Communications Regulatory Authority of the Republic of Lithuania

Reference paper for creating bottom up long run average incremental costs model (BU-LRAIC)

24 October, 2008

Glossary

The terminology used in this document is defined in legal acts of the Republic of Lithuania. List of other terminology and abbreviations is placed in following table.

No.	Abbreviation	Term	Explanation
1.		$\lfloor X \rfloor$	A function that returns the highest integer less than or equal to X.
2.		$\lceil X \rceil$	A function that returns the smallest integer not less than X.
3.	A	A interface	Link between the BSS and MSC/MGW.
4.	B	Byte	Basic unit of information equal to 8 bits
5.	bit	Bit	A bit is a binary digit, taking a value of either 0 or 1. Binary digits are a basic unit of information storage and communication in digital computing and digital information theory
6.	BSC	Base Station Controller	The BSC is the functional entity within the GSM architecture that is responsible for radio resource allocation to a mobile station, frequency administration and handover between BTS controlled by the BSC.
7.	BTS	Base Transceiver Station	In cellular system the Base Transceiver Station terminates the radio interface. Each BTS may consist of a number of TRX, typically between 1 and 16.
8.	BHCA	Busy hour call attempts	Number of call attempts in a busy hour.
9.	BHE	Busy Hour Erlangs	Measurement of traffic in telecommunications network during a busy hour expressed in Erlangs.
10.	BHT	Busy Hour Traffic	Amount of traffic in a busy hour.
11.		Call	Connection established by means of a publicly available telephone service allowing two-way communication in real time.
12.	CAPEX	CAPEX	Capital expenditure costs. CAPEX costs comprise depreciation and ROI.
13.		Channel	Logical unit in a circuit used for transmitting electric signals.
14.		Circuit	Telecommunications line which ensures transmission of electric signals.
15.	CSD	Circuit Switched Data	CSD is the original form of data transmission developed for the time division multiple accesses (TDMA)-based mobile phone systems like Global System for Mobile Communications.
16.	CJC	Common and joint costs	Cost that need to be allocated to several services.
17.	CCS	Common-Channel Signalling	CCS is the transmission of signalling information (control information) on a separate channel to the data.
18.		Cost driver	A factor that influences the existence and amount of costs.
19.	CVR	Cost volume relationship	Relationship between total value of cost and cost driver.
20.		Costs	Decrease in economic value for a company due to usage of fixed assets, sale of assets, loss of assets, decrease in asset value or increase in liabilities over a period, which results in decrease in equity capital.
21.	CCA	Current cost accounting	Accounting of costs in terms of current costs and prices of products and services.
22.	CD	Current depreciation	Depreciation cost expressed in current cost accounting terms.
23.	DDF	Digital distribution frame	DDF is the distribution equipment used between digital multiplexers, between digital multiplexer and exchange equipment or non voice service equipment, carrying out such functions as cables connection, cable patching and test of loops that transmitting digital signals.
24.	EIR	Equipment identity register	EIR is a database employed within mobile networks. It stores information about user equipment state (stolen, non-conforming and other).
25.		Erlang	Measurement of traffic indicating number of call minutes on a network during one minute time.
26.	FC	Fixed costs	Costs that are fixed and not influenced by change in volume of service.

No.	Abbreviation	Term	Explanation
27.		Forward looking cost accounting	Accounting of costs in terms of forward looking costs and prices of products and services.
28.	GGSN	Gateway GPRS Support Node	GGSN supports the edge routing function of the GPRS network.
29.	Gb	Gb interface	Link between the SGSN and PCU.
30.	GSM	Global System for Mobile communication	GSM is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity.
31.	GBV	Gross book value	Acquisition cost of an asset.
32.	GRC	Gross replacement cost	Cost incurred for replacing object of similar type and characteristics not taking into account accumulated depreciation.
33.	HSCSD	High Speed Circuit Switched Data	HSCSD is an enhancement to Circuit Switched Data.
34.	HSDPA	High Speed Downlink Packet Access	HSDPA improves system capacity and increases user data rates in the downlink direction, that is, transmission from the Radio Access Network to the mobile terminal.
35.	HCA	Historic cost accounting	Accounting of costs in terms of historic (actual) costs and priced of products and services.
36.	HG	Holding gain	Income that results due to increase in asset value.
37.	HLR	Home Location Register	The Home Location Register is a database, which provides routing information for mobile terminated calls and SMS.
38.	HCC	Homogenous cost category	A set of costs, which have the same driver, the same cost volume relationship pattern and the same rate of technology change.
39.		Incremental cost	Increase in costs due to increase in volume of service.
40.		Indirect costs	Costs that are indirectly related to a specific product and service and that need to be allocated to different using economically justifiable drivers.
41.	Iub	Iub Interface	Link between the RNC and the Node B.
42.	LRAIC	Long run average incremental costing	The principle of long run average incremental costing – estimating change in costs as a result of change in cost driver volume and dividing them over a unit of service. The costs are measured in the long run, which means that the company based on the level of demand can change the amount of resources involved in providing a service i.e. all costs become variable.
43.	Max (…)	Maximum	It is a function, which returns the biggest number in a set of values defined in brackets.
44.	MGW	Media Gateway	A gateway that supports both bearer traffic and signalling traffic
45.	Min (…)	Minimum	Min (minimum) is a function, which returns the smallest number in a set of values defined in brackets.
46.	MSC	Mobile Switching Centre	A Mobile Switching Centre is a telecommunication switch or exchange within a cellular network architecture which is capable of inter working with location databases.
47.	MSS	MSC Server	MSC Server handles call control for circuit-based services including bearer services, tele services, supplementary services, charging and security, besides controlling resources related to circuit-based services.
48.	MMSC	Multimedia Messaging Service Centre	The Multimedia Messaging Service Centre provides a store and forward facility for multimedia messages sent across a mobile network.
49.	NBV	Net book value	Remaining value of an asset calculated as a difference between gross book value and accumulated depreciation plus changes in asset revaluation over time.
50.	NRC	Net replacement cost	Cost incurred for replacing object of similar type and characteristics taking into account accumulated depreciation.
51.	NC	Network Component	Network Components represent logical elements that are functionally integrated and in combining those elements any services may be modelled.
52.	NE	Network element	Any network object, which physically or logically can be identified as an independent network unit.
53.		Node B	The Node B is the function within the UMTS network that provides the physical radio link between the user equipment and the network
54.	OPEX	OPEX	Operating expenditures that comprise salaries, material and other external service costs.

No.	Abbreviation	Term	Explanation
55.	ODF	Optical distribution frame	ODF are used for connection and patching of optical cables, mainly used as the interface between optical transmit network and optical transmit equipment and between optical cables in access network of optical fiber subscribers.
56.		Port	A device for connecting lines with network nodes accepting and forwarding electric signals.
57.	RNC	Radio Network Controller	The main element in Radio Network Subsystem that controls the use and the reliability of the radio resources.
58.	ROI	Return on investment	Required return on investment calculated by multiplying WACC and capital employed.
59.		Routing matrix	Matrix which represents the intensity of NE usage for different services.
60.	SCP	Service Control Point	The SCP processes the request and issues a "response" to the MSC so that it may continue call processing as appropriate.
61.	SGSN	Serving GPRS Support Node	SGSN keeps track of the location of an individual Mobile Station and performs security functions and access control.
62.	SMSC	Short Message Service Centre	The SMSC forwards the short message to the indicated destination subscriber number.
63.	SFH	Soft Handover	Soft handover is a category of handover procedures where the radio links are added and abandoned in such manner that the mobile always keeps at least one radio link established.
64.	SDCCH	Stand-alone Dedicated Control Channel	This channel is used in the GSM system to provide a reliable connection for signalling and SMS messages.
65.		Supporting activity	Supporting activity comprise administration, accounting, planning, human resource management and other supplementary activities.
66.		Switch (switching host)	Network element that switches calls between two network nodes.
67.		Telecommunications network	Telecommunication network used to provide public telephone service including transmission of voice between network end points and other services such as fax or data transmission.
68.		Termination	Transmission of a call from a switch (including switch) where interconnection can be established located closest to the subscriber receiving the call to the final network point where the call ends.
69.	TRX	Transceiver	A device that is capable of both transmission and reception of a signal.
70.	TRC	Transcoder Controller	Function of TRC is transmitting data between switching controllers in a data transmission network.
71.		Transit	Transmission of a call from a switch where interconnection can be established located closest to a subscriber initiating a call (excluding the switch) to a switch where interconnection can be established located closest to a subscriber receiving a call (excluding the switch) via one or more switches.
72.		Transmission link	A link which ensures transmission of optical and electric signal between two remote geographic units.
73.		Transmission network	Telecommunication equipment which ensures transmission of optical and electric signals among separate core network components.
74.		Tributary card	Component of a multiplexer constituting interface between multiplexer and other telecommunication equipment.
75.	UMTS	Universal Mobile Telecommunications System	It is a 3G mobile communications system which provides an enhanced range of multimedia services.
76.		Unsuccessful call	Unsuccessful calls comprise calls when the line is busy and calls when the recipient does not answer the call.
77.	VC	Variable costs	Costs that are directly related to change in volume of services.
78.	VLR	Visitor Location Register	The Visitor Location Register contains all subscriber data required for call handling and mobility management for mobile subscribers currently located in the area controlled by the VLR.
79.	VMS	Voice Mail Service	Network element, which executes recording of voice messages for users, who are unable to answer a call.
80.		WAP Gateway	WAP Gateway accesses web content for a mobile.
81.	WACC	Weighted average cost of capital	Cost of capital calculated as a weighted cost of borrowed and equity capital.

No.	Abbreviation	Term	Explanation
82.		Wholesale billing system	Information system which involves estimating and invoicing for wholesale services.
83.	WAP	Wireless Application Protocol	A standard designed to allow the content of the Internet to be viewed on the screen of a mobile device such as mobile phones, personal organisers and pagers.

Table of contents

1. Introduction

1.1. Legal background

Elaboration of a tool for calculation of cost-based carrier specific interconnection prices of the Lithuanian mobile telecom networks developed by bottom-up method of long-run incremental costs (further – BU-LRAIC) method is maintained by these legal regulations:

- European Union Electronic Communications Regulation System (directives);
- Law on Electronic Communications of Republic of Lithuania;
- Market analysis conducted by the Communications Regulatory Authority of Republic of Lithuania (further – RRT);
- Executive orders and decisions of the Director of the RRT.

The directive on a common regulatory framework for electronic communications networks and services (Framework Directive) was established by the European Parliament in 2002. The aim of Framework Directive is to create a harmonised regulation of electronic communications services, electronic communications networks, associated facilities and associated services across Europe.

In 2005, RRT initiated market analyses of wholesale mobile voice call termination in Lithuania, which, as a result, concluded that:

- There are 3 dominant mobile operators having significant market power (SMP) in mobile voice call termination market in Lithuania;
- Call termination costs in dominant mobile operators' network are not significantly lower, compared to retail prices (moreover, in most of the cases, they are even higher); this creates entrance barriers for the new entrants and leads to reduced competition in the market.

In order to promote efficient competition, RRT issued executive orders by which Lithuania's mobile operators, having SMP (further – Operators), are obliged to set mobile termination rates on a level that could solve the competition issues mentioned above. RRT having evaluated major price control tools, concluded, that the most appropriate tool for mobile termination rate control is BU-LRAIC, which is a common price control tool for mobile termination rates in European Union countries.

1.2. Document objective

The objectives of this reference paper (further – BU-LRAIC model reference paper or MRP) are:

- To present the scope and the detailed principles of the BU-LRAIC modelling (guidelines and concept of the BU-LRAIC model);

BU-LRAIC modelling is theoretical and might have difference from real market situation, however, it models mobile telephone operator operating efficiently in competitive market.

While using BU-LRAIC method, there is a risk that some of the practical aspects will be excluded from the scope of the model. Seeking to avoid this kind of situation it is expected that all market players will take an active participation in model implementation. In case there is a lack of data for BU-LRAIC modelling, benchmarks will be used.

2. LRAIC methodology

All calculations in model are based on Forward – Looking Long Run Average Incremental Cost (LRAIC) methodology, assuming efficient operator operating in a fully competitive market.

The meaning of the definition of LRAIC is as follows:

1. ***Long run.*** In the short-run incremental costs can split into fixed and variable incremental costs, however, in the long run all costs are variable, which is the principle of LRAIC. Consequently, all input factors (as well as capital) should be included to the forecasted demand for services.
2. ***Average Incremental.*** The principle of average incremental costs involves estimating a change in costs which is caused by production (service) increment (or decrease) and allocating estimated costs to one unit of service. Figure 1 illustrates the concepts of incremental and average incremental costs.

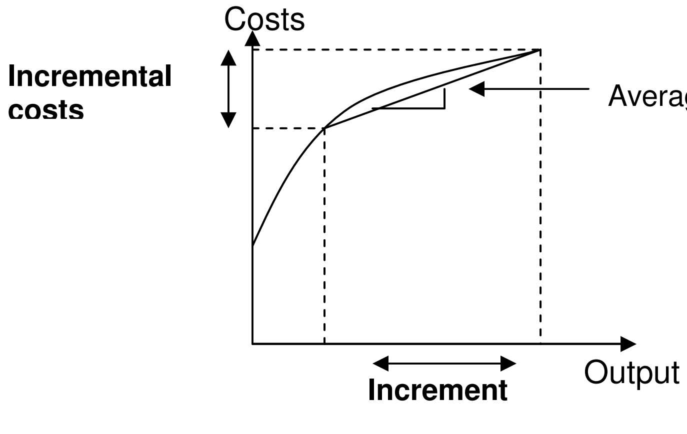

Figure 1: incremental and average incremental costs

3. ***Forward looking.*** Forward-looking costs are the costs incurred today building a network which has to face future demand and asset prices. In practice this means that if modelling is done in a year X, the cost of services are calculated for the year X+1 (e.g. if modelling is done in 2008, service costs are calculated for the year 2009).

In a broader meaning, LRAIC (together with the efficiency assumption) is the approximation of incremental costs, which, according to the economic theory, reflects the economic costs (and the price) of an efficient operator operating in a fully competitive market. As a result, seeking for efficient competition, mobile termination rates should come up to the same rates as calculated using the LRAIC method.

2.1. Network modelling

In current BU-LRAIC model network modelling is not constrained by current network design or topology. It is assumed that network is built from scratch with forward-looking technology. Number of network elements and their locations are derived from modelling efficient operator operating in a fully competitive market. Consequently, this approach determines the level of optimization, that closely approximates long-run economic costs of providing interconnection costs and assures that Operators have incentives to migrate to a more efficient architecture.

Following network modelling principles described above, the detailed calculations of required network elements are provided in section *7. Network dimensioning.*

2.2. Increments

In LRAIC methodology increments refer to elements that influence costs of objects subject to analysis (objects under analysis are provided in section *5.1 List of services*). In LRAIC model effect of change in increment to change in costs of a particular service is calculated (further – incremental costs) and a particular mark-up is added to such costs to cover joint and common costs related to service provision. So the costs of services calculated in BU-LRAIC model would consist of two components: incremental costs (derived mainly through engineering models) and common and joint cost (derived typically as a percentage mark-up on the network cost). Increments of current BU-LRAIC model are:

- Coverage (geographical scope of mobile network);
- Traffic (voice and video calls, data services, SMS, MMS, etc);
- Subscribers.

The increment "coverage (geographical scope of mobile network)" effect on costs is assessed respect to costs, which are incurred seeking to accomplish territory coverage obligations, which are stated in the licenses of frequency handling.

This BU-LRAIC model during sensitivity analysis will also be tested with a more narrow increment. The narrow increment will be determined in the extent of “coverage”, “traffic”, “subscribers” (e.g. narrow increment could be change of calls traffic). In order to find out an incremental costs when the increment is defined as a particular service, two scenarios (one assesses the increment (decrement) effect on costs, in other scenario case increment equals to zero (0), i.e. there is no increment) of the BU-LRAIC model need to be ran. The difference in scenarios' results would show incremental costs of particular service when increment is defined narrowly.

Detailed description of mark-ups to cover common and joint costs is provided in section *8.2. Mark-ups*.

2.3. Modelling period

In order to get a deeper insight into mobile network operator cost structure, it is common practice to calculate service costs for at least several periods. BU-LRAIC model will calculate nominal service costs for the years 2006 – 2010.

2.4. Cost accounting

Network costs derived in BU-LRAIC modelling have to be valued at replacement cost (GRC). There are two methods of measuring costs in terms of replacement cost: historical cost accounting and current cost accounting.

Historical cost accounting is an approach to accounting using asset values based on the actual amount on money paid for assets. The main advantages of using historical costs are simplicity and certainty. The major disadvantage of this approach is that book values may be based on out of date costs due to exclusion of adjustments for equipment price changes related to technology improvement and (or) inflation.

The objective of current cost accounting approach is to derive information what it would cost to acquire assets and other required resources now or in the near future. The current cost is calculated by using the current (or the latest) market prices (replacement cost) or adjusting the historical cost for asset specific inflation and therefore getting more realistic values of assets and other resources used in business.

It has to be noted that BU-LRAIC calculation, as a rule, is based on current cost basis. In the situation, when fixed assets that are still in use are outdated or no longer available on the market, it may be difficult to assign their current price. In this situation the concept of modern equivalent asset (MEA) has to be adopted. MEA means an asset that would perform the same function as the asset to be replaced and is currently available on the market. Historical costs may be also used as a proxy for current costs, when assets are being purchased quite recently and no better source for current costs (including MEA) are available.

2.5. Cost of capital

Weighted Average Cost of Capital (WACC) is used in BU-LRAIC model for cost of capital estimation. WACC measures a company's cost of debt and equity financing weighted by the percentage of debt and percentage of equity in a company's target capital structure.

Calculation and elaboration of WACC of Lithuanian mobile network operators will be provided in a separate report.

2.6. Technological background

At the moment of the BU-LRAIC modelling, all Operators used GSM and UMTS network technologies to provide services and there is no evidence for significant changes in mobile network technology in a modelling period. Therefore, joint GSM / UMTS network approach is used in the network modelling.

It is also assumed that voice traffic can be fully accomodated in GSM network. According to the data available as of 30th of June 2008, total number of mobile network subscribers was 4964,3[1] thousand and number of UMTS subsribers was 213,4[1]thousand (UMTS subscribers proportion is equal to 4,3%). Assuming that majority of UMTS subscribers use UMTS network mostly for data services, therefore UMTS voice traffic proportion is insignificantly small in total voice traffic.

More detailed explanation about network services split between GSM and UMTS network is provided in section *6. Demand*.

Taking into account operators practical experience in Lithuania and abroad two alternative core network architectures for handling the voice services traffic are being evaluated:

- Establishment of Mobile Switching Centres (all voice in MSCs);
- Establishment of Mobile Switching Centre Server and Media Gateways (all voice in MSS and MGW).

