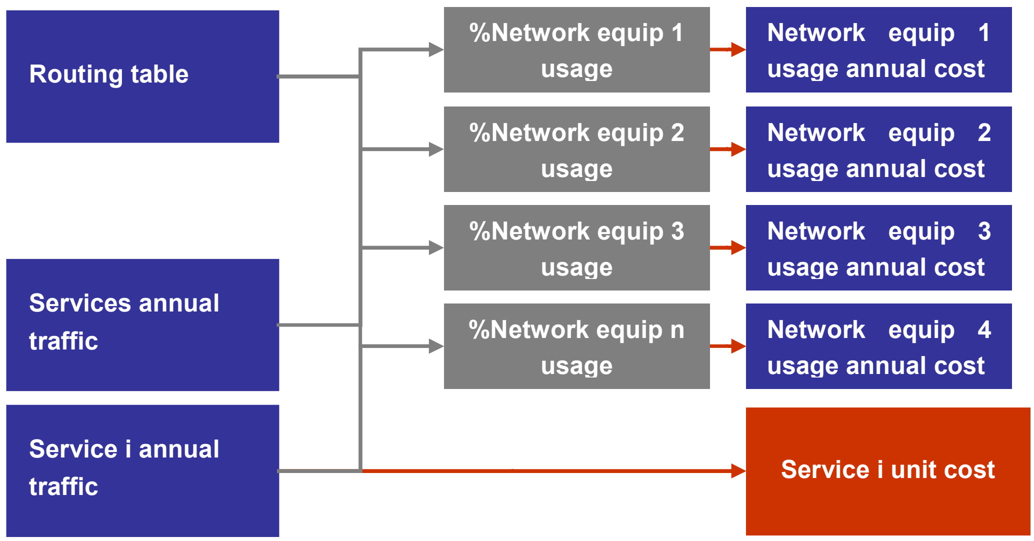
The percentage of usage of network nodes by the different services is calculated using the routing table provided by each operator.

For example: an on-net call needs to activate 2 BTS while an off-net call needs to activate only one BTS of the operator's network. Doing the same with all the services, and taking into account the busy hour traffic of each service, it becomes possible to determine the percentage of usage of a BTS by each equipment. It is assumed in the model that allocation is done according to busy hour traffics.

The calculated cost using this method represents the total annual cost allocated to all the service annual traffic. The following step is to determine the cost per unit of traffic of the service. This is achieved by dividing the total calculated cost by the service total annual traffic.

[17] If the Busy Hour bandwidth (= most relevant cost driver) consumption of the various services differs depending on the network's segments, it is necessary to break up the total cost by the network's segments before carrying out the cost allocation.

Figure 37 - LRAIC cost allocation



Source: TERA Consultants

7.1.2 Additional costs allocation

With the Required Capacity Allocation, the allocation of the total cost of an additional cost item (E.g: interconnection staff total cost) between all the services, is based on the total commercial traffic of each service. As traffic is expressed in different units (minutes for voice, units for SMS and MMS, Mbytes for data), the model has to convert the traffic in a homogenous unit to allocate the network cost among all services. In the model all the services traffic units are converted to 2G minutes.

Regarding the licence cost (one-off), the allocation is done as business overhead

The allocation is also based on total commercial traffic of services.

7.2 Pure LRIC cost allocation approach

The Pure LRIC approach consists in modeling the network while not considering the incoming traffic. The avoided cost resulting in (hypothetically) removing the incoming traffic of a service is then recovered only through the incoming traffic.

The model uses a specific macro to handle this approach. This macro, first, removes the traffic volumes that are to be taken into the “pure increment” (i.e. puts to zero the incoming traffic). Then, the total network cost obtained with the removal of the “pure increment” is subtracted to the total network cost obtained with all services (including the “pure increment”). The resulting difference is divided by the “pure increment” (i.e. the incoming traffic) in order to get a unit traffic cost for the service.