BU-LRAIC model has a functionality to model both of the scenarios. Based on the modelling results the most cost effective core network architecture will be selected.

Dimensioning rules for all network elements are given in the section *7. Network Dimensioning.*

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[1] Report on the electronic communications sector 2008 Quarter II. www.rrt.lt

2.7. Mark – ups

As already discused in section *2.2 Increments* a mark-up approach is foreseen in the BU-LRAIC model to cover common and joint costs. The major driver of network structure and development is service demand. Increasing service demand requires additional network capacity and appropriate network elements. This results in increased network related operational costs (e.g. more designing engineers are need to built and supervise network). Network related operational cost (headcount) is a driver for administration and support operational and capital costs. Service demand and mark-up relation is illustrated in figure 2:

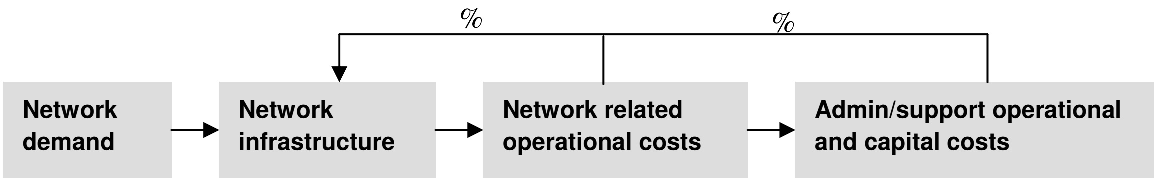

Figure 2. Service demand and mark-up relation

More detailed description of mark-ups usage and allocation is provided in section *8.2 Mark-up allocation.* Referring to the best practices and international experience, mark-ups to cover common and joint costs are estimated by collecting data from Operators, further they are adjusted by benchmarks derived from foreign operators' data. Currently it is assumed that latest data from the following sources will be adopted for the purpose of mark-up calculation:

1. Reports published by Information Society Directorate of the European Commission related to bottom-up costing models used for the interconnection cost calculation in European Union countries.
2. Reports on LRAIC projects, LRAIC models that are used in other EU countries.
3. Federal Communications Commission (FCC) reports summarizing financial statements of telecommunication operators in USA.
4. Australian Competition and Consumer Commission (ACCC) documents related to interconnection cost calculation in Australia based on the Long Run Incremental Costing.

3. Outline of the modelling principles

3.1. Sub-models

The current BU-LRAIC model consists of two separate sub-models. Each of them includes different services (see Table 2). The sub-models are physically separated into two independent (not inter-linked) MS Excel models.

Table 2. Sub-models of the BU-LRAIC model

First sub-model – services included	Second sub-model – services included
Call origination	Point of interconnection services
Call termination	Point of interconnection capacity services
Call within the operator's network	
Data communication services (WAP, GPRS, EDGE, CSD, HSCSD, UMTS, HSDPA)	
Short messages services (SMS)	
Multimedia messages services (MMS)	

In First sub-model the following costs are calculated:

- CAPEX related network costs;
- OPEX related network costs;
- CAPEX – administration and support;
- OPEX – administration and support.

CAPEX related network costs cover network components listed in section *5.3 List of network components*[2]. CAPEX related network management system costs, OPEX related network costs, OPEX and CAPEX for administration and support, are listed and discussed in section *8.2. Mark-ups*.

The modelling principles used in the second BU-LRAIC sub-model are presented in Annex 1.

3.2. Model scenarios

Modelling scenarios in the first BU-LRAIC sub-model are as follows:

- Individual model scenarios for each Operator (in total three scenarios);
- Generic model scenario for estimation of costs of efficient operator operating in competitive market (in total one scenario).

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[2] Costs of network management system (NMS) are calculated as a mark-up.

According to orders of the Director of RRT, prices of regulated services provided by Operators should not be higher than prices of services provided by efficient operator operating in competitive market. Prices of an efficient operator are set referring to the results of BU-LRAIC modelling.

Seeking to assess whether there are objective justified differences of costs of services modelled for different Operators and seeking to evaluate efficiency of the Operators, separate scenarios for each Operator operating in Lithuania would be created. Individual model scenarios are merged to one generic model scenario to calculate costs of an efficient operator operating in a competitive market.

Essential parameters that define generic model comprise:

- Market share (demand inputs are generally assumed to be equal to 1/3 from the total retail market);
- Area coverage (averaged for all three Operators)
- Traffic profile (based on actual most efficient Operator's data);
- Network equipment prices (based on most cost efficient prices Operators can get from suppliers. Also realistic purchase combination of network equipment will be evaluated).

Individual scenarios for every Operator are foreseen only for the first sub-model.

In the second sub-model simplified algorithm for calculating point of interconnection service related costs will be realised.

4. Flow of BU-LRAIC modelling

Objective of BU-LRAIC method is to define the costs of services that would be incurred by a new efficient operator in a competitive market assuming that network is rebuilt to meet current and forward looking demand.

Figure 3 illustrates the overall flow of BU-LRAIC methodology. Accordingly, structure of this reference paper is aligned with the provided flow as well.

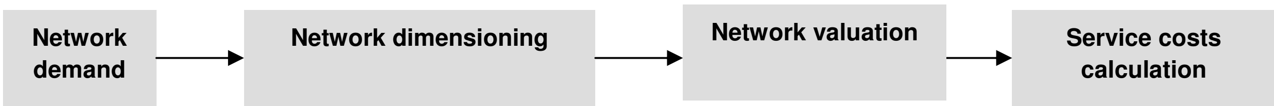

Figure 3: the overall flow of BU-LRAIC methodology.

4.1. Network demand

Network demand section of the model is required to translate the relevant portfolio of service demand into network dimensioning demand. As the dimensioned network should handle the traffic during the peak period, measured service volumes are translated into busy-hour throughput network element demand.

No network is built for today's demand. Networks are constructed to meet future demands. In order to reflect this requirement the planning horizon to which networks are designed has to be considered. In principle this is determined on the basis of economic considerations by examining the trade off between the costs of spare capacity in the short term and the costs of repeatedly augmenting capacity on a just-in-time basis.

The detailed explanation of network demand principles is provided in section *6. Demand.*

4.2. Network dimensioning

Following the identification of demand on a network element basis, the next stage in the process is the identification of the necessary network equipment to support the identified level of busy-hour demand. This is achieved through the use of engineering rules, which consider the modular nature of network equipment and hence identify the individual components within each defined network element. This then allows variable cost structures to determine the costs on an element-by-element basis.

The detailed explanation of network dimensioning principles is provided in section *7. Network dimensioning.*

4.3. Network valuation

After all necessary network equipments are identified Homogenous Cost Categories (HCC) are derived (physical units of network elements identified are multiplied by current prices and investments calculated later on are annualized). HCC is a set of costs, which have the same driver, the same cost volume relationship (CVR) pattern and the same rate of technology change. HCC values are calculated by multiplying physical units of network elements by current prices. Later on, calculated investments are annualized and mark-ups (both for CAPEX and OPEX costs) are set. HCC list is provided in section *5.2 List of homogeneous cost categories*.

All mobile network elements identified during network dimensioning must be revalued at Gross Replacement Cost (GRC). On the basis of GRC value its annual cost is calculated. This cost includes both:

- Annualised capital costs (CAPEX);
- Annual operating expenses (OPEX).

CAPEX costs are cost of capital and depreciation. OPEX costs consist of salaries (including social insurance), material and costs of external services (external services – transportation, security, utilities, etc).

The detailed analysis of methodologies to annualize CAPEX costs is provided in section *8.1. Cost annualization.*

Detailed explanation of Mark-ups used (both for CAPEX and OPEX) is provided in sections *2.7 Mark-ups* and *8.2. Mark-ups.*

List of HCCs, Network Components (NCs) and services used in the model is provided in section *5. Scope of the model.*

4.4. Service cost calculation

The fundamental principle of LRAIC methodology – costs are allocated to network components, network components are mapped with network services and in this way the costs are calculated (see figure 4).

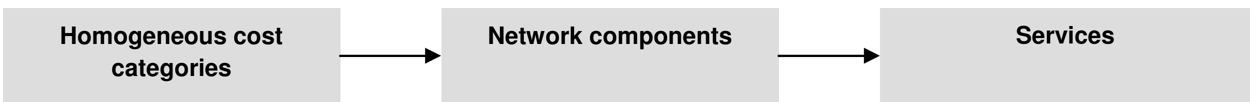

Figure 4: Cost allocation principle

After HCC are derived they are allocated to a particular Network Component (NC). NCs represent logical elements that are functionally integrated and in combining those elements any services may be modelled. NC list is provided in the section *5.3 List of network components.* Later, total NC costs are calculated by summing appropriate HCCs. NC costs are divided by service volumes. Costs of services are calculated on a basis of network component unit costs according to network component usage statistics.

The detailed explanation of service cost calculation is provided in secion *9. Service cost calculation.*

5. Scope of the model

The scope of the model is defined with respect to the range of services, network components and homogenous cost categories to be included into the BU-LRAIC model. This determines the modelled network architecture and its granularity level.

5.1. List of services

List of services included in the first BU-LRAIC sub-model comprise:

1. Call origination;
2. Call termination;
3. Call within the operator's network;
4. Data communication services (WAP, GPRS, EDGE, CSD, HSCSD);
5. Short messages services (SMS);
6. Multimedia messages services (MMS).

List of services included in the second BU-LRAIC sub-model comprise:

1. Point of interconnection services;
2. Providing capacity in point of interconnection services.

BU-LRAIC model is fitted to estimation of costs of services modelling the provision of services on the ground of GSM (900 MHz), DCS (1800 MHz), UMTS and HSDPA standards.

Referring to the list of services in the first BU-LRAIC sub-model provided above and BU-LRAIC modelling principles covered in this reference paper, respective outcome of the first BU-LRAIC sub-model is expected:

Table 3. Outcome of the first BU-LRAIC sub-model

Service name	Unit costs	Costs of Network Components, Lt																	
		Tower and site preparation	BTS	BSC	NodeB	RNC	MSC or MSS / MGW	TX / BTS/NodeB-BSC/RNC	BSC-MGW or RNC-MGW	TX / MSC-MSC or MGW-MGW	SMSC	MMSC	SGSN / GGSN	EDGE	HSDPA	WAP	HLR	BILLING	Number portability platform
On-net call, per minute																			
Call origination, per minute																			
Call termination, per minute																			

Service name	Unit costs	Costs of Network Components, Lt																	
		Tower and site preparation	BTS	BSC	NodeB	RNC	MSC or MSS / MGW	TX / BTS/NodeB-BSC/RNC	BSC-MGW or RNC-MGW	TX / MSC-MSC or MGW-MGW	SMSC	MMSC	SGSN / GGSN	EDGE	HSDPA	WAP	HLR	BILLING	Number portability platform
WAP data, per MB																			
GPRS data, per MB																			
EDGE data, per MB																			
UMTS data, per MB																			
HSDPA data per MB																			
CSD data, per minute																			
HSCSD data, per minute																			
SMS, per message																			
MMS, per message																			

5.2. List of homogeneous cost categories

As it was mentioned in section *4. Flow of BU-LRAIC modelling*, HCC values are calculated by annualising CAPEX costs calculated in network dimensioning part of the model and by application of a set of mark-ups (both for CAPEX and OPEX costs).

Table 4 indicates the list of homogeneous cost categories (HCC) in BU-LRAIC model.

Table 4. List of HCC in BU-LRAIC model

HCC name	HCC sub-components
Site	*Macro cell: tower and site preparation* *Micro cell: site preparation* *Pico cell: site preparation* *Stand-alone transmission radio link: tower and site preparation*

HCC name	HCC sub-components
BTS	*Macro cell: equipment (omni sector)* *Macro cell: equipment (2 sector)* *Macro cell: equipment (3 sector)* *Micro cell: equipment* *Pico cell: equipment* *Macro cell: TRXs* *Micro cell: TRXs* *Pico cell: TRXs*
Node B	*Macro cell: equipment (omni sector)* *Macro cell: equipment (2 sector)* *Macro cell: equipment (3 sector)* *Micro cell: equipment* *Pico cell: equipment*
PDH / SDH Radio link	*PDH radio link 2 Mb/s microwave link* *PDH radio link 8 Mb/s microwave link* *PDH radio link 16 Mb/s microwave link* *PDH radio link 32 Mb/s microwave link* *SDH radio link STM-1 microwave link (1+1)*
BSC / RNC	*BSC: base unit* *BSC: BS TRX extension* *TRC: transcoder base unit* *TRC: transcoder E1 (A interface) extension* *RNC: basic units* *RNC: extension units (Iub link)* *RNC: extension units (sectors)* *RNC: extension units (sites)*

HCC name	HCC sub-components
MSC	*MSC: basic unit and software* *MSC: processor extension* *MSC: VLR, EIR extension* *MSC: SS7 extension* *MSC: trunk port extension* *MSC: I/O peripherals* *MSS: basic unit and software* *MSS: processor extension* *MGW: basic unit and software* *MGW: processor extension* *MGW: trunk port extension*
Network Functionality	*SFH: soft handover (network-wide)* *SFH: soft handover (MSS extension)* *SFH: soft handover (RNC extension)* *SFH: soft handover (NodeB extension)* *GSM/DCS: control (network-wide)* *GSM/DCS: control (MSC extension)* *GSM/DCS: control (BSC extension)* *GSM/DCS: control (BTS extension)*
Data Network	*EDGE: data transfer (network-wide)* *EDGE: data transfer (MSC extension)* *EDGE: data transfer (BSC extension)* *EDGE: data transfer (BTS extension)* *HSDPA: data transfer (network-wide)* *HSPDA: data transfer (MSS extension)* *HSDPA: data transfer (RNC extension)* *HSDPA: data transfer (NodeB extension)* *PCU: base unit* *PCU: extension units (Gb link)* *SGSN: base unit* *SGSN: processing extension* *GGSN: basic unit and licence* *WAP: gateway*

HCC name	HCC sub-components
SMSC / MMSC	*SMSC: base unit* *SMSC: extension* *MMSC: base unit* *MMSC: extension*
Other Network	*SSP: service switching point (network-wide)* *SCP: service control point - base unit (pre-paid related)* *SCP: extension - subscribers* *SCP: extension - tps* *VMS: base unit* *VMS: extension* *HLR: base unit* *HLR: extension* *Billing IC hardware and software* *Number portability system: hardware and software*
License and frequency fee	*Concession right - GSM 900 MHz (total value)* *Concession right - GSM 1800 MHz (total value)* *Concession right - UMTS (total value)*
Leased Line	*Leased Lines BSC-MSC or BSC-MGW (RNC – MSC or RNC-MGW), per link* *Leased Lines BSC-MSC or BSC-MGW (RNC – MSC or RNC-MGW), per km* *Leased Lines MSC-MSC or MGW- MGW, per link* *Leased Lines MSC-MSC or MGW- MGW or MGW, per km*
Network management system[3]	-

5.3. List of network components

List of NC used in BU-LRAIC model is as follows:

- Tower and site preparation;
- Base transceiver station (BTS);
- Base station controller (BSC);

[3] Costs of network management system (NMS) are calculated as a mark-up. See section *8.2 Mark-ups*

- Node B;
- Radio network controller (RNC);
- Mobile switching centre (MSC);
- MSC server (MSS) and Media Gateway (MGW);
- Transmission (TX):
    - BTS-BSC (Node B – RNC);
    - BSC-MSC or BSC-MGW (RNC – MSC or RNC-MGW);
    - MSC-MSC or MGW – MGW;
- Short Message Service Centre (SMSC);
- Multimedia Messaging Service Centre (MMSC);
- Serving GPRS Support Node / Gateway GPRS Support Node (SGSN / GGSN);
- Enhanced Data rates for GSM Evolution (EDGE) (software and license);
- High-Speed Downlink Packet Access (HSDPA);
- Wireless Application Protocol (WAP) Gateway;
- Home Location Register (HLR);
- GPRS specific components;
- Billing system;
- Number portability platform;
- Other costs.

6. Demand

Mobile networks are dimensioned to handle traffic in the peak periods not the average traffic loads. The average traffic load must therefore be converted into peak loads by the application of traffic distribution factors drawn from the operator's network management statistics. Consequently, data related to service demand and customer profile in BU-LRAIC model comprises of the following type of information:

- Service demand in terms of voice and video call minutes, SMS and MMS quantities, data minutes and bytes;
- Number of subscribers;
- Traffic flows, network element usage factors;
- Service profiles in terms of daily traffic structure, set-up time, rate of unsuccessful call attempts.

Demand calculation is also split in two parts according to mobile network technology used:

- UMTS network;
- GSM network.

The load is measured with busy hour Erlangs (BHE). BHE is calculated for services in the network by network element or transmission type between elements. BHE calculation algorithms for services and two mobile network technologies analysed are presented in the following sections.

6.1. GSM network

The demand for GSM network consists of:

1. Voice calls, minutes[4];
2. SMS, messages;
3. MMS, messages;
4. Circuit data transmission (HSCSD/CSD), minutes;
5. Packet data transmission, MB.

Voice calls minutes are analysed in four groups:

- On-net minutes[4] (call minutes originated and terminated in own mobile network, including Mobile virtual network operator's (further – MVNO) and inbound roaming traffic (calls originated and terminated on the same network);

[4] Actual minutes of traffic in the network, not rounded billing system data.

- Off-net minutes[4] (call minutes originated in own network and terminated in fixed networks, in international networks and in other mobile networks, including MVNO‘s and inbound roaming traffic (calls originated on network but terminated on the other network);
- Incoming minutes[4] (call minutes originated in fixed networks, international networks and in other mobile networks, including MVNO‘s and inbound roaming traffic (incoming roaming calls) and terminated in own network);
- Transit minutes[4] (traffic, which is neither originated nor terminated in the own network, bridge traffic between different operators).

SMS is split into three groups:

- On-net SMS (SMS sent from own mobile network to own mobile network, including MVNO‘s and inbound roaming traffic (SMS originated and terminated on the same network);
- Outgoing SMS (SMS sent from own mobile network to international networks and to other mobile networks, including MVNO‘s and inbound roaming traffic (SMS originated on own network, but terminated on the other network);
- Incoming SMS (SMS sent from international networks and from other mobile networks, including MVNO‘s and inbound roaming traffic (SMS originated on the other network but terminated on own network) to own mobile network).

MMS is split into three groups:

- On-net MMS (MMS sent from own mobile network to own mobile network, including MVNO‘s and inbound roaming traffic (MMS originated and terminated on the same network);
- Outgoing MMS (MMS sent from own mobile network to international networks and to other mobile networks, including MVNO‘s and inbound roaming traffic (MMS originated on own network, but terminated on the other network);
- Incoming MMS (MMS sent from international networks and from other mobile networks, including MVNO‘s and inbound roaming traffic (MMS originated on the other network but terminated on own network) to own mobile network).