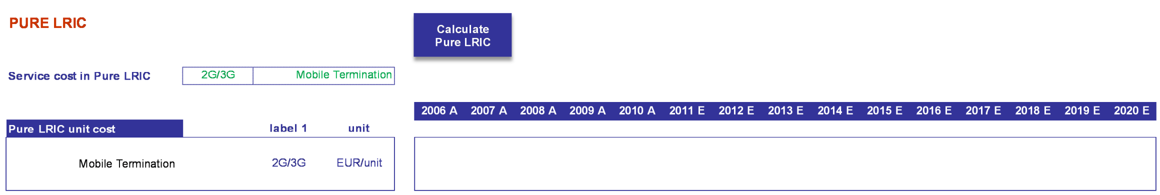
After 2020 the traffic is maintained as is until 2030, because the model considers that additional traffic represents the traffic corresponding to 4G (LTE). In consequence, the pure LRIC cost is assumed to be constant from 2020 to 2030.

As both business overheads and license fees are true common cots, they are not taken into account for the “pure LRIC”. It is also assumed that interconnection staffs are not taken into account in the calculation of “pure LRIC”. Thus all additional costs are not considered in Pure LRIC calculation.

The model allows the user in the ‘Control Panel’ to choose between the following services for Pure LRIC cost calculation in 2G, 3G, and 2G/3G:

- Mobile voice termination;
- SMS termination;
- MMS termination;
- Data

Figure 38 - Pure LRIC user interface in Control Panel



Source: TERA Consultants

In practice, in the model the definition of the increment for each category (2G, 3G, 2G/3G as well as voice, SMS, MMS and data) is defined in Sheet #4.0, line 260 to 343.

The model also calculates the pure LRIC economic cost of the services (in Sheet #8.3) for the period 2006-2030. It considers the previously calculated pure LRIC costs for the services (see section 7.2), weighted by the annual traffic of the considered service on which the WACC is applied:

The equation for a specific service is as follows:

$$\sum_i \frac{pureLRIC_i \times TrafficVolume_i}{(1+\omega)^i} = pLRIC \times \sum_i \frac{TrafficVolume_i}{(1+\omega)^i}$$

Where:

$pureLRIC_i$: previously calculated pure LRIC cost for service in year i
$TrafficVolume_i$: annual volume traffic of service in the year i
ω : the WACC
pLRIC : constant economic pure LRIC cost for the service which is the aim of the calculation

8 Main results

The model presents the calculated unit costs in the *'Sheet #0. Control'*, in both LRAIC+ and Pure LRIC allocations, with the split between:

- Network costs:
    - Radio Access Network;
    - Core Network;
    - Transmission Network.
- Other non-network costs.

9 Model Calibration

The costs presented in the *'Sheet #0. Control'* are issued from the calibration of the model with the following inputs:

- Cell radii: the model uses calibrated cell radii leading to a number of base stations coherent with operators' figures;
- Unit costs: the unit cost of equipment provided by operators are cross-checked and completed with international benchmark.

Moreover, the model includes a Sheet for Sensitivity Analysis. This module allows to assess the model sensitivity to the following parameters:

- Traffic growth;
- Unit costs of equipment;
- Opex markup (as percentage of Capex).

For each parameter the model defines three scenarios with three different values of delta from the base case as shown in the following figure:

Figure 39 - Sensitivity Analysis calculation

Opex Markup (as % of Capex)

Apply in the model

Δ from Base case

Voice services blended termination	Unit	2006 A	2007 A	2008 A	2009 A	2010 A	2011 E	2012 E	2013 E	2014 E	2015 E	2016 E	2017 E	2018 E	2019 E	2020 E
Service																
On-net	EUR															
Outgoing off-net	EUR															
Incoming off-net	EUR															

Δ from Base case 0% Scenario 2 (0%)

Voice services blended termination	Unit	2006 A	2007 A	2008 A	2009 A	2010 A	2011 E	2012 E	2013 E	2014 E	2015 E	2016 E	2017 E	2018 E	2019 E	2020 E
Service																
On-net	EUR															
Outgoing off-net	EUR															
Incoming off-net	EUR															

Δ from Base case 20% Scenario 3 (20%)

Voice services blended termination	Unit	2006 A	2007 A	2008 A	2009 A	2010 A	2011 E	2012 E	2013 E	2014 E	2015 E	2016 E	2017 E	2018 E	2019 E	2020 E
Service																
On-net	EUR															
Outgoing off-net	EUR															
Incoming off-net	EUR															