Packet data traffic volumes comprise of year total up-link and year total down-link traffic loads MB[5].

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[5] Volumes also include traffic of roaming data services.

6.2. UMTS network

As it was explained in section *2.6. Technological background*, UMTS voice traffic proportion is insignificantly small in total voice traffic and it is accommodated in GSM network and at a current stage of network development no subscriber would connect to UMTS network just to use the voice. Therefore it is assumed that demand for UMTS network in modelling period consists of:

1. Video calls, minutes[6];
2. Packet data transmission, MB.

Video calls are split into 3 groups:

- On-net minutes[6] (call minutes originated and terminated in own mobile network, including MVNO‘s and inbound roaming traffic (calls originated and terminated on the same network);
- Off-net minutes[6] (call minutes originated in own network and terminated in fixed networks, in international networks and in other mobile networks, including MVNO‘s and inbound roaming traffic (video calls originated on network but terminated on the other network);
- Incoming minutes[6] (call minutes originated in fixed networks, international networks and in other mobile networks, including MVNO‘s and inbound roaming traffic (incoming roaming video calls) and terminated in own network).

Packet data traffic volumes in UMTS network are distinguished as it is in GSM network: year total up-link and year total down-link traffic load (MB)[7].

6.3. Service demand conversion

The average traffic load conversion to peak loads is needed for evaluation of network (network elements, equipment amounts), which would effectively service the required services demand. Average traffic load conversion to peak loads is done to each network element, i.e. BHE is calculated to each network element. Amount of network elements is calculated according to estimated BHE (for UMTS data transmission – busy hour MB). The average traffic load consists of statistic raw service data. Peak loads consist of statistic raw service data evaluated according to routing, inhomogeneity factors other coefficients.

Average service demand conversion to BHE will be done in the followings steps:

1. Calculating the number of call attempts (for voice and video calls);

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[6] Actual minutes of traffic in the network, not rounded billing system data.

[7] Volumes also include traffic of roaming data services.

2. Weighting billed traffic volumes by routing factors;
3. Adjusting billed voice and video minutes volumes for unbilled traffic;
4. Converting service volumes to minute equivalent;
5. Traffic volumes (minutes) adjusted by de-averaging factors.

Call-attempts number (N_{CA}, units) is calculated according to the following formula:

$$N_{CA} = \frac{T_{call}}{\alpha_{CD}} \qquad (1)$$

Where:

T_{call} – Voice or video calls traffic, minutes;

α_{CD} – Average call duration, minutes.

Call-attempts in BU-LRAIC reference paper are converted to busy hour call-attempts for each network element. This size is used to estimate processor part capacity of mobile switching centre (MSC), mobile switching centre server (MSS), media gateway (MGW) and intelligent network (IN).

Busy hour call-attempts per minute are calculated the annual call-attempts (N_{CA}) amount evaluating with routing factors (formula No. 2 is applied and instead of services traffic call-attempts are inserted), with average traffic to busy hour traffic factors (respectively applying formula No. 16), with unsuccessful compared to successful calls ratio and dividing by amount of minutes in a year. So, busy hour call-attempts amount (N_{BHCA}, units) is calculated according to the following formula:

$$N_{BHCA} = \frac{N_{CA} \times r_f \times f_{DA} \times (1 + r_u)}{365 \times 24 \times 60} \qquad (2)$$

Where:

N_{CA} – Call-attempts number, units. See formula No. 1

f_R – Routing factor for particular service traffic in a particular network element. See table No. 5

f_{DA} – De-averaging factor. See formula No. 18

r_u – Ratio of unsuccessful calls compared to successful calls, %. See table No. 6

Division by 365 is year to days conversion, division by 24 is day to hours conversion and division by 60 is hour to minutes conversion.

Weighted traffic volumes (T_W, minutes, messages or MB) for particular network element by routing factors are calculated according to the principle given in the following formula:

$$T_W = T \times f_R \qquad (3)$$

Where:

T – Traffic volume, minutes, messages or MB;

f_R – Routing factor. Routing factor for a particular service traffic in a particular network element. See table No. 5

Routing factors are given in the Routing factors matrix (see table 5). In this matrix each row represents separate traffic of service type and each column represent separate element in the network. The routing factor is estimated having in mind traffic nature and it shows the minimum number of times particular service type traffic utilises particular network element. For instance, on-net SMS messages service in element BTS routing factor is two, which means on-net SMS in its path from user device to user device steps through BTS element on average two times.

Table 5. Routing factors

Service type		Routing factors						
		1	2	3	4	5	6	7
		BTS/ NodeB	BSC/ RNC	MSC/MGW or SMSC or MMSC or SGSN	BTS-BSC/ NodeB-RNC	BSC/ RNC-MSC/ MGW/ SGSN	MSC/MGW/ SGSN-MSC/MGW/ SGSN	MSC/ MGW -IC
Voice traffic (minutes of use)								
1	On-net minutes	2,00	2,00	1,20	2,00	2,00	0,20	0,00
2	Off-net minutes	1,00	1,00	1,50	1,00	1,00	0,50	1.00
3	Incoming minutes	1,00	1,00	1,50	1,00	1,00	0,50	1,00
4	Transit minutes	0,00	0,00	1,00	0,00	0,00	0,00	2.00
Video traffic (minutes of use)								
5	On-net minutes	2,00	2,00	1,20	2,00	2,00	0,20	0,00
6	Off-net minutes	1,00	1,00	1,00	1,00	1,00	0,00	1.00
7	Incoming minutes	1,00	1,00	1,00	1,00	1,00	0,00	1,00
SMS traffic (units								
8	On-net SMS messages	2,00	2,00	1,00	2,00	2,00	0,00	0,00
9	Outgoing SMS messages	1,00	1,00	1,00	1,00	1,00	0,00	1,00
10	Incoming SMS messages	1,00	1,00	1,00	1,00	1,00	0,00	1,00
MMS traffic (units)								
11	On-net MMS messages	2,00	2,00	1,00	2,00	2,00	0,00	0,00
12	Outgoing MMS messages	1,00	1,00	1,00	1,00	1,00	0,00	1,00
13	Incoming MMS messages	1,00	1,00	1,00	1,00	1,00	0,00	1,00
Circuit data traffic (minutes of use)								
14	HSCSD/CSD minutes	1,00	1,00	1,00	1,00	1,00	0,00	1,00
Packet data traffic (Mbytes)								
15	Up-link (GSM subscribers)	1,00	1,00	1,00	1,00	1,00	1,00	0,00
	Down-link (GSM subscribers)	1,00	1,00	1,00	1,00	1,00	1,00	0,00
	Up-link (UMTS subscribers - data)	1,00	1,00	1,00	1,00	1,00	1,00	0,00
	Down-link (UMTS subscribers - data)	1,00	1,00	1,00	1,00	1,00	1,00	0,00

The adjustment for unbilled traffic in the network applies separately for the following traffic groups: voice calls, video calls. Billed minutes traffic or just billed minutes is defined as call duration from a connection start, when a phone is picked up to a connection end, when a phone is hanged up.

Performing calculations billed traffic includes short, emergency, information and similar numbers minutes traffic, i.e. all actual call minutes in the network. Unbilled traffic is related to call set-up duration and unsuccessful calls. Unsuccessful calls comprise of calls both when the line is busy and when the recipient does not answer the call.

Other services (SMS, MMS and data) are billed as they use the network resources; therefore the adjustment for unbilled traffic is not needed.

Calls traffic (T_{B+U}) (billed plus unbilled traffic) is calculated according to the following formulas:

$$T_{B+U} = T_W \times (1 + f_A) \quad (4)$$

$$f_A = \frac{S_s}{\alpha_{CD} \times 60} + \frac{S_u \times r_u}{\alpha_{CD} \times 60} \quad (5)$$

Where:

f_A – Adjusting factor;

T_W – Weighted calls traffic for particular network element, minutes. It is calculated according to the principle given in the formula No. 3

S_s – Call set-up duration for successful calls, seconds. See table No. 6

S_u – Call set-up duration for unsuccessful calls, seconds. See table No. 6

r_u – Ratio of unsuccessful calls compared to successful calls, %. See table No. 6

α_{CD} – Average call duration, seconds. See table No. 6

Division by 60 is second conversion to minute number.

Parameters for calculation of formula No. 4 and No. 5 are provided in the table 6.

Table 6. T_{B+U} calculation parameters

Parameter	Unit	Values per total network
Call set-up duration for successful calls	seconds	8
Call set-up duration for unsuccessful calls	seconds	15
Call duration	seconds	120
Unsuccessful call attempts as percentage of successful calls	%	40

In order to come to homogenous service volume measures, volumes of all non minute services are converted to minute equivalent. This homogenous service volume measure is needed in order to dimension elements, which are used in the network dimensioning generally. The list of converted services is provided below:

1. Video calls;
2. SMS (SMS);

3. MMS (MMS);
4. Packet data traffic for GSM network:
    a. GPRS transmission technology;
    b. EDGE transmission technology.
5. Packet data traffic for UMTS network:
    a. UMTS R99 transmission technology;
    b. HSDPA transmission technology.

Traffic conversion to minute equivalent is done according to the principle given in the following formula:

$$T_C = T_W \times f_C \quad (6)$$

Where:

T_C – Converted particular service traffic, minutes;

T_W – Weighted particular service traffic (in this case voice calls traffic is not included), messages or MB. It is calculated according to the principle given in the formula No. 3.

f_C – Refers to a particular service (video calls, SMS, MMS, GPRS, EDGE, UMTS R99, HSDPA) conversion factor. Factors calculations are provided in formulas 7-14.

Different conversion factors are applied for different type of services. Further in the document conversion factor calculation algorithms are presented.

6.3.1. Conversion of video calls

Conversion factor for video call minutes to voice minute equivalent (f_{vi}) is calculated according to the following formula:

$$f_{vi} = \frac{\rho_{vi}}{\rho_{vo}} \quad (7)$$

Where:

ρ_{vi} – Video call bit rate, kbit/s. See table No. 7

ρ_{vo} – Voice call bit rate, kbit/s. See table No. 7

Video conversion factor is a proportion of video and voice bit rates, which technical average values are given in the table 7.

Table 7. Video conversion parameters

Parameter	Unit	Values per total network
Voice call bit rate	kbit/s	12.20
Video call bit rate	kbit/s	64.00

6.3.2. Conversion of SMS and MMS

SMS message to minute equivalent conversion factor (f_{SMS}) is calculated according to the following formula:

$$f_{SMS} = \frac{L_{SMS}}{\rho_{ch}} \times \frac{8}{60} \qquad (8)$$

Where:

L_{SMS} – Average length of SMS message, B. See table No. 8

ρ_{ch} – SDCCH channel bit rate, kbit/s. See table No. 8

Division by 60 is second conversion to minute number and multiplication by 8 is bytes conversion to bits.

MMS message to minute equivalent conversion factor (f_{MMS}) is calculated according to the following formula:

$$f_{MMS} = \frac{f_G \times L_{MMS}}{10^6} \qquad (9)$$

Where:

f_G – GPRS MB to minute conversion factor. It is calculated according to the principle given in the formula No. 10

L_{MMS} – Average length of MMS message, B.

Division by 10^6 is bytes conversion to megabytes.

SMS and MMS to minute equivalent conversion is based on SDCCH channel bit rate and the length of particular message (B), which technical values are given in the table No. 8

Table 8. SMS/MMS conversion parameters

Parameter	Unit	Values per total network
SDCCH bit rate	bit/s	765.00
Average SMS length	B	40.00
Average MMS length	B	40,000.00

6.3.3. Conversion of GSM packet data

Packet data traffic conversion factor calculation for GSM network is split in two parts, according to the technologies, on which data transmission is based. So, there will be following conversion factors calculated in GSM network:

- GPRS MB to minute conversion factor;
- EDGE MB to minute conversion factor;
- General GSM MB to minute conversion factor.

GPRS/EDGE data traffic conversion factor (f_G or f_E) in megabytes to minute equivalent is calculated according to the principle given in the following formula:

$$f_{G\ or\ E} = 1000 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{G\ or\ E}} \qquad (10)$$

Where:

ρ_G – GPRS bit rate, kbit/s. See table No. 9

ρ_E – EDGE bit rate, kbit/s. See table No. 9

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1000 is megabyte conversion to kilobytes.

General data traffic conversion factor (f_{GSM}) in GSM network in megabytes to minute equivalent is calculated according to the following formula:

$$f_{GSM} = 1000 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_G \times (P_G + P_{GW}) + \rho_E \times (P_E + P_{EW})} \qquad (11)$$

Where:

P_{GD} – GPRS data traffic proportion in GSM network, %;

P_{GW} – GPRS WAP traffic proportion in GSM network, %;

P_E – EDGE data traffic proportion in GSM network, %;

P_{EW} – EDGE WAP traffic proportion in GSM network, %;

ρ_G – GPRS bit rate, kbit/s. See table No. 9

ρ_E – EDGE bit rate, kbit/s. See table No. 9

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1000 is megabyte conversion to kilobytes.

6.3.4. Conversion of UMTS data

Packet data conversion to equivalent minutes in UMTS network is done to estimate networks joint traffic in minutes and allocate for it network component's "Tower and site preparation", which is employed to provide all in this document described services, costs.

Packet data traffic conversion factor calculation for UMTS R99 network is split in two parts, according to the technologies, on which data transmission is based. So, there will be following conversion factors calculated in UMTS network:

- UMTS R99 MB to minute conversion factor;
- HSDPA MB to minute conversion factor;
- General UMTS MB to minute conversion factor.

UMTS R99 and HSDPA data traffic conversion factor (f_{umts} and f_{HSDPA}) in megabytes to minute equivalent is calculated according to the following formulas:

$$f_{umts} = 1000 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{umts}} \quad (12)$$

$$f_{HSDPA} = 8 \times \frac{1}{60} \times \frac{1}{\rho_{HSDPA}} \quad (13)$$

Where:

ρ_{umts} – UMTS bit rate, kbit/s. See table No. 9

ρ_{HSDPA} – HSDPA bit rate, Mbit/s. See table No. 9

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1000 is megabyte conversion to kilobytes.

General data traffic conversion factor (f_{UMTS}) in UMTS network in megabytes to minute equivalent is calculated according to the following formula:

$$f_{UMTS} = 1000 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{umts} \times P_{umts} + 1000 \times \rho_{HSDPA} \times P_{HSDPA}} \quad (14)$$

Where:

P_{umts} – UMTS R99 data traffic proportion in UMTS network, %;

P_{HSDPA} – HSDPA data traffic proportion in UMTS network, %;

ρ_{umts} – UMTS bit rate, kbit/s. See table No. 9

ρ_{HSDPA} – HSDPA bit rate, Mbit/s. See table No. 9

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1000 is megabyte conversion to kilobytes.

Data to minute equivalent conversion factors are based on specific bit rates, which values are given in the table 9.

Table 9. Data conversion parameters

Parameter	Unit	Values per total network
GPRS bit rate (ρ_G)	kbit/s	13,04
EDGE bit rate (ρ_E)	kbit/s	39,12
UMTS bit rate (ρ_{umts})	kbit/s	325,00
HSDPA bit rate (ρ_{HSDPA})	Mbit/s	5,50

To sum up, converted to minute equivalent traffic (T_C, minutes) for particular services (video calls, SMS, MMS, data) is calculated according to the following formula:

$$T_C^j = T_W^j \times f_j \qquad (15)$$

Where:

T_W^j – Specific service weighted traffic, video minutes, SMS messages, MMS messages, GSM and UMTS data transmission).

f_j – Specific service type conversion factor to minute equivalent. These factors are calculated, respectively, in formulas No. 7, 8, 9, 11 and 14.

j – Defines a specific service.

Particular service traffic (volume), converted to equivalent minutes is used to estimate network components average unit costs in section *9.2 Network Component average unit costs* . General GSM and UMTS services (not including voice calls) traffic converted to equivalent minutes and voice calls traffic is used to calculate average unit cost of network component “Tower and site preparation”.

In the next step, particular GSM services and video calls equivalent minute traffic (for voice calls – billed and unbilled traffic) is adjusted to busy hour traffic. Differently from GSM services and video calls, UMTS packet data traffic in megabytes not in equivalent minutes is adjusted to busy hour traffic. It is important also to note, that every network elements group has different traffic aggregation level, so inhomogeneity factor (see table No. 11) for peak load distribution in time should be applied separately for each network element. Average annual traffic is adjusted to annual busy hour traffic (T_{BH}, minutes or MB) according to the principle given in the following formulas:

$$T_{BH} = T_C / T_{B+U} / T_W \times f_{DA} \qquad (16)$$

$$f_{DA} = r_{BA} \times r_{WA} \times f_H \quad (17)$$

Where:

$T_C / T_{B+U} / T_W$ – Particular GSM service or video calls traffic, converted to minute equivalent (minutes), voice calls traffic (billed and unbilled, minutes) or UMTS packet data weighted traffic, MB.

f_{DA} – De-averaging factor;

r_{BA} – Busy hour traffic to average hourly traffic ratio. This factor shows proportion of busy and average traffic. Value of this factor is provided in the table No. 10.

r_{WA} – Working days traffic to average daily traffic ratio. This factor shows proportion of working day and average daily traffic. Value of this factor is provided the in the table No. 10.

f_H – Inhomogeneity factor for peak load distribution. This factor shows traffic aggregation level in the network element. Value of this factor is provided the in the table No. 11.

Table 10. De-averaging parameters

Parameter	Values per total network
Busy hour traffic to average hourly traffic ratio (r_{BA})	2.00
Working days traffic to average daily traffic ratio (r_{WA})	1.40

Table 11. Inhomogeneity factors

BTS/ NodeB	BSC/ RNC	MSC/MGW or SMSC or MMSC or SGSN	BTS/ NodeB-BSC/ RNC	BSC/RNC-MSC/ MGW/SGSN	MSC/MGW/SGSN-MSC/MGW/SGSN	MSC/MGW -IC
1.50	1.00	1.00	1.00	1.00	1.00	1.00

Finally, annual total traffic (except UMTS packet data) in busy hour (weighted by routing factors, adjusted by unbilled traffic (applied only to voice calls), converted to minute equivalent (not applied only to voice calls), converted to busy hour and de-averaged) volume for particular service is converted to busy hour Erlangs (*BHE*, BHE) by applying the principle given in the following formula:

$$BHE = \frac{T_{BH}}{365 \times 24 \times 60} \quad (18)$$

Where:

T_{BH} – Annual particular GSM services or video calls busy hour traffic, minutes. It is calculated according to the principle given in the formula No. 16

Division by 365 is year to days conversion, division by 24 is day to hours conversion and division by 60 is hour to minutes conversion.

To dimension GSM network general demand for GSM (BHE_{GSM}, BHE) network is calculated according to the following formula:

$$BHE_{GSM} = \sum_i BHE_i \tag{19}$$

Where:

i – Particular service in GSM network (voice calls or video calls, SMS, MMS, HSCSD/CSD, GPRS, EDGE packet data).