10 Illustrations table

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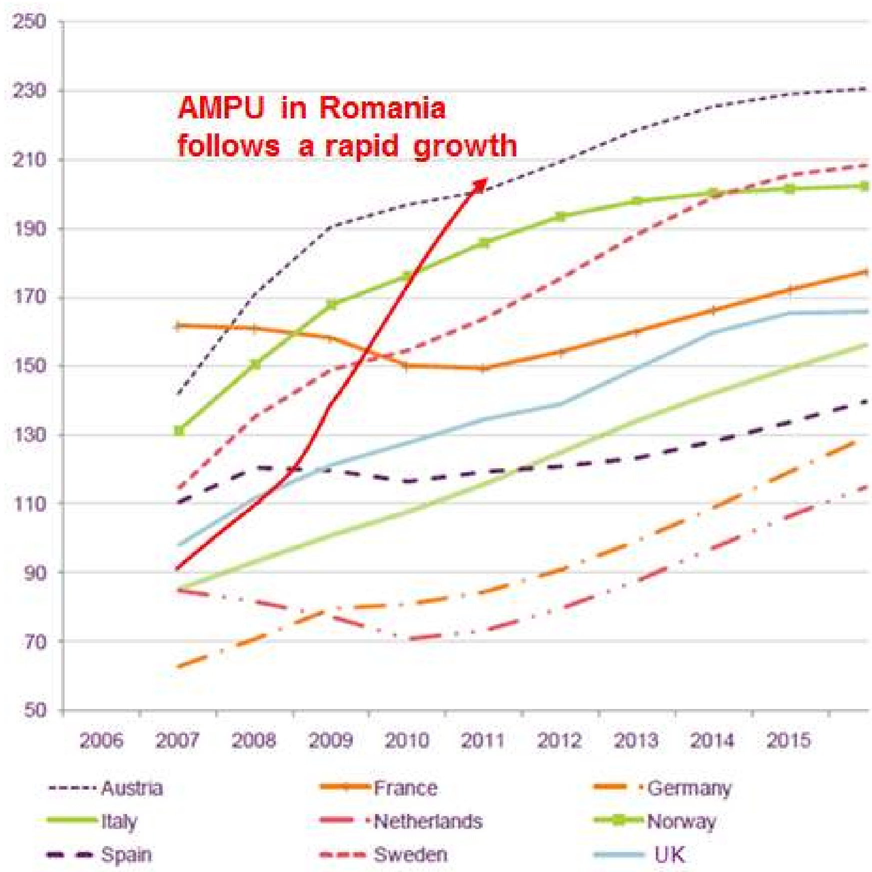
12 Appendix