Next to evaluate data transmission equipment in UMTS network, busy hour megabytes traffic ($BHMB_{UMTS}$, MB) (weighted by routing factors, converted to busy hour and de-averaged) in UMTS network is calculated according to the following formulas:

$$BHMB_{umts} = \frac{T_{BH} \times P_{umts}}{365 \times 24} \tag{20}$$

$$BHMB_{HSDPA} = \frac{T_{BH} \times P_{HSDPA}}{365 \times 24} \tag{21}$$

$$BHMB_{UMTS} = BHMB_{umts} + BHMB_{HSDPA} \tag{22}$$

Where:

T_{BH} – Year total busy hour traffic, MB. It is calculated according to the principle given in the formula No. 16

P_{umts} – UMTS R99 data traffic proportion in UMTS network, %;

P_{HSDPA} – HSDPA data traffic proportion in UMTS network, %;

Division by 365 is year to days conversion and division by 24 is day to hour conversion.

7. Network Dimensioning

Having in mind complexity of network dimensioning, the algorithms are further divided into separate phases according to GSM and UMTS network architecture:

1. Base Station System (BSS) for GSM or Radio Network System (RNS) for UMTS;
2. Network Switching System (NSS).

Elements of BSS or RNS layer are driven by the traffic demand and coverage of the network that is necessary to provide a given quality of service. Elements of NSS layer are driven by number of subscribers, traffic demand (as in BSS/RNS layer) and other parameters (e.g. number of voice mailboxes).

7.1. *Base and extension units*

Having in mind modular nature of mobile network, the dimensioning of network elements returns amount of base units (BU) and, if applicable, extensions units (EU) for particular network elements. Extension unit is an additional piece in base unit, which enhances BU capacity. EUs are dimensioned, when there is not enough capacity to serve the traffic with n BUs, but n+1 BUs would lead to over capacity of resources needed. It is cost effective to install extension unit in base unit, then to install additional base unit as long as the required traffic is served. Algorithms for calculation amounts of BU and EU are general for all network elements analysed in the scope of BU-LRAIC model. Figure 5 represents BU and EU calculation algorithm.

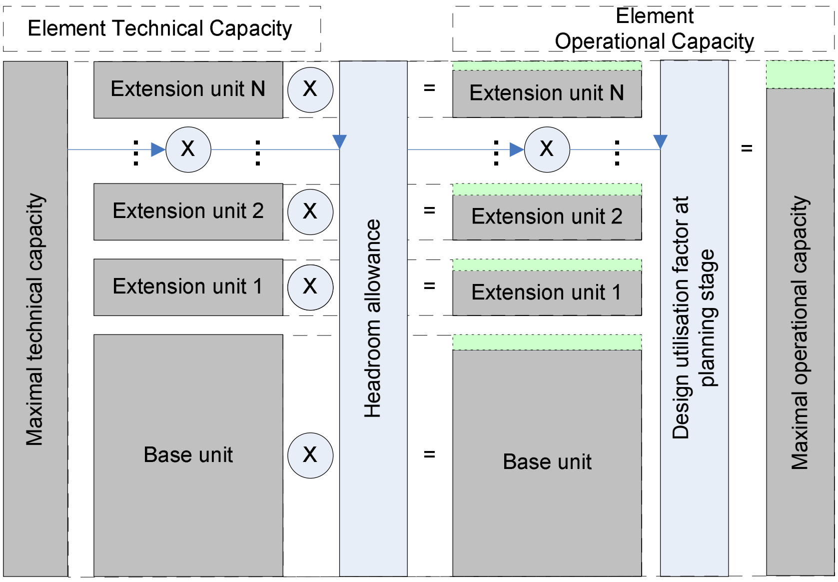


Figure 5: BU and EU calculation algorithm.

Amount of network element base units (*BU*, units) required is generally calculated according to the principle given in the following formula:

$$BU = \left\lceil \frac{DV}{C^{\psi}} \right\rceil \qquad (23)$$

Where:

DV – Dividend (demand) variable, measurement unit depends on the network element. DV is a particular traffic demand, on which the BU dimensioning depends directly.

C^{ψ} – Maximal operational capacity of network element, measurement unit is the same as for DV. Calculation principle of C^{ψ} is provided in the formula No. 25.

Operational capacity of a base unit or extension unit shows what traffic volumes it can maintain.

Amount of network element extension units (*EU*, units) required, if applicable, is generally calculated according to the principle given in the following formula:

$$EU = \left\lceil \frac{BU \times \left(C^{\psi} - C^{o}_{BU}\right)}{C^{o}_{ES}} \right\rceil \qquad (24)$$

Where:

C^{ψ} – Maximal operational capacity of a network element, measurement unit is the same as for *DV*. Calculation principle of C^{ψ} is provided in the formula No. 25

BU – Base unit, units;

C^{o}_{BU} – Base unit operational capacity, measurement unit depends on the network element;

C^{o}_{ES} – Extension step (additional extension unit to BU) operational capacity, measurement unit depends on the network element.

Maximal operational capacity (C^{ψ}, BHCA, subscribers, etc.) for a particular network element is calculated according to the principle given in the following formula:

$$C^{\psi} = C^{\tau} \times OA \qquad (25)$$

Where:

C^{τ} – Maximal technical capacity (including possible extension), measurement unit depends on the element. C^{τ} shows maximal technical theoretical capacity of a network element in composition of *BU* and *EU*.

OA – Operational allowance, %. Calculation principle of *OA* is provided in the formula No. 26.

Operational allowance (*OA*, %) shows both design and future planning utilization of a network equipment, expressed in percents. *OA* is calculated according to the principle given in the following formula:

$$OA = HA \times f_U \qquad (26)$$

Where:

HA – Headroom allowance, %. *HA* shows what part of BU or EU capacity is reserved for future traffic growth. Calculation principle of *HA* is provided in formula No. 28.

f_U – Design utilisation factor at a planning stage, %. It is equipment (vendor designated) maximum utilisation parameter. This utilisation parameter ensures that the equipment in the network is not overloaded by any transient spikes in demand.

BU and ES operational capacity (C_i^o, BHCA, subscribers, etc.) are calculated according to the principle given in the following formula by applying capacity values respectively.

$$C_i^o = C_i \times HA_i \qquad (27)$$

Where:

C_i – Base unit or extension unit capacity, measurement unit depends on the element. C_i defines technical parameter of BU or EU capacity.

HA_i – Headroom allowance of BU or EU, %. Calculation principle of *HA* is provided in the formula No. 29.

i – Specifies BU or EU.

Operational allowance and capacity calculations depend on the headroom allowance figure (HA, %). Headroom allowance is calculated according to the principle given in the following formula:

$$HA = \frac{1}{r_{SDG}} \qquad (28)$$

Where:

r_{SDG} – Service demand growth ratio.

r_{SDG} determines the level of under-utilisation in the network, as a function of equipment planning periods and expected demand. Planning period shows the time it takes to make all the necessary preparations to bring new equipment online. This period can be from weeks to years. Consequently, traffic volumes by groups (demand aggregates given below) are planned according to the service demand growth.

Service demand growth ratio is calculated for each one following demand aggregates:

- Total subscribers number;
- CCS traffic, which comprises of voice, circuit data and converted to minute equivalent video traffic;
- Air interface traffic, which comprises of converted to minute equivalent SMS, MMS and packet data traffic. Packet data traffic in this case means GSM and UMTS traffic sum of up-link or down-link traffic subject to greater value.

Particular demand growth ratio is assigned to a particular network element's equipment.

7.2. Base Transceiver Station

The first step in dimensioning Base Station Subsystem (BSS) layer is modelling the Base Transceiver Stations (BTS). The outcome of the algorithms presented in this section is the number of BTS locations (sites).

All of the BTS calculations presented in this section are executed by subdividing Republic of Lithuania territory (for coverage) and traffic (for capacity) into the following geographical areas:

1. Urban – Built up city or large town with large building and houses. Building heights above 4 storeys (about 10m). As a reference to Republic of Lithuania it would be major cities: Vilnius, Kaunas, Klaipeda, Siauliai, Panevezys, Alytus, and Marijampole. If parks, forests fall in this area, they are treated as suburban or rural geographical area.
2. Suburban – Village, highway scattered with trees and houses. Some obstacles near the mobile, but not very congested. As a reference to Republic of Lithuania it would be previously not mentioned towns.
3. Rural[8] – Open space, forests, no tall trees or building in path. As a reference to Republic of Lithuania it would be the rest of Republic of Lithuania's territory.

Traffic and coverage geographical areas equally corresponds with geographical areas definitions when dimensioning the network.

Estimation of minimum number of BTS locations required is a function of requirements to meet coverage and traffic demand.

Coverage requirements

[8] Concepts of geographical areas used in this document are in line with the respective Okumura – Hata model concepts.

Minimal number of localizations required to satisfy coverage requirements (N_{COV}^{Si} , units) are determined by the following formulas:

$$N_{COV}^{Si} = \left\lceil \frac{A_C}{A_C^c} \right\rceil \quad (29)$$

$$A_C^c = 1.5 \times \sqrt{3} \times R^2 = 2.6 \times R^2 \quad (30)$$

Where:

A_C – Coverage area in GSM network for a particular geographical area type, km^2. This size is calculated multiplying particular geographical area coverage proportion in GSM network (%) with total GSM coverage area.

A_C^c – Coverage area of one cell, km^2;

R – Maximal cell range, km.

The basis of a formula for cell coverage area (A_C^c, km^2) is a formula to calculate hexagon area.

Maximal cell range in every geographical area in the BU-LRAIC model is given below in the list:

- Urban area *R* = 0.90 km;
- Suburban area *R* = 3.00 km;
- Rural area *R* = 9.00 km.

Parameters given above are taken as the assumed dimensioning parameters of average effectively utilized BTS in Republic of Lithuania at a given area to provide current quality of services in the network.

Traffic demand

Number of sites required to meet traffic demand are calculated in the following steps:

1. Calculation of spectrum and physical capacity of a sector;
2. Calculation of effective sector capacity;
3. Calculation of a number of sites to meet the traffic demand.

Sector capacities are calculated for each type of a cell (macro, micro and pico) as well as single and dual bands. As before, calculations for cells are also split by geographical areas types. The traffic is split by geographical area type either.

Consequently, following cell types for sector capacity calculations are used:

- Macro cell – urban area;
- Macro cell – suburban area;
- Macro cell – rural area;
- Micro cell – urban area;
- Micro cell – suburban area;
- Pico cell – urban area;
- Pico cell – suburban area.

Spectrum capacity of BTS is a required TRXs number to cover the spectrum specifications. A spectrum capacity (C_{Ss}, TRXs) for single band cell is calculated according to the principle given in the following formula:

$$C_{Ss} = \left\lfloor \frac{N_{900}}{f_{su} \times \lambda_{TRX}} \right\rfloor - 0.5 \qquad (31)$$

Where:

N_{900} – Amount of 900 MHz spectrum, 2 x MHz. This value is calculated according to the public information (permissions to operate radio channels) placed on RRT website and according to information provided by RRT.

f_{su} –- Sector re-use factor for 900 MHz, units;

λ_{TRX} – Bandwidth of a transceiver, MHz. According to technical transceiver parameters, it is assumed λ_{TRX} equals to 0.2 MHz.

Similarly, spectrum capacity (C_{Sd}, TRXs) of a logical sector for dual band is calculated according to the following formula:

$$C_{Sd} = C_{Ss} + \left\lfloor \frac{N_{1800}}{f_{du} \times \lambda_{TRX}} \right\rfloor \qquad (32)$$

Where:

C_{Ss} – Spectrum capacity for single band cell, TRXs. It is calculated according to the principle given in the formula No. 31.

N_{1800} –- Amount of 1800 MHz spectrum, 2 x MHz. This value is calculated according to the public information (permissions to operate radio channels) placed on RRT website.

f_{du} –- Sector re-use factor for 1800 MHz, units;

λ_{TRX} – Bandwidth of a transceiver, MHz. The same assumption is applied as in the formula No. 31.

Physical capacity (C_P, TRXs) of a logical sector for single and dual band is a technical specification value. Effective sector capacity (C_E, TRXs) for macro (urban, suburban and rural), micro, pico cell groups respectively single and dual band frequency is calculated according to the principle given in the following formula:

$$C_E = \min(C_S; C_P) \qquad (33)$$

Where:

C_S – Spectrum sector capacity (single C_{Ss} or dual band C_{Sd}), TRX;

C_P – Physical (equipment technical limitation) sector capacity (single or dual band[9]), TRX. This value describes maximal TRX amount, which can be physically installed in mikro, pico or makro cells.

It is assumed in BU-LRAIC model, that first TRX in BTS handles 7 traffic channels and each additional TRX in BTS handles 8 traffic channels.

TRXs conversion (N_{TRX}, units) to channels (N_{CH}, units) is done according to the following formula:

$$N_{CH} = 7 + 8 \times (N_{TRX} - 1) \qquad (34)$$

Where:

N_{TRX} – Number of TRXs, TRX. See formula No. 43.

As the TRXs number is converted to channels, effective sector capacity (C_E) for single and dual band (in channels) is translated into BHE (C_E^{Erl}) according to Erlangs table, assuming blocking probability equals to 2%.

Number of sectors (N_{CAP}^{Se}, units) to serve the traffic is calculated according to the principle given in the following formula:

$$N_{CAP}^{Se} = \frac{BHE_{GSM}^{A}}{C_E^{Erl} \times HA_{BTS}} \qquad (35)$$

Where:

[9] Single or dual band physical capacity. This parameter is included in questionnaire.

BHE_{GSM}^{A} – GSM services busy hour traffic part in particular geographical area, BHE. This size is calculated multiplying particular geographical area traffic proportion in GSM network (%) with total GSM traffic.

C_{E}^{Erl} – Effective sector capacity of dual or single band (for a particular cell type), BHE.

HA_{BTS} – Headroom allowance of BTS equipment, %. It is calculated according to the principle given in the formula No. 29

Number of sites (N_{CAP}^{Si} , units) to serve the traffic is calculated according to the following formulas:

$$N_{CAP}^{Si} = \frac{N_{CAP}^{Se}}{N_{Se/Si}} \qquad (36)$$

$$N_{Se/Si} = \frac{\sum_{i=1}^{3} i \times N_{iSe}^{Si}}{\sum_{i=1}^{3} N_{iSe}^{Si}} \qquad (37)$$

Where:

N_{CAP}^{Se} – Sectors number to serve the traffic, units;

$N_{Se/Si}$ – Average number of sectors per site, units.

N_{iSe}^{Si} – I sectored sites in GSM network, units. This size is calculated total sites number multiplying with proportions (%) of I sectored sites in the network.

i – Defines number of sectors in the site (one, two or three).

Total amount of GSM sites

Total amount of BTS sites in a mobile network (N_{Total}^{Si} , units) is calculated according to the following formula:

$$N_{Total}^{Si} = Max(N_{COV}^{Si}; N_{CAP}^{Si}) \qquad (38)$$

Where:

N_{COV}^{Si} – Sites to serve the coverage, units;

N_{CAP}^{Si} – Sites to serve the traffic, units.

It is assumed that each GSM site handles EDGE, single band base stations are present in rural area and double band base stations are present in suburban and urban areas.

7.3. Transceiver

The second step in dimensioning Base Station Subsystem (BSS) layer is modelling of Transceivers (TRX). The outcome of the algorithms presented in this section is the number of TRX units.

Similarly to BTS modelling case, all of the TRX calculations are executed by subdividing the Republic of Lithuania territory into the geographical areas, defined in section *7.2 Base Transceiver Station*.

Next step, to estimate TRX number, is calculation of traffic load per one sector (BHE_{GSM}^{Se}, BHE). It is calculated according to the principle given in the following formula:

$$BHE_{GSM}^{Se} = \frac{BHE_{GSM}^{A}}{N_{Total}^{Si} \times N_{\mathrm{Se/Si}}} \quad (39)$$

Where:

BHE_{GSM}^{A} – GSM services busy hour traffic part in particular geographical area, BHE.

N_{Total}^{Si} – Total BTS sites in a mobile network, units. See formula No. 38.

$N_{Se/Si}$ – Average number of sectors per site, units (see formula No. 37).

Traffic load per one sector (BHE_{GSM}^{Se} , BHE) is translated into channels per sector ($N_{CH/Se}$) according to Erlangs table with a blocking probability of 2%.

Further, number of TRXs per sector ($N_{TRX/Se}$, units) is calculated according to the following formulas for macro, micro and pico cells respectively:

$$N_{TRX/Se}(macro) = \frac{N_{CH/Se}}{7 + 8 \times (N_{TRX} - 1)} + \gamma \quad (40)$$

$$N_{TRX/Se}(micro) = \frac{N_{CH/Se}}{7 + 8 \times (N_{TRX} - 1)} + \gamma \quad (41)$$

$$N_{TRX/Se}(pico) = \frac{N_{CH/Se}}{7 + 8 \times (N_{TRX} - 1)} + \gamma \quad (42)$$

Where:

$N_{CH/Se}$ – Channels per sector, units;

N_{TRX} – TRX number, TRX. See formula No. 43.

γ – TRX utilization adjustment, which equals to 0.5 TRX per sector. Non-uniform allowance is the ½ unit of capacity per sector allowance for the fact that traffic is not evenly distributed (in both time and space) across each area type.

Total number of TRXs in mobile network (N_{TRX} , units) is calculated according to the following formulas:

$$N_{TRX} = \left| N_{TRX/Se} \times N_{Total}^{Se} \right| \quad (43)$$

$$N_{TRX/Se} = N_{TRX/Se}(macro) + N_{TRX/Se}(micro) + N_{TRX/Se}(pico) \quad (44)$$

$$N_{Total}^{Se} = \sum_{i=1}^{3} i \times N_{iSe}^{Si} \quad (45)$$

Where:

$N_{TRX/Se}$ – Average number of TRXs per sector, units. See formula No. 40, 41 and 42.

N_{Total}^{Se} – Total amount of sectors in mobile network, units;

N_{iSe}^{Si} – I sectored sites in GSM network, units. This size is calculated total sites number multiplying with proportions (%) of I sectored sites in the network.

i – Defines number of sectors in the site (one, two or three)

7.4. Node B

In UMTS network, the first step in dimensioning RNS layer is modelling the Node B element. The outcome of the algorithms presented in this section is the number of Node B sites. All Node B calculations are divided by geographical area proportions.

The Node B calculations are performed based on the assumption that under forecasted traffic volume (video and data) for 2010 the expected cell capacities / cell ranges for 3-sector Node B will be as follows:

Urban area: cell range R_{UMTS} = 0.45 km, cell capacity $C_{\min}^{Se}$ = 512 kbit/s.

Suburban area: cell range R_{UMTS} = 0.80 km, cell capacity $C_{\min}^{Se}$ = 256 kbit/s.

Rural area: cell range R_{UMTS} = 4.70 km, cell capacity $C_{\min}^{Se}$ = 256 kbit/s.

These assumptions are provided for effectively working Node B in Republic of Lithuania territory.

In BU-LRAIC model assumption is made that effectively working HSDPA sector's capacity (C_{HSDPA}^{Se}) is 1024 kbit/s and video calls capacity (C_{V}^{Erl}) is 28 Erlangs.

Coverage

UMTS network area coverage is split by geographical areas, defined in section *7.2 Base Transceiver Station.*

Minimal number of Node B sites required to satisfy coverage requirements (N_{COV}^{SiB}, units) are determined by the following formulas:

$$N_{COV}^{SiB} = \left\lceil \frac{bA_C}{bA_C^c} \right\rceil \quad (46)$$

$$bA_C^c = 1.5 \times \sqrt{3} \times R_{UMTS}^2 = 2.6 \times R_{UMTS}^2 \quad (47)$$

Where:

bA_C – Coverage area in UMTS network for a particular geographical area type, km^2. This size is calculated multiplying particular geographical area coverage proportion (%) in UMTS network with total UMTS coverage area.

bA_C^c – Coverage area of one Node B cell, km^2;

R_{UMTS} – Maximal cell range, km. Assumptions on maximal cell range are given above.

The basis of a formula for cell coverage area is a formula to calculate hexagon area.

Traffic demand

Capacity required (C_{UMTS}, kbit/s) to handle the packet data traffic in UMTS network is calculated according to the following formula:

$$C_{UMTS} = \frac{BHMB_{UMTS}}{60 \times 60} \times 8 \times 1000 \quad (48)$$

Where:

$BHMB_{UMTS}$ – Capacity to be handled by UMTS network, MB. It is a busy hour traffic part in particular geographical area and cell type (macro, micro and pico) in UMTS network (see formula No. 22).

Division by 60 and 60 is hour conversion to seconds, multiplication by 8 is a bytes conversion to bits and multiplication by 1000 is megabyte conversion to kilobytes. There is an assumption in the BU-LRAIC modelling that cell capacity in BHT in the UMTS network is utilized by 120%.

Sector number (N_{CAP}^{SeB}, units) to meet capacity requirements is calculated according to the principle given in the following formula:

$$N_{CAP}^{SeB} = \left(\frac{C_{UMTS}}{C_{\min}^{Se}} + \frac{BHE_V}{C_V^{Erl}} \right) \times LU \quad (49)$$

Where:

C_{UMTS} – Capacity required to handle the traffic in UMTS network, kbit/s. See formula No. 48.

$C_{\min}^{Se}$ – Sector capacity in BHT, kbit/s. Assumptions for this value are provided above in this section.

LU – Cell capacity utilization in BHT, %. BU-LRAIC modelling that cell capacity in BHT in the UMTS network is utilized by 120%.

BHE_V – Video calls demand in UMTS network, BHE. It is calculated according to the principle given in the formula No. 18.

C_V^{Erl} – Sector capacity for video calls, BHE. Assumptions on sector capacity for voice calls are given above in the document.

Number of UMTS sites (N_{CAP}^{SiB}, units) to meet capacity requirements is calculated according to the following formulas:

$$N_{CAP}^{SiB} = \sum_{i=1}^{3} N_{iSeB}^{SiB} \quad (50)$$

$$N_{iSeB}^{SiB} = \frac{N_{iCAP}^{SeB}}{i} \quad (51)$$

Where:

N_{iCAP}^{SeB} – Sectors number to meet capacity requirements in UMTS network, distinguished by particular sectorization, units. This size is calculated total sectors number (N_{CAP}^{SeB}, see formula No. 49) multiplying by respective sectorization proportions (%).

N_{CAP}^{SiB} – UMTS sites number to meet capacity requirements, units;

N_{iSeB}^{Si} – *I* sectored sites in UMTS network, units;

i – Defines number of sectors in the site (one, two or three).

Total amount of Node B sites

Finally, total Node B sites number (N_{Total}^{SiB} , units) is calculated according to the following formulas:

$$N_{Total}^{SiB} = N_{CAP}^{SiB} + Adj \qquad (52)$$

$$Adj = \frac{N_{COV}^{SiB} - N_{CAP}^{SiB}}{2} \qquad (53)$$

Where:

N_{CAP}^{SiB} – Sectors to meet capacity requirements, units (see formula No. 50).

N_{COV}^{SiB} – Sectors to meet coverage requirements, units (see formula No. 46).

Adj – Adjustments (sites number) for planning assumptions, units.

In UMTS network Node Bs number to meet capacity and coverage requirements are correlated figures, therefore adjustment is applied to calculated total Node Bs number, not the maximum value out the two, as it is in GSM BTSs case.

It is assumed that each UMTS site handles HSDPA.

7.5. Sites

In BU-LRAIC model to built mobile network for both UMTS and GSM, minimal number of sites is calculated to serve both types of traffic. Sites are distinguished by particular types given in the following list:

- Urban macro cells (omni sector);
- Urban macro cells (2 sector);
- Urban macro cells (3 sector);
- Suburban macro cell (omni sector);
- Suburban macro cell (2 sector);

- Suburban macro cell (3 sector);
- Rural macro cell (omni sector);
- Rural macro cell (2 sector);
- Rural macro cell (3 sector);
- All micro cells;
- All pico cells.

Total number of sites (N_{SI}, units) in the mobile network is calculated according to the following formula:

$$N_{SI} = \sum_i Max(N_i^{Si}; N_i^{SiB}) \tag{54}$$

Where:

N_i^{Si} – Particular i type sites in GSM network, units;

N_i^{Sib} – Particular i type sites in UMTS network, units.

i – Defines number of sectors in the site (one, two or three).

7.6. Base Station Controller

Base station controller comprises of two parts:

- Base unit;
- Base station extension (TRXs).

The outcome in this section is the amount of base units and the amount of extension units. The dividend variable for both units calculation is number of TRXs.

Total amount of BSC base units and extension units is calculated according to the algorithm provided in section *7.1. Base and extension units* with TRXs as dividend variable for both parts.

7.7. Transcoder Controller

Transcoder controller (TRC) comprises of two parts:

- Base unit;
- Transcoder E1 extension (A interfaces).

The outcome of the algorithms presented in this section is the amount of base units and Transcoder E1 extension (A interfaces) units. Therefore, calculations are described respectively to these parts. The dividend variable for both parts is total 2 Mbit/s link capacity (C_L, E1 A interface). Total 2 Mbit/s link capacity is calculated according to the following formula:

$$C_L = \rho_C \times \frac{TH_{GSM}}{C_b} \times \frac{BHE_{GSM} - BHE_{PD}}{BHE_{GSM}} \quad (55)$$

Where:

TH_{GSM} – Throughput in TRC, kbit/s. See formula No. 93.

C_b – Basic 2 Mbit/s link capacity, kbit/s.

ρ_C – TRC compression rate, equal to 4;

BHE_{GSM} – Demand for GSM network, BHE (see formula No. 19);

BHE_{PD} – Packet data demand for GSM network, BHE. It is calculated according to the principle provided in the formula No. 18.

Assumption is made that basic 2 Mbit/s link capacity is 2048 kbit/s.

Next as it was in BSC calculations, TRC base units and extension units are calculated according to algorithm provided in section *7.1. Base and extension units* with E1 number (A interface) as dividend variable for both parts.

7.8. Radio Network Controller

In UMTS network, the next step in dimensioning BSS layer is modelling the Radio Network Controller (RNC). RNC comprises of the following parts:

- Base unit;
- Extension units:
    - Iub links extension;
    - Sectors extension;
    - Sites extension.

The outcome of the algorithms presented in this section is the amount of base units and extension units.

Estimation of minimum number of RNC base units required is a function of requirements to meet Iub links number, sectors number and sites number.

Total amount of RNC base units (BU_{RNC}, units) is calculated according to the following formulas:

$$BU_{RNC} = \left\lceil Max\left(\frac{TH_{Iub}}{C_{Iub}};\frac{N_{Total}^{SeB}}{C_{RNC}^{Se}};\frac{N_{Total}^{SiB}}{C_{RNC}^{Si}}\right)\right\rceil \quad (56)$$

$$N_{Total}^{SeB} = \sum_{i=1}^{3} i \times N_{iSe}^{SiB} \quad (57)$$

Where:

TH_{Iub} – Iub link throughput, Mbit/s. The same as UMTS throughput (see formula No. 91)

C_{Iub} – RNC maximal operational capacity to satisfy Iub interface throughput, Mbit/s; Calculated according to the principle provided in formula No. 25.

N_{Total}^{SeB} – Total number of sectors in UMTS network, units;

C_{RNC}^{Se} – RNC maximal operational capacity to satisfy number of sectors, units; Calculated according to the principle provided in formula No. 25.

N_{Total}^{SiB} – Total number of Node B sites in UMTS network, units;

C_{RNC}^{Si} – RNC maximal operational capacity to satisfy number of sites, units; Calculated according to the principle provided in formula No. 25.

N_{iSe}^{SiB} – I sectored sites in UMTS network, units. This parameter is calculated multiplying total number of sites by appropriate proportion (%) according to number of sectors.

i – Defines number of sectors in the site (one, two or three).

Extension units for RNC - Iub links extension, sectors extension and sites extension – are calculated according to the algorithm provided in section *7.1. Base and extension units.* RNC Iub link throughput, sectors number and Node B sites number are the respective dividend variables.

7.9. Mobile Switching Centre

Mobile Switching Centre (MSC) is dimensioned for the first alternative core network modelling scenario (see section *2.6. Technological background*).

All voice services traffic is handled by MSC and it comprises of the following parts:

- Base unit and software;
- MSC extensions:
  - Processor extension;
  - VLR, EIR extension;
  - SS7 extension;
  - Trunk port extension;
  - Input/Output peripherals.

Estimation of minimum number of MSC base units required is a function of requirements to meet:

1. Minimal network configurations;
2. Switching capacity (CPU part);
3. Ports number in MSC;
4. Subscribers number (VLR, EIR part).

In each component's case calculation algorithms are described below.

For the requirements to meet minimal network configuration demand there is an assumption adopted in BU-LRAIC model that minimal number of MSCs in a mobile network is two. This requirement is for the security reasons; in case one MSC will not work another will maintain the traffic.

Number of MSC base units (BU^{C}_{MSC} , units) to meet switching capacity requirements (central processing unit (CPU) case) are calculated according to the following formulas:

$$BU^{C}_{MSC} = \frac{N_{BHCA}}{C_{CPU}} \quad (58)$$

$$C_{CPU} = C^{\psi}_{MSC,s} \times N_{CPU/MSC} \quad (59)$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA. Look at formula No. 2.

$C^{\psi}_{MSC,s}$ – Maximal MSC operational capacity, BHCA (see formula No. 25);

C_{CPU} – CPU capacity of MSC, BHCA;

$N_{CPU/MSC}$ – CPUs per MSC, units.

Default MSC's configuration in most usual case gives one PCU per MSC, consequently it is assumed there is one CPU per MSC.

Number of MSC base units (BU_{MSC}^{p} , units) to meet port number requirements is calculated according to the following formula:

$$BU_{MSC}^{p} = \frac{N_p}{C_{MSC,p}^{\psi}} \tag{60}$$

Where:

N_p – Total ports required, units;

$C_{MSC,p}^{\psi}$ – Maximal MSC operational capacity to satisfy number of ports (see formula No. 25).

Total number of ports required (N_p, units) is calculated according to the following formula:

$$N_p = p_{BSC} + p_{ic} + p_{is} \tag{61}$$

Where:

p_{BSC} – BSC-facing ports, units;

p_{ic} – Interconnect-facing ports, units. See formula No. 62.

p_{is} – Inter-switch 2 Mbit/s ports, units. See formula No. 64.

Number of BSC-facing ports is the same number as total 2 Mbit/s link capacity, E1 A interfaces, which is calculated in section *7.7. Transcoder Controller* (see formula No. 55).

Number of interconnect-facing ports (p_{ic}, units) is calculated according to the following formula:

$$p_{ic} = T_{ic} \times \frac{1}{0.7} \times \frac{1}{31} \tag{62}$$

Where:

T_{ic} – Interconnect traffic, BHE.

Division by 0.7 is BHE conversion to channels number and division by 31 is channels conversion to 2 Mbit ports number.

Interconnect traffic (T_{ic}, BHE) is calculated according to the following formula:

$$T_{ic} = M_{Total} + SMS_{Total} \tag{63}$$

Where:

M_{Total} – Total call minutes between MSC and point of interconnection, BHE;

SMS_{Total} – Total SMS messages between MSC and point of interconnection, BHE.

Number of inter-switch 2 Mbit/s ports (p_{is}, units) is calculated according to the following formula:

$$p_{is} = T_{is} \times \frac{1}{0.7} \times \frac{1}{31} \quad (64)$$

Where:

T_{is} – Inter-switch traffic, BHE (see formula No. 65).

Division by 0.7 is BHE conversion to channels number and division by 31 is channels conversion to 2 Mbit ports number.

Inter-switch traffic (T_{is}, BHE) is calculated according to the following formula:

$$T_{ic} = M_{ON} + SMS_{ON} \quad (65)$$

Where:

M_{ON} – Total on-net minutes in MSC, BHE;

SMS_{ON} – Total on-net SMS messages in MSC, BHE.

Number of MSC base units (BU_{MSC}^{S} , units) to meet subscribers' requirements (visitor location register (VLR, EIR) case) is calculated according to the following formula:

$$BU_{MSC}^{S} = \frac{N_{Sub}^{GSM}}{C_{MSC,sub}^{\psi}} \quad (66)$$

Where:

N_{Sub}^{GSM} – GSM network subscribers, units;

$C_{MSC,sub}^{\psi}$ – Maximal MSC operational capacity to satisfy number subscribers, subscribers (see formula No. 25).

So, total amount of MSC base units (BU_{MSC}, units) is calculated according to the following formula:

$$BU_{MSC} = Max\left(BU_{MSC}^{C}; BU_{MSC}^{p}; BU_{MSC}^{S}\right) \quad (67)$$

Where:

BU_{MSC}^{C} – Number of MSC base units to meet switching capacity requirements, units (see formula No. 58).

BU_{MSC}^{p} – Number of MSC base units to meet port number requirements, units (see formula No. 60).

BU_{MSC}^{S} – Number of MSC base units to meet subscribers' requirements, units (see formula No. 66).

Number of extension units is calculated for:

- Processor;
- VLR, EIR;
- Signalling System (SS7);
- Trunk ports.

Dividend variable of processor part is number of BHCA, VLR, EIR – number of subscribers, SS7 – number of SS7 links, trunk ports – total number of ports required in MSC.

Number of SS7 links is calculated according to the following formula:

$$N_{SS7} = \frac{p_{is} + p_{ic}}{N_{p/SS7}} \quad (68)$$

Where:

p_{is} – Inter-switch 2 Mbit/s ports, units (see formula No. 64).

p_{ic} – Interconnect-facing ports, units (see formula No. 62).

$N_{p/SS7}$ – Trunks per SS7 link, units.

It is assumed there are 16 trunks per SS7 link.

As Input/Output peripherals number in MSC is a part of MSC configuration, it equals to the number of MSCs base units.

Amount of MSC extension units for each, processor, VLR, EIR, trunk port and SS7 is calculated according to algorithm provided in section *7.1. Base and extension units* with number of BHCA, number of subscribers, number of SS7 links, total number of ports required in MSC as dividend variables respectively.

7.10. Mobile Switching Centre Server

Mobile Switching Centre Server (MSS) is dimensioned for the second alternative core network modelling scenario (see section *2.6. Technological background*).

MSS handles video calls and voice services traffic. As MSS is a processing unit of the core network and it does not handle the traffic, its calculations are based only on busy hour call attempts amount.

The outcome of the algorithms presented in this section is the amount of MSS base and extension units.

Estimation of minimum number of MSS base units required is a function of requirements to meet minimal network configurations and switching capacity (CPU part).

For the requirements to meet minimal network configuration demand there is an assumption adopted in BU-LRAIC model that minimal number of MSS in a mobile network is two.

Number of MSS base units (BU^{C}_{MSS} , units) to meet switching capacity requirements (central processing unit (CPU) case) are calculated according to the following formulas:

$$BU^{C}_{MSS} = \frac{N_{BHCA}}{C_{CPU}} \qquad (69)$$

$$C_{CPU} = C^{\psi}_{MSS,s} \times N_{CPU/MSS} \qquad (70)$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA (see formula No. 2).

$C^{\psi}_{MSS,s}$ – Maximal MSS operational capacity to satisfy call attempts in BHT, BHCA (see formula No. 25).

C_{CPU} – CPU capacity of MSS, BHCA;

$N_{CPU/MSS}$ – CPUs per MSS, units.

Default MSS's configuration in most usual case gives one PCU per MSS, consequently it is assumed there is one CPU per MSS.

So total amount of MSS base units (BU_{MSS}, units) is calculated according to the following formula:

$$BU_{MSS} = Max\left(BU^{\min}_{MSS}; BU^{c}_{MSS}\right) \qquad (71)$$

Where:

$BU^{\min}_{MSS}$ – Number of MSS base units to meet minimal requirements of the network, units. This number is assumption which is provided at the beginning of this section.

BU_{MSS}^{C} – Number of MSS base units to meet switching capacity requirements, units (see formula No. 69).

Amount of MSS extension units is calculated according to the algorithm provided in section *7.1. Base and extension units* with number of BHCA as dividend variable.

7.11. Media Gateway

Similarly to MSS, Media Gateway (MG) is dimensioned for the second alternative core network modelling scenario (see section *2.6. Technological background*). MGW handles video calls and voice services traffic.

MGW comprises of the following parts:

- Base unit and software;
- MGW extensions:
    - Processor extension;
    - Trunk port extension;

Estimation of minimum number of MGW base units required is a function of requirements to meet:

1. Minimal network configurations;
2. Switching capacity (CPU part);
3. Ports number in MGW;

In each component's case calculation algorithms are described below.

For the requirements to meet minimal network configuration demand there is an assumption adopted in BU-LRAIC model that minimal number of MGWs in a mobile network is one.

Number of MGW base units (BU_{MGW}^{C}, units) to meet switching capacity requirements (central processing unit (CPU) case) are calculated according to the following formulas:

$$BU_{MGW}^{C} = \frac{N_{BHCA}}{C_{CPU}} \qquad (72)$$

$$C_{CPU} = C_{MGW,s}^{\psi} \times N_{CPU/MGW} \qquad (73)$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA. See formula No. 2.

$C^{\psi}_{MGW,s}$ – Maximal MGW operational capacity to satisfy call attempts in BHT, BHCA (see formula No. 25).

C_{CPU} – CPU capacity of MGW, BHCA;

$N_{CPU/MGW}$ – CPUs per MGW, units.