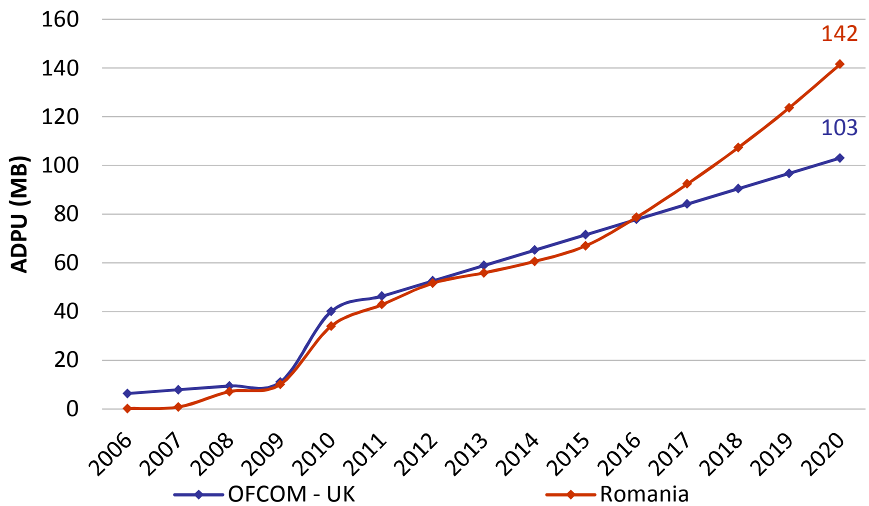
12.1 Annual demand in Romania

12.1.1 Benchmark of monthly outgoing traffic per subscriber



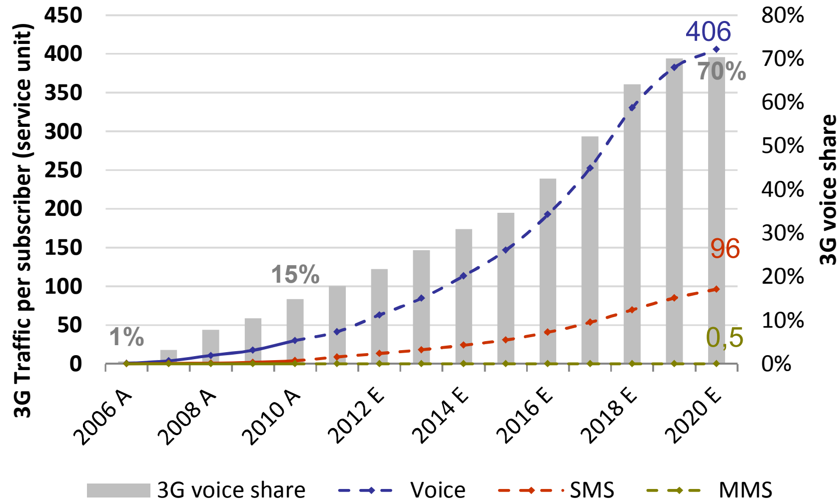
Source: TERA Consultants, Ofcom

12.1.2 Forecast of monthly ADPU in UK and Romania

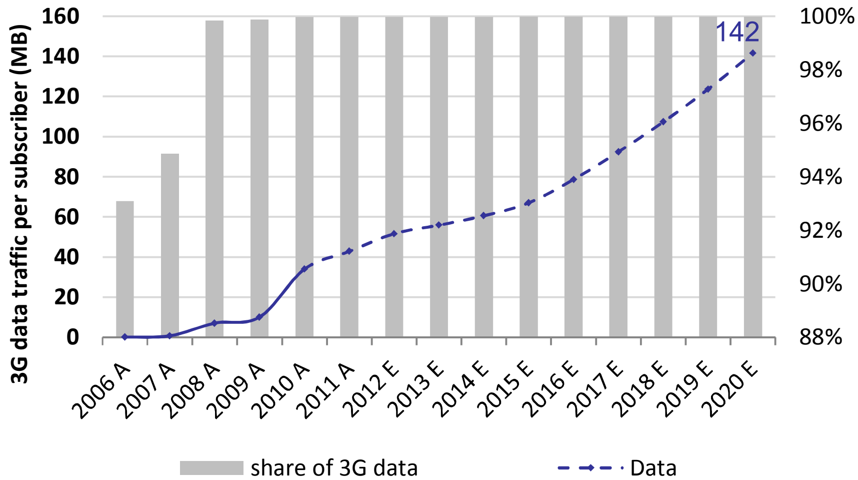


Source: TERA Consultants, Operators, Ofcom

12.1.3 3G services monthly traffic evolution in Romania



Source: TERA Consultants, Operators



Source: TERA Consultants, Operators

12.2 Annual traffic to BH traffic conversion factors

Table 11 - Yeraly traffic to BH Erlangs (Access)

Yearly traffic to BH Erlangs - Access	unit		2G	3G
Minutes	Erlangs/unit		4.53E-06	4.53E-06
SMS	Erlangs/unit		2.49E-08	2.49E-08
MMS	Erlangs/unit		4.04E-08	4.04E-08
Data Mbytes	Erlangs/unit		2.83E-07	2.83E-07
Video Minutes	Erlangs/unit			3.11E-06

Source: Mobile Model

Table 12 - Yearly traffic to BH Erlangs (Core)

Yearly traffic to BH Erlangs - Core	unit		2G	3G
Minutes	Erlangs/unit		4.53E-06	4.53E-06
SMS	Erlangs/unit		2.49E-08	2.49E-08
MMS	Erlangs/unit		4.04E-08	4.04E-08
Data Mbytes	Erlangs/unit		2.83E-07	2.83E-07
Video Minutes	Erlangs/unit			3.11E-06

Source: Mobile Model

Table 13 - Yearly traffic to BH Mbps (Access)