Default MGW's configuration in most usual case gives one PCU per MGW, consequently it is assumed there is one CPU per MGW.

Number of MGW base units (BU^{p}_{MGW} , units) to meet ports number requirements is calculated according to the following formula:

$$BU^{p}_{MGW} = \frac{N^{p}_{MGW}}{C^{\psi}_{MGW,p}} \quad (74)$$

Where:

N^{p}_{MGW} – Total ports required in MGW, units. See formula No. 75.

$C^{\psi}_{MGW,p}$ – Maximal MGW operational capacity to satisfy number ports, ports. See formula No. 25.

Total number of ports required (N^{p}_{MGW} , units) in MGW is calculated according to the following formula:

$$N^{p}_{MGW} = p_{RNC} + p^{mgw}_{ic} + p^{mgw}_{is} \quad (75)$$

Where:

p_{RNC} – RNC-facing ports in MGW, units. See formula No. 76.

p^{mgw}_{ic} – Interconnect-facing ports in MGW, units. See formula No. 78.

p^{mgw}_{is} – Inter-switch 2 Mbit/s ports in MGW, units. See formula No. 80.

Number of RNC-facing ports (p_{RNC}, units) is calculated according to the following formula:

$$p_{RNC} = T_{RNC} \times \frac{1}{0.7} \times \frac{1}{31} \quad (76)$$

Where:

T_{RNC} – RNC-MGW traffic, BHE.

Division by 0.7 is BHE conversion to channels number and division by 31 is channels conversion to 2 Mbit ports number.

RNC-MGW traffic (T_{RNC}, BHE) is calculated according to the following formula:

$$T_{RNC} = M_{Total} + VM_{Total} + SMS_{Total} + MMS_{Total} \quad (77)$$

Where:

M_{Total} – Total voice minutes traffic in RNC, BHE;

VM_{Total} – Total video minutes traffic in RNC, BHE;

SMS_{Total} – Total SMS messages traffic in RNC, BHE.

MMS_{Total} - Total MMS messages traffic in RNC, BHE.

Number of interconnect-facing ports (p_{ic}^{mgw}, units) in MGW is calculated according to the following formula:

$$p_{ic}^{mgw} = T_{ic}^{mgw} \times \frac{1}{0.7} \times \frac{1}{31} \quad (78)$$

Where:

T_{ic}^{mgw} – Interconnect traffic in MGW, BHE.

Division by 0.7 is BHE conversion to channels number and division by 31 is channels conversion to 2 Mbit ports number.

Interconnect traffic (T_{ic}^{mgw} , BHE) in MGW is calculated according to the following formula:

$$T_{ic} = M_{Total} + MV_{Total} + SMS_{Total} + MMS_{Total} \quad (79)$$

Where:

M_{Total} – Total call minutes between MGW and point of interconnection, BHE.

VM_{Total} - Total video call minutes between MGW and point of interconnection, BHE.

SMS_{Total} – Total SMS messages between MGW and point of interconnection, BHE.

MMS_{Total} – Total SMS messages between MGW and point of interconnection, BHE;

Number of inter-switch 2 Mbit/s ports (p_{is}^{mgw} , units) in MGW is calculated according to the following formula:

$$p_{is}^{mgw} = T_{is}^{mgw} \times \frac{1}{0.7} \times \frac{1}{31} \quad (80)$$

Where:

T_{is}^{mgw} – Inter-switch traffic in MGW, BHE.

Division by 0.7 is BHE conversion to channels number and division by 31 is channels conversion to 2 Mbit ports number.

Inter-switch traffic (T_{is}^{mgw}, BHE) in MGW is calculated according to the following formula:

$$T_{is}^{mgw} = M_{ON} + VM_{ON} + SMS_{ON} + MMS_{ON} \tag{81}$$

Where:

M_{ON} – Total on-net voice minutes traffic in MGW, BHE;

SMS_{ON} – Total on-net SMS messages traffic in MGW, BHE;

VM_{ON} – Total on-net video minutes traffic in MGW, BHE.

MMS_{ON} – Total on-net SMS messages traffic in MGW, BHE;

So, total amount of MGW base units (BU_{MGW}, units) is calculated according to the following formula:

$$BU_{MGW} = Max\left(BU_{MGW}^{\min}; BU_{MGW}^{C}; BU_{MGW}^{p}\right) \tag{82}$$

Where:

$BU_{MGW}^{\min}$ – Number of MGW base units to meet minimal network requirements, units. Value of this parameter is assumption provided at the beginning of this section.

BU_{MGW}^{C} – Number of MGW base units to meet switching capacity requirements, units (see formula No. 72).

BU_{MGW}^{p} – Number of MGW base units to meet port number requirements, units (see formula 74).

Amount of MGW extension units for both processor and ports part is calculated according to algorithm provided in section *7.1. Base and extension units* with number of BHCA and total number of ports required in MGW as dividend variables respectively.

7.12. SMSC and MMSC

The fourth step in dimensioning NSS layer is modelling the SMSC and MMSC. Each SMSC and MMSC comprises of two parts:

- Base unit;
- Extension units.

The outcome of the algorithm presented in this section is number of base unit and extension unit for SMSC and MMSC.

SMSC and MMSC in BU-LRAIC are dimensioned according to the same engineering rules, so one algorithm for both network elements is provided.

The dividend variable for both parts is the number of busy hour messages (SMS or MMS messages) per second ($M_{MS/s}$, messages/s) and is calculated according to the following formula:

$$N_{MS/s} = \frac{1}{60} \times \frac{T_{MS}}{f_{MS}} \qquad (83)$$

Where:

f_{MS} – Message to minute equivalent conversion factor. They are calculated in the formulas No. 8 and 9.

T_{MS} – Total minute equivalent for messages in the network element per minute in busy hour, minutes.

Amount of SMSC and MMSC base units and extension units is calculated according to algorithm provided in section *7.1. Base and extension units* with busy hour SMS and MMS messages as dividend variable.

7.13. Packet Control Unit and Serving GPRS Support Node

Every Packet Control Unit (PCU) and Serving GPRS Support Node (SGSN) comprises of two parts:

- Base unit;
- Extension units.

The outcome of the algorithm presented in this section is number of base units and extension units for PCU, SGSN and GGSN. GGSN is presented under model assumption.

First step in PCU base unit number calculation is to estimate Gb link throughput (TH_{Gb}, Mbit/s). So, it is calculated according to the formula:

$$TH_{Gb} = \frac{1}{60} \times \frac{\max(BHE_{PDu}; BHE_{PDd})}{f_{GSM}} \qquad (84)$$

Where:

BHE_{PDu} – Total minute equivalent for up-link packet data megabytes in the GSM network element per minute in busy hour, minutes (see formula No. 18).

BHE_{PDd} – Total minute equivalent for down-link packet data megabytes in the GSM network element per minute in busy hour, minutes (see formula No. 18).

f_{GSM} – GSM data traffic to minute equivalent conversion factor (see formula No. 11);

Number of PCU base units is calculated according to the formula:

$$BU_{PCU} = \max\left(\left\lceil \frac{TH_{Gb}}{C^{\psi}_{PCU}} \right\rceil; BU_{RNC} + BU_{BSC}\right) \tag{85}$$

Where:

TH_{Gb} – Gb link throughput, Mbit/s (see formula No. 84);

C^{ψ}_{PCU} – Maximal operational capacity of PCU, Mbit/s (see formula No. 25);

BU_{RNC} – RNC base units, units (see formula No. 56);

BU_{BSC} – BSC base units, units. Calculated according algorithm provided in section *7.6 Base Station Controller.*

First step in SGSN base unit number calculation is to estimate Gb link throughput (TH_{Gbp}, BH packets/s). So, it is calculated according to the formula:

$$TH_{Gbp} = \frac{10^6}{8} \times \frac{TH_{Gb}}{\alpha_{b/p}} \tag{86}$$

Where:

TH_{Gb} – Gb link throughput, Mbit/s (see formula No. 84);

$\alpha_{b/p}$ – Average number of bytes per packet, bytes;

It is assumed $\alpha_{b/p}$ is equal to 650 bytes.

Number of SGSN base units (BU_{SGSN}, units) is calculated according to the formula:

$$BU_{SGSN} = \left\lceil \frac{TH_{Gbp}}{C^{\psi}_{SGSN}} \right\rceil \tag{87}$$

Where:

TH_{Gbp} – Gb link throughput, BH packets/s (see formula No. 86);

C^{ψ}_{SGSN} – Maximal operational capacity of SGSN to satisfy BH packets traffic, BH packets/s (see formula No. 25).

Amount of PCU and SGSN extension units is calculated according to algorithm provided in section *7.1. Base and extension units* with Gb link throughput (Mbit/s) and Gb link throughput (BH packets/s) as dividend variables respectively.

7.14. Voice Mail Service and Home Location Register

Each Voice mail service (VMS) and Home location register (HLR) comprises of two parts:

- Base unit;
- Extension units.

The outcome of the algorithm presented in this section is number of base units and extension units for VMS and HLR. The dividend variable for VMS is measured by mailboxes and HLR by subscribers' number.

Amount of VMS and HLR base units and extension units is calculated according to algorithm provided in section *7.1. Base and extension units* with mailboxes and subscribers number as dividend variables.

7.15. Service Control Point (Intelligent Network)

Service Control Point (SCP) is the network element, which services pre-paid subscribers. SCP comprises of two parts:

- Base unit (pre - paid related);
- Extension:
  - Subscribers part;
  - Transactions part.

Estimation of minimum number of SCP base units required is a function of requirements to meet subscribers and traffic demand. In each component's case calculation algorithms are described below.

Total amount of SCP base units (BU_{SCP}, units) is calculated according to the following formulas:

$$BU_{SCP} = Max\left(\frac{N_{pre}}{C^{\psi}_{SCP,sub}};\frac{N_{Tr/s}}{C^{\psi}_{SCP,Tr}}\right) \quad (88)$$

$$N_{Tr/s} = \frac{N_{pre}}{N_{TSub}} \times \frac{N_{BHCA}}{60} \times \alpha_{t/c} \quad (89)$$

Where:

N_{pre} – Pre-paid subscribers, units;

$N_{Tr/s}$ – Busy hour transactions per second, units;

$C^{\psi}_{SCP,sub}$ – Maximal operational capacity to satisfy number of subscribers (see formula No. 25);

$C^{\psi}_{SCP,Tr}$ – Maximal operational capacity to satisfy number of transactions, BH transactions/s (see formula No. 25);

N_{TSub} – GSM and UMTS subscribers, units;

N_{BHCA} – Call attempts in BHT, BHCA (see formula No. 2).

$\alpha_{t/c}$- Average number of IN transactions per one pre-paid subscriber call (on-net and off-net). Assumption is made that $\alpha_{t/c}$ is 8 transactions per call.

Amount of SCP extension units for subscribers and transactions part is calculated according to algorithm provided in section *7.1. Base and extension units* with subscribers' number and BH transactions per second dividend variables.

7.16. Network Functionality

Network functionality (NF) elements in BU-LRAIC comprise of the following elements:

- Soft handover (SFH);
- GSM/DCS control;
- EDGE data transfer;
- HSDPA data transfer.

BU-LRAIC model assumes that amount of NE elements is equal to amount of other NE, according to the table 12.

Table 12. Amount of NE elements

HCC name	Total amount of units
SFH: soft handover (network-wide)	One unit in a mobile network
SFH: soft handover (RNC extension)	Equal to a number RNC base units
SFH: soft handover (NodeB extension)	Equal to a number of Node Bs
GSM/DCS: control (network-wide)	One unit in a mobile network
GSM/DCS: control (MSC extension)	Equal to a number of MSC base units
GSM/DCS: control (BSC extension)	Equal to a number of BSC base units
GSM/DCS: control (BTS extension)	Equal to a number of dual band BTS sites
EDGE: data transfer (network-wide)	One unit in a mobile network
EDGE: data transfer (MSC extension)	Equal to a number of MSC base units

EDGE: data transfer (BSC extension)	Equal to a number of BSC base units
EDGE: data transfer (BTS extension)	Equal to a number of BTS macro cells
HSDPA: data transfer (network-wide)	One unit in a mobile network
HSDPA: data transfer (MSS extension)	Equal to a number of MSS base units
HSDPA: data transfer (RNC extension)	Equal to a number of RNC base units
HSDPA: data transfer (NodeB extension)	Total number of Node B sites in the network

7.17. Other Network

It is assumed that in BU-LRAIC model there is one billing system (hardware and software). Also it is assumed that there is one Gateway GPRS Support Node (GGSN), one WAP gateway in the GSM network and one number portability system (hardware and software).

7.18. Transmission

Transmission network connects physically separated nodes in mobile network (BTSs/Node B, BSCs/RNC, MSCs or MSS/MGWs) and allows transmission of communication signals over far distances.

Transmission network, according to the mobile network topology in BU-LRAIC model is split into the following hierarchical levels:

- Backhaul transmission:
  - BTS/Node B – BSC/RNC;
- Core transmission:
  - BSC/RNC – MSC or BSC/RNC – MGW transmission;
  - MSC – MSC or MGW – MGW transmission.

BU – LRAIC model also assumes two different transmission technologies:

- PDH technology in backhaul transmission;
- SDH technology in core transmission. Leased lines are modelled in core transmission as well. Leased lines are defined as leased technology.

The following sections provide algorithms for calculating transmission network capacity in each hierarchical level of the mobile network.

Backhaul transmission

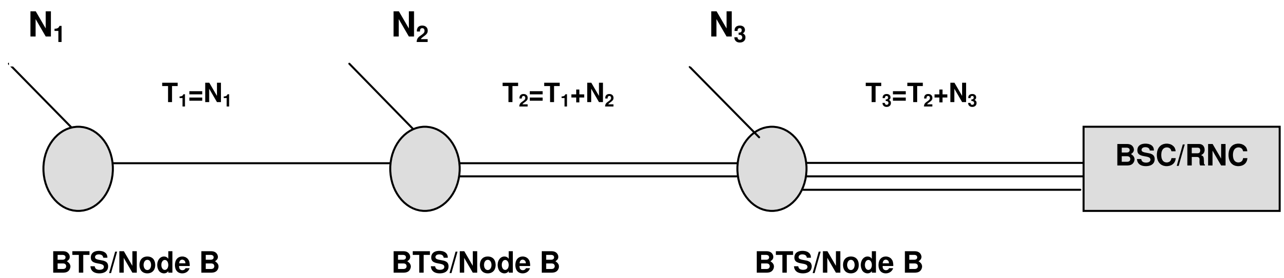
Backhaul transmission connects BTSs with BSCs (GSM network) and Node Bs with RNCs (UMTS network). PDH technology is used to transport data between mentioned nodes of mobile network. PDH comprise the following transmission modes:

- PDH radio link 2 Mbit/s microwave link;
- PDH radio link 8 Mbit/s microwave link;
- PDH radio link 16 Mbit/s microwave link;
- PDH radio link 32 Mbit/s microwave link.

To calculate backhaul transmission costs the proportion of each using PDH radio link needs to be estimated. Consequently, essential assumption in backhaul transmission is made that BTSs/Node Bs are linked to one transmission line. Then, the proportion of each PDH radio link is set depending on:

- The number of sites (BTS/Node B) per transmission line which connects BSC/RNC and the furthest BTS/Node B;
- Average throughput per site.

Figure 6 illustrates principal transmission scheme between BTSs/Node Bs and BSCs/RNCs.



N_1=N_2=N_3 - Average throughput per site in (kbit/s)

Figure 6: Calculating proportions of each PDH radio link.

Key characteristics for backhaul transmission modelling are[10]:

- Transmission network equipment is built with minimal capacity level to assure BTS/Node B – BSC/RNC transmission on the level sufficient to serve the traffic demand.

[10] When network is built in a ring structure data traffic is going through the shortest way. This is the reason why these characteristics are accepted.

- Each BTS/Node B that belongs to particular transmission line put additional volume of data to the transmission line. It results in higher loading of transmission line coming up to BSC and lower loading moving backwards.
- Assumption that the average number of sites per transmission line is three is set.

Below, algorithm of PDH radio links number calculation by different transmission modes (2 Mbit/s; 8 Mbit/s; 16 Mbit/s; 32 Mbit/s) is provided. As all PDH radio link modes are calculated with reference to one algorithm, common PDH radio link number calculation algorithm is provided.

At first, average throughput per site (α_{TH}, kbit/s) is calculated according to the following formula:

$$\alpha_{TH} = \frac{TH_{UMTS} + TH_{GSM}}{N_{SI}} \qquad (90)$$

Where:

TH_{UMTS} – Total throughout per UMTS sites taking in account all type of cells, sub-areas and sectors, kbit/s;

TH_{GSM} – Total throughput per GSM sites taking in account all type of cells, sub-areas and sectors, kbit/s;

N_{SI} – Total number of sites (both GSM and UMTS networks), units (calculated in formula No. 54).

TH_{UMTS} is calculated according to the following formula:

$$TH_{UMTS} = \sum_{i,j,k} TH_{i,j,k}^{UMTS} \times N_{i,j,k}^{UMTS} \qquad (91)$$

Where:

$TH_{i,j,k}^{UMTS}$ – Throughput per UMTS site, kbit/s. See formula No. 92.

$N_{i,j,k}^{UMTS}$ – Number of UMTS sites, units;

i – Type of area;

j – Type of cell;

k – Type of sector.

$TH_{i,j,k}^{UMTS}$ is calculated according to the following formula:

$$TH_{i,j,k}^{UMTS} = \frac{N_{CAP}^{SeB} \times (P_{UMTS} \times C_{\min}^{Se} + P_{HSDPA} \times C_{HSDPA}^{Se})}{N_{iSeB}^{Si}} \times i \qquad (92)$$

Where:

N_{CAP}^{SeB} - Number of sectors to meet capacity requirements in all types of area and cell, calculated in formula No. 49, units;

P_{UMTS} – UMTS data traffic proportion in UMTS network, %;

P_{HSDPA} – HSDPA data traffic proportion in UMTS network, %;

$C_{\min}^{Se}$ – Sector capacity in BHT in all types of area and cell, kbit/s. Assumptions for this value are provided in the beginning of section *7.4 Node B.*

C_{HSDPA}^{Se} - Sector capacity – HSDPA, in BHT in all types of area and cell, kbit/s. Assumptions for this value are provided in the beginning of section *7.4 Node B.*

N_{iSeB}^{Si} – i sectored sites in UMTS network, calculated in formula No. 57, units;

i - 1, 2 or 3, respectively to omni sector, 2 sector or 3 sector.

TH_{GSM} is calculated according to the following formula:

$$TH_{GSM} = \sum_{i,j,k} TH_{i,j,k}^{GSM} \times N_{i,j,k}^{GSM} \qquad (93)$$

Where:

$TH_{i,j,k}^{GSM}$ - Throughput per GSM site, kbit/s;

$N_{i,j,k}^{GSM}$ - Number of GSM sites, units;

i – Type of area;

j – Type of cell;

k – Type of sector.