Yearly traffic to BH Mbps - Access	unit	2G	3G
Minutes	Mbps/unit	5.27E-08	6.92E-08
SMS	Mbps/unit	8.07E-11	8.07E-11
MMS	Mbps/unit	1.48E-08	1.48E-08
Data Mbytes	Mbps/unit	4.14E-07	4.14E-07
Video Minutes	Mbps/unit		1.90E-07

Source: Mobile Model

Table 14 - Yearly traffic to BH Mbps (Core)

Yearly traffic to BH Mbps - Core	unit	2G	3G
Minutes	Mbps/unit	2.77E-07	6.92E-08
SMS	Mbps/unit	8.07E-11	8.07E-11
MMS	Mbps/unit	1.48E-08	1.48E-08
Data Mbytes	Mbps/unit	4.14E-07	4.14E-07
Video Minutes	Mbps/unit		1.90E-07

Source: Mobile Model

12.3 Conversion rules for non-network costs

Table 15 - Conversion rules to 2G minutes

conversion to 2G min.	unit	Conv. Factor
2G min.	2G min./2Gmin.	1.000
2G SMS	2G min./2G SMS	0.002
2G MMS	2G min./2G MMS	0.410
2G MB	2G min./2G MB	11.460
3G min	2G min./3G min.	1.000
3G SMS	2G min./3G SMS	0.002
3G MMS	2G min./3G MMS	0.410
3G MB	2G min./3G MB	11.460
3G Vid. Call min.	2G min./3G Vid Call min	5.246