$TH_{i,j,k}^{GSM}$ is calculated according to the following formula:

$$TH_{i,j,k}^{GSM} = N_{TRX/Se} \times TH^{Se} \times i \qquad (94)$$

Where:

$N_{TRX/Se}$ - Number of TRXs per sector (taking in account all types of area and cell), calculated in formulas No. 40, 41, 42, units;

TH^{Se} – Throughput per TRX, kbit/s; as there are 8 channels in one TRX and it is assumed that throughput per one channel equals 16 kbit/s, throughput per TRX is calculated multiplying 8 (channels) by 16 (throughput per one channel);

i - 1, 2 or 3, respectively to omni sector, 2 sector or 3 sector.

Further, link capacity of transmission modes (C_i^l, circuits) is calculated according to the following formula:

$$C_i^l = C_b \times OA \times N_i^{lc} \quad (95)$$

Where:

C_b – Basic 2 Mbit/s link capacity, kbit/s; Mbit/s will be translated into kbit/s using 1000 multiple.

OA – Operational allowance, %; Algorithm of operational allowance is provided in formula No. 25 (calculated according to PDH equipment).

N_i^{lc} – Number, which multiplies basic 2 Mbit/s link capacity;

i – PDH links at 2 Mbit/s, 8 Mbit/s, 16 Mbit/s, and 32 Mbit/s.

N_i^{lc} values are:

- PDH radio link 2 Mbit/s microwave link – 1;
- PDH radio link 8 Mbit/s microwave link – 4;
- PDH radio link 16 Mbit/s microwave link – 8;
- PDH radio link 32 Mbit/s microwave link – 16.

Maximum number of transmission modes sections per transmission line ($N_i^{MAX,\sec}$, units) is calculated according to the following formula:

$$N_i^{MAX,\sec} = \left\lfloor \frac{C_i^l}{\alpha_{TH}} \right\rfloor \quad (96)$$

Where:

C_i^l – Particular link capacity of transmission modes, kbit/s;

α_{TH} – average throughput per site, kbit/s. Calculation of this dimension is provided in formula No. 90.

Number of transmission modes sections per transmission line is calculated with different algorithms for different types of PDH radio links. Number of 2 Mbit/s sections per transmission line ($N_2^{\sec}$, units) is calculated according to the following formula:

$$N_2^{\sec} = MIN(N_2^{MAX,\sec}; \alpha_{BTS}) \quad (97)$$

Where:

$N_2^{MAX,\sec}$ – Maximum number of 2 Mbit/s sections per transmission line, units (see formula No. 96).

α BTS – Average number of BTS sites per transmission line, units. Assumption is provided in page 73.

Number of 8 Mbit/s sections per transmission line ($N_8^{\sec}$, units) is calculated according to the following formula:

$$N_8^{\sec} = MIN(N_8^{MAX,\sec}; \alpha_{BTS}) - N_2^{\sec} \quad (98)$$

Where:

$N_8^{MAX,\sec}$ – Maximum number of 8 Mbit/s sections per transmission line, units. (see formula No. 96).

α BTS – Average number of BTS sites per transmission line, units. Assumption is provided in page 73.

$N_2^{\sec}$ – Number of 2 Mbit/s sections per transmission line, units. Look at formula No. 97.

Number of 16 Mbit/s sections per transmission line ($N_{16}^{\sec}$, units) is calculated according to the following formula:

$$N_{16}^{\sec} = MIN(N_{16}^{MAX,\sec}; \alpha_{BTS}) - N_8^{\sec} - N_2^{\sec} \quad (99)$$

Where:

$N_{16}^{MAX,\sec}$ – Maximum number of 16 Mbit/s sections per transmission line, units. (see formula No. 96).

α BTS – Average number of BTS sites per transmission line, units. Assumption is provided in page 73.

$N_2^{\sec}$ – Number of 2 Mbit/s sections per transmission line, units (see formula No. 97)

$N_8^{\sec}$ – Number of 8 Mbit/s sections per transmission line, units (see formula No. 98).

Number of 32 Mbit/s sections per transmission line ($N_{32}^{\sec}$, units) is calculated according to the following formula:

$$N_{32}^{\sec} = MIN(N_{32}^{MAX,\sec}; \alpha_{BTS}) - N_{16}^{\sec} - N_8^{\sec} - N_2^{\sec} \quad (100)$$

Where:

$N_{32}^{MAX,\sec}$ – Maximum number of 16 Mbit/s sections per transmission line, units (see formula No. 96)

α BTS – Average number of BTS sites per transmission line, units. Assumption is provided in page 73.

N_2^{sec} – Number of 2 Mbit/s sections per transmission line, units. Look at formula No. 97.

N_8^{sec} – Number of 8 Mbit/s sections per transmission line, units. Look at formula No. 98.

N_{16}^{sec} – Number of 16 Mbit/s sections per transmission line, units. Look at formula No. 99.

Share of transmission modes sections per transmission line (P_i^{sec}, %) is calculated according to the following formula:

$$P_i^{sec} = \frac{N_i^{sec}}{MIN(\alpha_{BTS}; N^{sec})} \qquad (101)$$

Where:

N_i^{sec} – Number of transmission mode sections per transmission line, units. Look at formulas 97 – 100.

i – PDH 2 Mbit/s, 8 Mbit/s, 16 Mbit/s, 32 Mbit/s;

α BTS – Average number of BTS sites per transmission line, units. Assumption is provided in page 73.

N^{sec} – Total number of transmission modes sections per transmission line, units. Calculated summing up the results of formulas No. 97, 98, 99 and 100.

Finally, PDH radio links number by different transmission modes (N_i^{PDH}, units) is calculated according to the following formula:

$$N_i^{PDH} = P_i^{sec} \times N_{Total}^{Si} \qquad (102)$$

Where:

P_i^{sec} – Share of transmission modes sections per transmission line, %;

i – 2 Mb/s, 8 Mb/s, 16 Mb/s, 32 Mb/s;

N_{Total}^{Si} – Total number of sites in mobile network, units. This number is calculated in formula No. 54.

Core transmission

As it was mentioned before core transmission connects BSCs/RNCs and MSCs or MGWs. SDH technology and leased lines are modelled.

First of all, number of SDH radio links in BSC/RNC – MSC or BSC/RNC – MGW hierarchy level is calculated. Below, the calculation algorithm is provided. Number of BSC/RNC-MSC or BSC/RNC – MGW sections to meet capacity demand ($N_{SDH}^{\sec}$, units) is calculated according to the following formula:

$$N_{SDH}^{\sec} = \left\lceil \frac{D_C}{N_{BR} \times C_{SDH}^{\psi}} \right\rceil \quad (103)$$

Where:

D_C – BSC/RNC-MSC or BSC/RNC-MGW total demand for capacity covered by radio links, 2Mbit/s;

N_{BR} – Number of BSCs and RNCs (calculated in sections 7.6. *Base station controller* and 7.8. *Radio Network Controller*), units;

C_{SDH}^{ψ} – Maximal operational capacity of SDH radio link, E1 (calculated according principles provided in formula No. 25).

Total number of SDH links (N_{SDH}, units) is calculated according to the following formula:

$$N_{SDH} = N_{BR} \times P_m^t \times \alpha_{BSC} \times N_{SDH}^{\sec} \quad (104)$$

Where:

N_{BR} – Number of BSCs and RNCs (calculated in sections *7.6. Base Station Controller* and *7.8. Radio Network Controller*, units;

P_m^t – Share of transmission covered by microwave links, %;

α_{BSC} – Average number of BSC sites per link (SDH radio links), units;

$N_{PDH}^{\sec}$ – Number of BSC/RNC-MSC or BSC/RNC-MGW sections to meet capacity requirements, units.

If N_{SDH} is not an integer number, it is rounded to integer.

There is the assumption adopted that the average number of BSC sites per transmission line is two.

Alternative technology for transporting data in BSC/RNC – MSC or BSC/RNC – MGW hierarchy level is leased lines. Kilometres as additional measure besides pieces of leased lines are calculated, as the costs of leased lines increase together with increasing distance between BSC/RNC and MSC or MGW. Having in mind pricing model suppliers are using (access part is usually shorter but more expensive comparing with core network), Operators have to provide weighted (access and core network) average price of 1 km leased lines.

Number of leased lines BSC/RNC-MSC or BSC/RNC-MGW ($N^{l}_{BSC-MSC/MGW}$, units) is calculated according to the following formula:

$$N^{l}_{BSC-MSC/MGW} = N_{BR} \times P^{t}_{L} \qquad (105)$$

Where:

N_{BR} – Number of BSCs and RNCs, units (see formula No. 56).

P^{t}_{L} – Share of transmission covered by leased lines, %.

Total length of leased lines in BSC/RNC – MSC or BSC/RNC - MGW ($L_{BSC-MSC/MGW}$, km) is calculated according to the following formula:

$$L_{BSC-MSC/MGW} = N^{l}_{BSC-MSC/MGW} \times \alpha^{l}_{BSC-MSC/MGW} \qquad (106)$$

Where:

$N^{l}_{BSC-MSC/MGW}$ – Number of leased lines BSC/RNC-MSC or BSC/RNC-MGW, units (see formula No. 105).

$\alpha^{l}_{BSC-MSC/MGW}$ – Average distance of leased line between BSC/RNC and MSC or MGW, km.

Average distance of leased line between BSC/RNC and MSC or MGW ($\alpha^{l}_{BSC-MSC/MGW}$, km) is calculated according to the following formula:

$$\alpha^{l}_{BSC-MSC/MGW} = \frac{R}{\sqrt{2}} \qquad (107)$$

Where:

R – Radial distance of hexagon, km.

The area of hexagon equals to Area of Republic of Lithuania divided by the number of MSC or MGW.

$\alpha^{l}_{BSC-MSC/MGW}$ is shown in the figure 7.

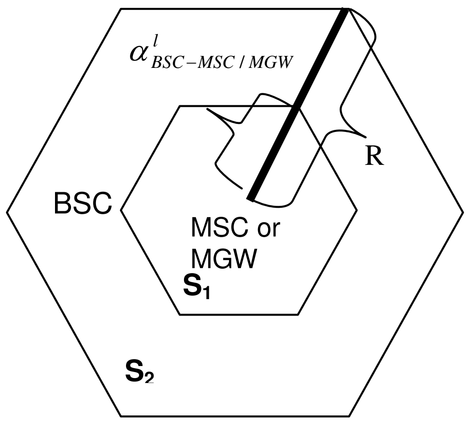


Figure 7. Average distance between BSC and MSC/MGW.

Further algorithm how $\alpha^{l}_{BSC-MSC/MGW}$ is calculated is provided below.

$$\frac{S_2}{S_1} = 2, \quad \frac{\frac{3\sqrt{3}}{2} \times R^2}{\frac{3\sqrt{3}}{2} \times (\alpha^{l}_{BSC-MSC/MGW})^2} = 2, \quad \alpha^{l}_{BSC-MSC/MGW} = \frac{R}{\sqrt{2}}.$$

Where:

S_1 – Area of bigger hexagon, km^2;

S_2 – Area of smaller hexagon, km^2.

In MSC-MSC or MGW – MGW hierarchy level two types of measure of leased lines are calculated as well. Number of leased lines MSC-MSC or MGW-MGW ($N^{l}_{MSC-MSC/MGW-MGW}$, units), assuming each MSC/MGW is connected with each of the rest of MSC/MGW, is calculated according to the following formula:

$$N^{l}_{MSC-MSC/MGW-MGW} = BU_{MSC/MGW} \times (BU_{MSC/MGW} - 1) \quad (108)$$

Where:

$BU_{MSC/MGW}$ – Number of MSC/MGW (see formula No. 67 or 82), units.

Total length of leased lines MSC-MSC or MGW-MGW ($L_{MSC-MSC/MGW-MGW}$, units) is calculated according to the following formula:

$$L_{MSC-MSC/MGW-MGW} = N^{l}_{MSC-MSC/MGW-MGW} \times \alpha^{l}_{MSC-MSC/MGW-MGW} \quad (109)$$

Where:

$N^{l}_{MSC-MSC/MGW-MGW}$ – Number of leased lines MSC/MSS/MGW-MSC/MSS/MGW, units;

$\alpha^{l}_{MSC-MSC/MGW-MGW}$ – Average distance of leased lines between MSCs/MGWs, km.

Average distance of leased lines between MSCs/MGWs ($\alpha^{l}_{MSC-MSC/MGW-MGW}$, km) is calculated according to the following formula:

$$\alpha^{l}_{MSC-MSC/MGW-MGW} = \frac{R_{MSC/MGW}}{\sqrt{2}} \quad (110)$$

Where:

$R_{MSC/MGW}$ – Radial distance of hexagon, km

The area of hexagon is equal to area of Republic of Lithuania. Assumption is adopted that area of Republic of Lithuania is one hexagon.

Stand-alone transmission radio link: tower and site preparation

As total number of PDH and SDH links is calculated, it is assumed that additional (to traffic and coverage) towers and sites are needed for transmission. These radio links are further referred as stand-alone transmission radio links

Total number of stand-alone transmission radio link (N^{t}_{S-A}, units) is calculated according to the following formula:

$$N^{t}_{S-A} = N^{S-A}_{B} + N^{S-A}_{C} \quad (111)$$

Where:

N^{S-A}_{B} – Number of stand-alone microwave sites in backhaul transmission, units;

N^{S-A}_{C} – Number of stand-alone microwave sites in core transmission, units.

N^{S-A}_{B} is calculated according to the following formulas:

$$N^{S-A}_{B} = N^{PDH} \times P^{PDH}_{S-A} \quad (112)$$

$$N^{PDH} = \sum_{i} N^{PDH}_{i} \quad (113)$$

Where:

N^{PDH} – Total number of PDH radio links in BTS/NodeB–BSC/RNC transmission, units;

P^{PDH}_{S-A} – Percent of stand-alone PDH radio links, %. Data related to stand-alone PDH radio links will be gathered from Operators.

N_i^{PDH} – 2 Mbit/s, 8 Mbit/s, 16 Mbit/s, 32 Mbit/s PDH radio links.

N_C^{S-A} is calculated according to the following formula:

$$N_C^{S-A} = N_{SDH} \times P_{S-A}^{SDH} \qquad (114)$$

Where:

N_{SDH} – Total number of SDH radio links (calculated in formula No. 104*),* units;

P_{S-A}^{SDH} – Percent of stand-alone SDH radio links, %. Data related to stand-alone SDH radio links will be gathered from Operators.

8. Network valuation

8.1. Cost annualization

All mobile network elements identified during network dimensioning are revalued at Gross Replacement Cost (GRC). On the basis of GRC value its annual CAPEX cost is being further calculated. In BU-LRAIC model there are four alternative methods that are used to calculate annual CAPEX costs:

- Straight-line method;
- Annuity method;
- Tilted Annuity method;
- Economic depreciation.

Algorithms to calculate annual CAPEX cost using straight-line, annuity and tilted annuity methods are described in the following sections.

Economic depreciation is a method to calculate annual costs based on a forecasted revenue distribution during the useful asset lifetime. This is the main reason why this method is favoured in theory. On the other hand, results from this method highly depend on revenue forecasts which, having in mind dynamic nature of telecommunications market, may be subjective and disputable. Consequently, in current BU-LRAIC model the use of economic depreciation method is excluded from modelling scope.

Straight-line method

The annual CAPEX costs under straight-line method are calculated according to the following formula:

$$C = CD - HG + ROI \qquad (115)$$

Where:

- $CD = \frac{GRC}{l}$ - current depreciation (l – useful life of an asset (data will be gathered from Operators); GRC –gross replacement cost of an asset);
- $HG = \frac{NBV}{GBV} GRC \times index$, holding gain (loss);
- $ROI = \frac{NBV}{GBV} GRC \times WACC$ - cost of capital;
- *Index* - price index change (data will be gathered from Operators);

- NBV – net book value;
- GBV – gross book value;
- *WACC* - weighted average cost of capital.

Annuity method

The annual CAPEX costs under annuity method are calculated according to the following formula:

$$C = GRC \frac{(WACC)}{1 - \left(\frac{1}{1 + WACC} \right)^{l}} \qquad (116)$$

Tilted annuity method

The annual CAPEX costs under tilted annuity method are calculated according to the following formula:

$$C = GRC \frac{(WACC - index)}{1 - \left(\frac{1 + index}{1 + WACC} \right)^{l}} \qquad (117)$$

Straight-line method will be used as a main method to calculate annual CAPEX costs due to simplicity and consistency with the most commonly adopted accounting method in financial accounts. Although the model will have a possibility to calculate annual CAPEX using the other two methods.

8.2. Mark-ups

BU-LRAIC model includes the common and joint cost (network or other related) OPEX and CAPEX costs as a percentage of the network costs. In current BU-LRAIC model following mark-ups are calculated:

Table 13. Mark-ups in BU-LRAIC modelling

<table>
<tr><th>Parameter name</th><th>Activities and equipments included</th></tr>
<tr><td colspan="2">Mark ups on GRC (joint network costs)</td></tr>
<tr><td colspan="2">Mark-ups of operational costs on network cost</td></tr>
<tr><td>Site infrastructure</td><td rowspan="4">Operational costs of planning, management, on—site visits, inspections, configuration and maintenance works, for particular network elements.</td></tr>
<tr><td>BSS infrastructure</td></tr>
<tr><td>Transmission</td></tr>
<tr><td>MSC/MGW and other networks</td></tr>
<tr><td colspan="2">Mark-ups of network management system on network costs</td></tr>
</table>

Parameter name	Activities and equipments included
BSS infrastructure	CAPEX of network management system equipment.
Transmission	
MSC/MGW and other networks	
Mark-ups on operational costs (Overheads)	
Mark-ups of administration and support operational cost	
Total network infrastructure	Operational cost of general administration, finance, human resources, information technology management and other administration and support activities (salaries, materials, services).
Mark-ups of administration and support capital cost	
Total network infrastructure	CAPEX of general administration, finance, human resources, information technology management and other administration and support activities (buildings, vehicles, computers, etc.).

Detailed mark-ups to cover common costs are provided in table 14.