Source: Mobile Model

Figure 40 - SMS to 2G minutes conversion rule

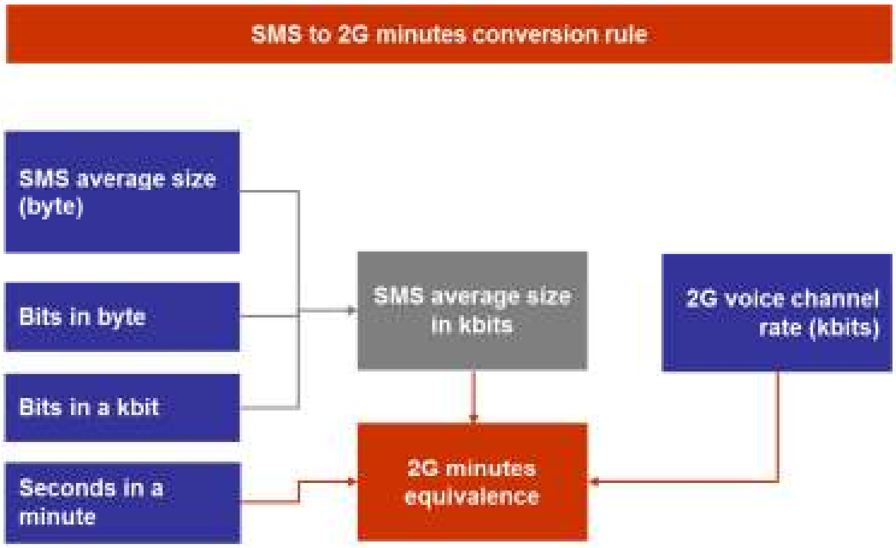


Figure 41 - MMS to 2G minutes conversion rule

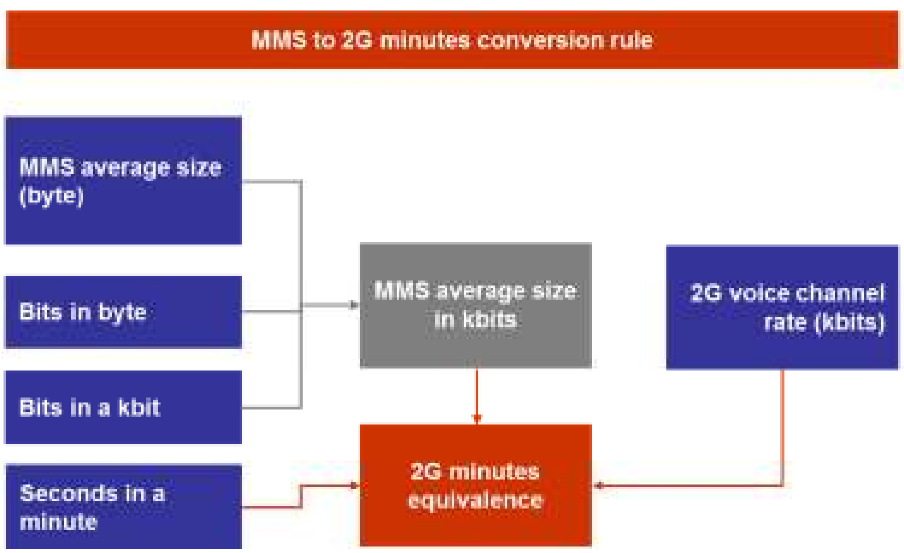


Figure 42 - Data MB to 2G minutes conversion rule

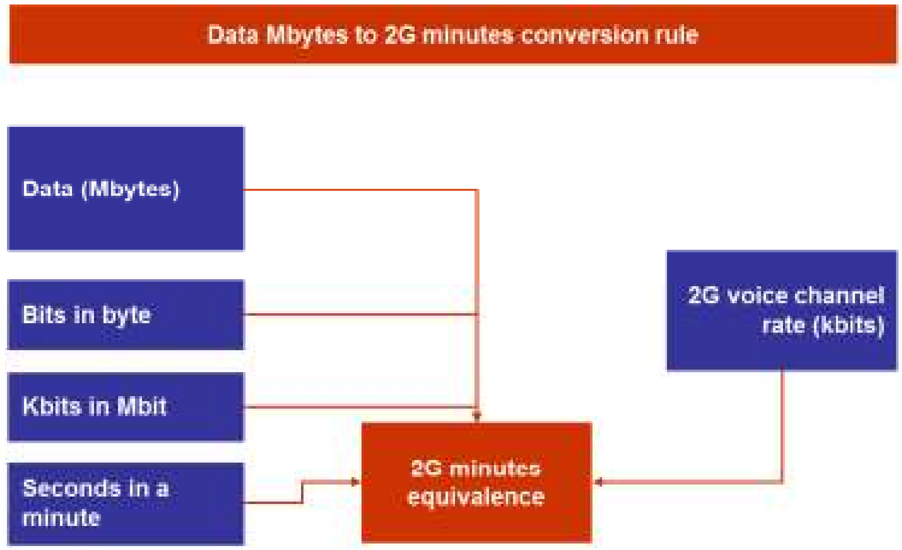


Figure 43 - Video calls minutes to 2G minutes conversion rule

12.4 Generic operator routing matrix

Table 16 - Routing matrix of the generic operator

		Access			Core														Backhaul	Backbone		
Routing Matrix	unit	BTS / Node B	Aggregators	BSC / RNC	MGW	MSC-S	SGSN	GGSN	SMS-C	MMS-C	HLR	VMS	VLR	IN	NMS	Portability platform	Signalling transfer platform	Billing platform	BTS-BSC/Node B-RNC	BSC/RNC - MGW	MGW - MSC-S	MSC-S - MSC-S
On Net calls	2G/3G 01	2.00	1.80	2.00	1.00	1.50	-	-	-	-	1.00	-	1.00	0.70	1.00	1.00	-	1.00	2.00	2.00	2.00	2.00
Outgoing Calls to Fixed Line	2G/3G 02	1.00	0.90	1.00	1.00	1.50	-	-	-	-	-	-	1.00	0.70	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00
Outgoing Calls to Other Mobile	2G/3G 03	1.00	0.90	1.00	1.00	1.50	-	-	-	-	-	-	1.00	0.70	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00
Outgoing Calls to International	2G/3G 04	1.00	0.90	1.00	1.00	1.50	-	-	-	-	-	-	1.00	0.60	1.00	1.00	-	1.00	1.00	1.00	-	-
Other Outgoing Calls	2G/3G 05	1.00	0.90	1.00	1.00	1.50	-	-	-	-	-	-	1.00	1.00	1.00	-	-	1.00	1.00	1.00	1.00	1.00
Outgoing inbound roaming call	2G/3G 06	1.00	0.90	1.00	1.00	1.50	-	-	-	-	-	-	1.00	0.70	1.00	-	-	1.00	1.00	1.00	-	-
Outgoing outbound roaming call	2G/3G 07	-	-	-	1.00	1.50	-	-	-	-	-	-	1.00	0.70	1.00	-	-	1.00	-	-	-	-
Incoming calls from fixed	2G/3G 08	1.00	0.90	1.00	1.00	1.50	-	-	-	-	1.00	-	1.00	0.02	1.00	1.00	-	1.00	1.00	1.00	-	-
Incoming calls from other mobile	2G/3G 09	1.00	0.90	1.00	1.00	1.50	-	-	-	-	1.00	-	1.00	0.02	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00
Incoming calls from international	2G/3G 10	1.00	0.90	1.00	1.00	1.50	-	-	-	-	1.00	-	1.00	0.01	1.00	1.00	-	1.00	1.00	1.00	-	-
Incoming inbound roaming call	2G/3G 11	1.00	0.90	1.00	1.00	1.50	-	-	-	-	1.00	-	1.00	0.02	1.00	1.00	-	1.00	1.00	1.00	-	-
incoming outbound roaming call	2G/3G 12	-	-	-	1.00	1.50	-	-	-	-	1.00	-	1.00	-	-	1.00	-	1.00	-	-	-	-
Voice Mail Retrieval	2G/3G 13	1.00	0.90	1.00	1.52	1.52	-	-	-	-	1.00	1.00	1.00	0.70	1.00	-	-	1.00	1.00	1.00	1.00	1.00
SMS on net	2G/3G 14	2.00	1.80	2.00	-	2.00	-	-	1.00	-	1.00	-	1.00	0.70	1.00	2.00	-	1.00	2.00	2.00	-	-
SMS outgoing to other network	2G/3G 15	1.00	0.90	1.00	-	1.50	-	-	1.00	-	-	-	1.00	0.70	1.00	1.00	-	1.00	1.00	1.00	-	-
SMS outgoing to international	2G/3G 16	1.00	0.90	1.00	-	1.50	-	-	1.00	-	-	-	1.00	0.70	1.00	1.00	-	1.00	1.00	1.00	-	-
SMS incoming from other network	2G/3G 17	1.00	0.90	1.00	-	1.50	-	-	1.00	-	1.00	-	1.00	-	1.00	1.00	-	1.00	1.00	1.00	-	-
SMS incoming from international	2G/3G 18	1.00	0.90	1.00	-	1.50	-	-	1.00	-	1.00	-	1.00	-	1.00	1.00	-	1.00	1.00	1.00	-	-
MMS on net	2G/3G 19	2.00	1.80	2.00	-	-	1.50	1.00	-	1.00	1.00	-	-	-	1.00	1.00	-	1.00	2.00	2.00	-	-
MMS outgoing to other network	2G/3G 20	1.00	0.90	1.00	-	-	-	-	-	1.00	-	-	-	-	1.00	1.00	-	1.00	1.00	1.00	-	-
MMS outgoing to international	2G/3G 21	1.00	0.90	1.00	-	-	-	-	-	1.00	-	-	-	-	1.00	1.00	-	1.00	1.00	1.00	-	-
MMS incoming from other network	2G/3G 22	1.00	0.90	1.00	-	-	1.50	-	-	1.00	1.00	-	-	-	1.00	1.00	-	1.00	1.00	1.00	-	-
MMS incoming from international	2G/3G 23	1.00	0.90	1.00	-	-	1.50	-	-	1.00	1.00	-	-	-	1.00	1.00	-	1.00	1.00	1.00	-	-
Data service	2G/3G 24	1.00	0.90	1.00	-	-	1.00	1.00	-	-	1.00	-	-	-	1.00	-	-	1.00	1.00	1.00	-	-
3G On Net Video Calls	2G/3G 25	2.00	1.80	2.00	1.50	1.50	-	-	-	-	1.00	-	-	0.50	1.00	1.00	-	1.00	2.00	2.00	2.00	2.00
3G Outgoing Video Calls to Other Mobile	2G/3G 26	1.00	0.90	1.00	1.70	1.70	-	-	-	-	1.00	-	-	0.50	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00
3G Incoming Video Calls from other mobile	2G/3G 27	1.00	0.90	1.00	1.50	1.50	-	-	-	-	1.00	-	-	0.02	1.00	1.00	-	1.00	1.00	1.00	1.00	1.00

12.5 Summary of equipment unit CAPEX (MEA)

Table 17 - Equipment Unit Cost (Generic Operator)

Nodes Equipment Costs			unit	Total fixed cost
				-
Macrocell			EUR	-
	2G BTS 900MHz		EUR	-
		BTS (regular)	EUR	21 500
	2G BTS 1800MHz		EUR	-
		BTS (regular)	EUR	21 700
	3G Node B		EUR	-
		Node B (regular)	EUR	20 200
				-
	2G TRX		EUR	800
	3G Transceivers		EUR	2 200
				-
Microcell or In-Building Solution (including repeaters)			EUR	-
	2G Microcell / IBS		EUR	2 500
	3G Microcell / IBS		EUR	2 200
	Repeaters		EUR	2 200
				-
Agregators			EUR	53 900
				-
2G BSC			EUR	627 000
3G RNC			EUR	591 400
				-
2G/3G MSC			EUR	1 132 500
Media Gateway			EUR	416 600
				-
HLR			EUR	1 096 900
VLR			EUR	336 900
Voice message server			EUR	1 995 700
EIR			EUR	-
Value Added Service Platform			EUR	634 100
SMS-C			EUR	560 000
MMS-C			EUR	966 100
SGSN/GGSN (for data transmission)			EUR	-
	SGSN		EUR	576 800
	GGSN		EUR	481 000
Intelligent network			EUR	10 167 800
Billing platform			EUR	7 271 800
Number portability			EUR	561 500
Signalling transfer platforms core			EUR	449 200
Signalling transfer platforms interconnect			EUR	404 300
Network management systems			EUR	336 900
				-

Source: TERA Consultants, Operators, Benchmark

12.6 Description of implemented Macros

In order to complete some calculations, the model needs to call some VBA functions which allows the automation of operations. These functions are explained below.

12.6.1 Pure_LRIC function

This function calculates the pure LRIC cost of the selected services (refer to Sheet #7.3).

The service Pure LRIC cost is the result of the division of service total cost (1st term of the division) by the service annual traffic (2nd term of the devision).

The different steps of this function are:

- **Step 1:** The cell 'AG20' of the Sheet #4.1 is set to 'LRAIC+' value. This means that the model will consider all the list of services.
- **Step 2:** The model then calculates the corresponding network cost (all services considered).
- **Step 3:** These network costs are then copied in values in the buffer in Sheet #6, line 524 to 544.
- **Step 4:** The model goes back to the cell 'AG20' of the Sheet #4.1, and sets it to 'Pure LRIC inverted'. This means that the model will consider only the services targeted by the Pure LRIC cost calculation (example: 2G terminating voice services).
- **Step 5:** The model then calculates the total annual commercial volume of traffic generated by these services (2nd term of the division), in the Sheet #4.1, line 639.
- **Step 6:** These volumes are copied in values in the Sheet #7.3, line 15.
- **Step 7:** The model goes back to the cell 'AG20' of the Sheet #4.1 which is set to 'Pure LRIC'. This time the model will consider all the services except the ones targeted by the Pure LRIC cost calculation.
- **Step 8:** The model will calculate the cost of a network built in order to handle all the services except the services targeted by the pure LRIC cost calculation.
- **Step 9:** The model calculates the difference between the cost of a network built to handle all the services (content of the buffer), and the cost of a network built to handle all the services except the one targeted by the Pure LRIC cost calculation (the last values of Sheet #6 line 499 to 519). This difference is calculated in Sheet #6 line 550 to 570.
- **Step 10:** This difference represents the cost of the pure LRIC increment, and is copied in values in the Sheet #7.3, line 20 (1st term of the division).
- **Step 11:** The model calculates the unit cost of the pure LRIC increment in Sheet #7.3, line 25.
- **Step 12:** the buffer in Sheet #6 line 524 to 544 is cleared.
- **Step 13:** the model goes back to the cell 'AG20' of the Sheet #4.1 and set it back to its initial value 'LRAIC+'.

12.6.2 Clear_Pure_LRIC function

This function clears the traffic and cost figures that are pasted in values in the sheet #7.3 lines 15 and 20.