Mark-ups are calculated based on the principles described in section *2.7 Mark-ups.*

Table 14. Mark-ups to cover common costs

	Mark-ups of operational costs on network cost	Mark-ups of network management system on network co	Mark-ups of administration and support operational cost	Mark-ups of administration and support capital cost
Site				
All sub-components	Site infrastructure (% on HCC GRC value)	-	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
BTS				
All sub-components	BSS infrastructure (% on HCC GRC value)	BSS infrastructure (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
Node B				
All sub-components	BSS infrastructure (% on HCC GRC value)	BSS infrastructure (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
PDH/SDH radio link				
All sub-components	Transmission (% on HCC GRC value)	Transmission (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
BSC/RNC				
All sub-components	BSS infrastructure (% on HCC GRC value)	BSS infrastructure (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
MSC/MGW				
All sub-components	MSC/MGW and other network (% on HCC GRC value)	MSC/MGW and other network (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
Network functionality				
All sub-components	MSC/MGW and other network (% on HCC GRC value)	MSC/MGW and other network (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
Data network				
All sub-components	MSC/MGW and other network (% on HCC GRC value)	MSC/MGW and other network (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
SMSC/MMSC				
All sub-components	MSC/MGW and other network (% on HCC GRC value)	MSC/MGW and other network (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)
Other Network				
All sub-components (network-wide)	MSC/MGW and other network (% on HCC GRC value)	MSC/MGW and other network (% on HCC GRC value)	Total network infrastructure (% on network OPEX)	Total network infrastructure (% on network OPEX)

9. Service cost calculation

After major costs with the help of engineering model are established, service cost calculation stage follows. The flow in figure 8 and explanation of processes are provided below.

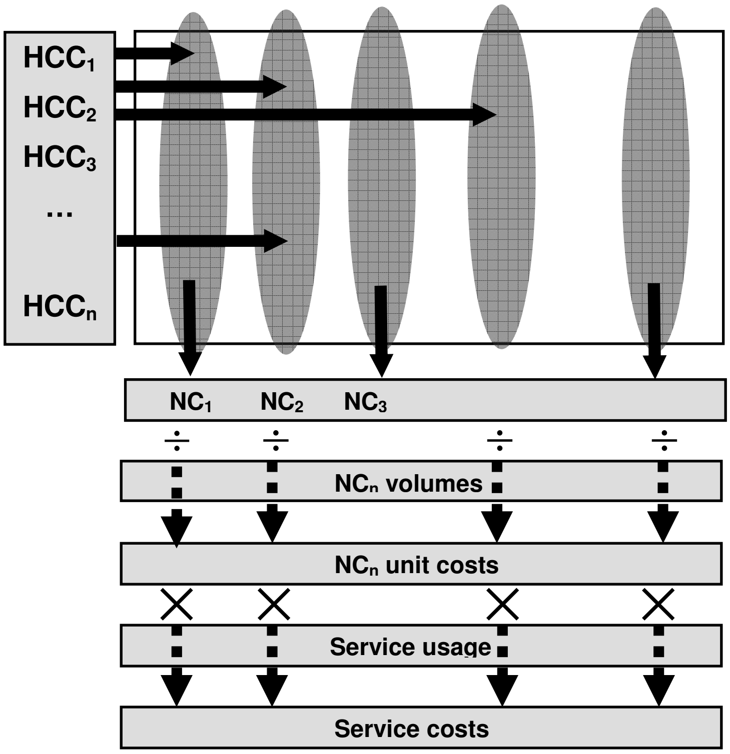


Figure 8. Service cost calclation flow

As the figure 8 shows, after network elements are established, HCCs are allocated to NCs (see section 9.2 HCC allocation to NC). Further total Network Components costs are calculated by summing appropriate HCCs. Total Network Components costs are divided by service volumes and Network Component unit costs are calculated. And finally Network Component unit costs are multiplied by service usage factor and service costs are calculated (see table 18. Service matrix).

9.1. Homogeneous cost categories allocation to Network Components

Essential part of LRAIC methodology is allocation of Homogenous Cost Categories on Network Components. Network Components represents logical elements that are functionally integrated and from combining which any services may be established. An example of Network Component is logical meaning of BTS which includes annual cost of BTS's along with all mark up costs resulting from maintenance, localization and supporting activities (e.g. administration, accounting etc.).

HCCs to NC allocation matrix is presented in table 15.

Table 15. HCC allocation to NC.

	Tower and site preparation	BTS	BSC	NodeB	RNC	MSC/MGW	TX / BTS/NodeB -BSC/RNC	TX / BSC/RNC-MSC/MGW	TX / MSC-MSC or MGW-MGW	SMSC	MMSC	SGSN / GGSN	EDGE	HSDPA	WAP	HLR	Billing	Number portability platform
Site																		
All sub-components	100%																	
BTS																		
All sub-components		100%																
Node B																		
All sub-components				100%														
PDH/SDH radio link																		
SDH								100%										
PDH							100%											
BSC/RNC																		
BSC: base unit			100%															
BSC: BS TRX extension			100%															
TRC: transcoder base unit			100%															
TRC: transcoder E1			100%															
RNC: basic units					100%													
RNC: extension units (lub link)					100%													
RNC: extension units (sectors)					100%													
RNC: extension units (sites)					100%													
MSC																		
All sub-components						100%												
Network functionality																		
SFH: soft handover (network)				100%														
SFH: (MSS extension)				100%														
SFH: (RNC extension)				100%														
SFH: (Node B extension)				100%														
GSM/DCS: control (BSC extension)		100%																
GSM/DCS: control (MSC extension)		100%																
GSM/DCS: control (BSC extension)		100%																
GSM/DCS: control (BTS extension)		100%																
Data network																		
EDGE: data transfer (network-wide)													100%					
EDGE: data transfer (MSC extension)													100%					
EDGE: data transfer (BSC extension)													100%					
EDGE: data transfer (BTS extension)													100%					
HSDPA: data transfer (network-wide)														100%				
HSDPA: data transfer (MSS extension)														100%				
HSDPA: data transfer (RNC extension)														100%				
HSDPA: data transfer (NodeB extension)														100%				
PCU: base unit												100%						
PCU: extension units (Gb link)												100%						
SGSN: base unit												100%						
SGSN: processing extension												100%						
GGSN: basic unit and licence												100%						
WAP: gateway															100%			
SMSC/MMSC																		
SMSC: base unit										100%								
SMSC: extension										100%								
MMSC: base unit											100%							
MMSC: extension											100%							
Other Network																		
SSP: service switching point (network-wide)																100%		
SCP: service control point - base unit (pre-paid related)																100%		
SCP: extension – subscribers																100%		
SCP: extension – tps						100%												
VMS: base unit						100%												
VMS: extension						100%												

	Tower and site preparation	BTS	BSC	NodeB	RNC	MSC/MGW	TX / BTS/ NodeB-BSC/RNC	TX / BSC/RNC-MSC/MGW	TX / MSC-MSC or MGW-MGW	SMSC	MMSC	SGSN / GGSN	EDGE	HSDPA	WAP	HLR	Billing	Number portability platform
HLR: base unit																100%		
HLR: extension																100%		
Billing IC hardware and software																	100%	
Number portability system: hardware and software																		100%
License and frequency fee																		
GSM 900 MHz	100%																	
GSM 1800 MHz		100%																
UMTS					100%													
Leased Line																		
Leased Lines BSC-MSC or BSC-MGW (units)								100%										
Leased Lines BSC-MSC or BSC-MGW (km)								100%										
Leased Lines MSC- MSC or MGW-MGW (units)									100%									
Leased Lines MSC- MSC or MGW-MGW (km)									100%									

9.2. Network Component average unit cost

After deriving total costs of each Network Component average unit costs of those Network Components are derived. Unit costs (*UC*, Lt) are derived by dividing total cost of each Network Component by yearly traffic utilizing that Network Component as formula shows:

$$UC = \frac{TNCC}{Volume} \qquad (118)$$

Where:

TNCC – Total Network Component costs, Lt;

Volume – Annual traffic[11] utilizing appropriate Network Component. Below, table 16 is provided which explains how appropriate volume is calculated.

Table 16. Traffic utilizing Network Components.

Network Component	Unit	Traffic included
Tower and site preparation	Weighted service volumes in equivalent minutes (conversion is not applied to voice traffic)	Voice traffic Video traffic SMS traffic MMS traffic Circuit data traffic Packet data traffic
BTS	Weighted service volumes in equivalent minutes (conversion is not applied to voice traffic) Weighted data traffic volume in megabytes	Voice traffic SMS traffic MMS traffic Circuit data traffic Packet data traffic: o *Data up-link (GSM subscribers)* o *Data down-link (GSM subscribers)*

[11] Only successful calls are included in this parameter.

Network Component	Unit	Traffic included
BSC	Weighted service volumes in equivalent minutes (conversion is not applied to voice traffic) Weighted data traffic volume in megabytes	Voice traffic (minutes of use) Video traffic (minutes of use) SMS traffic (pieces) MMS traffic (pieces) Circuit data traffic (minutes of use Packet data traffic (Mbytes): o *Up-link (GSM subscribers)* o *Down-link (GSM subscribers)*
Node B	Weighted service volumes in equivalent minutes Weighted data traffic volume in megabytes	Video traffic Packet data traffic (Mbytes): o *Up-link (UMTS subscribers)* o *Down-link (UMTS subscribers)*
RNC	Weighted service volumes in equivalent minutes Weighted data traffic volume in megabytes	Video traffic Packet data traffic (Mbytes): o *Up-link (UMTS subscribers)* o *Down-link (UMTS subscribers)*
MSC/MGW	Weighted service volumes in equivalent minutes	Voice traffic Video traffic
TX / BTS-BSC	Weighted service volumes in equivalent minutes Weighted data traffic volume in megabytes	Voice traffic Video traffic SMS traffic MMS traffic Circuit data traffic Packet data traffic

Network Component	Unit	Traffic included
TX / BSC-MSC/MGW	Weighted service volumes in equivalent minutes	Voice traffic Video traffic SMS traffic MMS traffic Circuit data traffic Packet data traffic
TX / MSC-MSC or MGW/MGW	Weighted service volumes in equivalent minutes Weighted data traffic volume in megabytes	Voice traffic Video traffic SMS traffic MMS traffic Circuit data traffic Packet data traffic
SMSC	Weighted service volumes	SMS traffic
MMSC	Weighted service volumes	MMS traffic
SGSN / GGSN	Weighted data traffic volume in megabytes	Packet data traffic
EDGE	Weighted data traffic volume in megabytes	EDGE data traffic in GSM network: o *Year total up-link (GSM subscribers)* o *Year total down-link (GSM subscribers)*
HSDPA	Weighted data traffic volume in megabytes	HSDPA data traffic in UMTS network: o *Year total up-link (UMTS subscribers)* o *Year total down-link (UMTS subscribers)*

Network Component	Unit	Traffic included
WAP	Weighted data traffic volume in megabytes	WAP data traffic in GSM network: o *Year total up-link (GSM subscribers)* o *Year total down-link (GSM subscribers)*
HLR	Number of users[12]	Year end mobile subscribers (GSM post-paid) Year end mobile subscribers (GSM pre-paid) Year end mobile subscribers (UMTS post-paid) Year end mobile subscribers (UMTS pre-paid)
Billing	Weighted voice traffic volume Weighted sessions volume Weighted SMS volume Weighted MMS volume	Voice traffic: o *Incoming* o *Transit* *Data services (sessions)* *SMS (messages)* *MMS (messages)*
Number portability platform	Weighted voice traffic volume Weighted sessions volume Weighted SMS volume Weighted MMS volume	Voice traffic (call attempts): o *On-net* o *Incoming* *Data services (sessions)* *SMS (messages)* *MMS (messages)*

9.3. Service cost

In order to calculate total service cost average service usage factors by each network component involved in a service are needed. Average service usage factors refer to the quantity of a particular network component involved in a service (e.g. average number of base stations, switches and transmission links involved in termination service).

Service matrix with service usage factors is provided in table 17.

[12] User is defined as active subscriber according to the document ”General terms and conditions for engaging in electronic communications activities” (Žin., 2005, Nr. 49-1641; 2006, Nr. 131-4976; 2007, Nr.43-1670).

Table 17. Service matrix

	Tower and site preparation	BTS	BSC	NodeB	RNC	MSC/MGW	TX / BTS/NodeB-BSC/RNC	TX / BSC/RNC-MSC/MGW	TX / MSC-MSC or MGW-MGW	SMSC	MMSC	SGSN - GGSN	EDGE	HSDPA	WAP	HLR	Billing	Number portability platform
On-net call	$f_R^{1,1}$	$f_R^{1,1}$	$f_R^{1,2}$	-	-	$f_R^{1,3}$	$f_R^{1,4}$	$f_R^{1,5}$	$f_R^{1,6}$	-	-	-	-	-	-	-	$60/\alpha_{CD}$	$60/\alpha_{CD}$
Call origination	$f_R^{2,1}$	$f_R^{2,1}$	$f_R^{2,2}$	-	-	$f_R^{2,3}$	$f_R^{2,4}$	$f_R^{2,5}$	$f_R^{2,6}$	-	-	-	-	-	-	-	$60/\alpha_{CD}$	-
Call termination	$f_R^{3,1}$	$f_R^{3,1}$	$f_R^{3,2}$	-	-	$f_R^{3,3}$	$f_R^{3,4}$	$f_R^{3,5}$	$f_R^{3,6}$	-	-	-	-	-	-	-	$60/\alpha_{CD}$	$60/\alpha_{CD}$
WAP data	$f_R^{15,1} * f_{GSM}$	$f_R^{15,1}$	$f_R^{15,2}$	-	-	-	$f_R^{15,4}$	$f_R^{15,5}$	-	-	-	$f_R^{15,3}$	-	-	$f_R^{15,3}$	-	$1/\rho_S$	$1/\rho_S$
GPRS data	$f_R^{15,1} * f_G$	$f_R^{15,1}$	$f_R^{15,2}$	-	-	-	$f_R^{15,4}$	$f_R^{15,5}$ *	-	-	-	$f_R^{15,3}$	-	-	-	-	$1/\rho_S$	$1/\rho_S$
EDGE data	$f_R^{15,1} * f_E$	$f_R^{15,1}$	$f_R^{15,2}$	-	-	-	$f_R^{15,4}$	$f_R^{15,5}$	-	-	-	$f_R^{15,3}$	$f_R^{15,3}$	-	-	-	$1/\rho_S$	$1/\rho_S$
UMTS data	$f_R^{15,1} * f_{umts}$	-	-	$f_R^{15,1}$	$f_R^{15,2}$	-	$f_R^{15,4}$	$f_R^{15,5}$	-	-	-	$f_R^{15,3}$	-	-	-	-	$1/\rho_S$	$1/\rho_S$
HSDPA data	$f_R^{15,1} * f_{HSDPA}$	-	-	$f_R^{15,1}$	$f_R^{15,2}$	-	$f_R^{15,4}$	$f_R^{15,5}$	-	-	-	$f_R^{15,3}$	-	$f_R^{15,3}$	-	-	$1/\rho_S$	$1/\rho_S$
CSD data	$f_R^{14,1}$	$f_R^{14,1}$	$f_R^{14,2}$	-	-	$f_R^{14,3}$	$f_R^{14,4}$	$f_R^{14,5}$	$f_R^{14,6}$	-	-	-	-	-	-	-	$1/\rho_S$	$1/\rho_S$
HSCSD data	$f_R^{14,1} * \alpha_H$	$f_R^{14,1} * \alpha_H$	$f_R^{14,2} * \alpha_H$	-	-	$f_R^{14,3} * \alpha_H$	$f_R^{14,4} * \alpha_H$	$f_R^{14,5} * \alpha_H$	$f_R^{14,6} * \alpha_H$	-	-	-	-	-	-	-	$1/\rho_S$	$1/\rho_S$
SMS termination	$f_R^{8,1} * f_{SMS}$	$f_R^{8,1} * f_{SMS}$	$f_R^{8,2} * f_{SMS}$	-	-	$f_R^{8,3} * f_{SMS}$	$f_R^{8,4} * f_{SMS}$	$f_R^{8,5} * f_{SMS}$	-	$f_R^{9/10,3}$	-	-	-	-	-	-	1	1
MMS termination	$f_R^{11,1} * f_{MMS}$	$f_R^{11,1} * f_{MMS}$	$f_R^{11,2} * f_{MMS}$	-	-	-	$f_R^{11,4} * f_{MMS}$	$f_R^{11,5} * f_{MMS}$	-	-	$f_R^{12/13,3}$	$L_{mms}/10^6$	-	-	-	-	1	1

Where:

f_R – Appropriate routing factor (Network element routing factors are provided in section *6.3 Service demand conversion in table 5)*;

$f^{x,y}$– x – Number of row in table 5; y – number of column in table 5.

$f_{G,E,GSM,umts,HSDPA,SMS,MMS}$– Appropriate conversion factor (Network element conversion factors are provided in section *6.3 Service demand conversion)*;

α_H - Average number of channels used for HSCDS is adopted as assumption and equals to two;

L_{mms} - Average MMS length, bytes;

α_{CD} – Average call duration, seconds;

ρ_S – Average volume of data transmitted during one session.

When the average routes of particular types of services are established, service cost (SC) of any service is calculated according to the following formula:

$$SC = \sum_{i=1}^{n} \left(f_{usei}^{\alpha} \times UC_i \right) \tag{119}$$

Where:

n – From 1 to 18 number of Network Component;

f_{usei}^{α} – Average service usage factor, provided in the service matrix. See table 17.

UC_i – Unit Network Component cost, Lt (see formula No. 118).

Annex 1. Second sub-model: point of interconnection related service cost calculation

In this annex, principles of second sub-model are provided. Annex comprises definitions of point of interconnection (POI), providing capacity for point of interconnection services and costs related to those services. The scheme of POI is provided below.

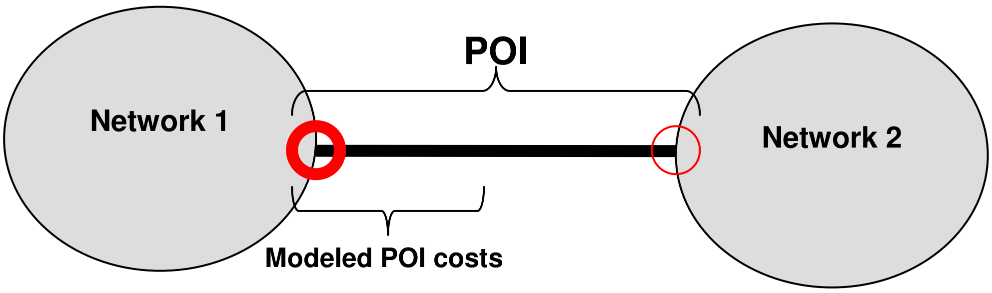


Figure 9. POI scheme

In table 18, definitions of second sub-model services are provided.

Table 18. Service definitions.

Service name	Service definition	Measure
Point of interconnection	Providing geographically defined location, equipment and other associated services where mobile networks of the same or another entity are connected physically or logically to enable mobile network service recipients of one entity to use interconnection and/or the services provided by the connections with the other entity‘s service recipients including all the entities with the access to respective networks.	Physical connection
Providing capacity for point of interconnection	Providing capacity of point of interconnection equipment, telephone switch access capacity (allocated at the point of interconnection) and other associated services enabling call exchange between the interconnected	2 Mbit/s link

	parties.	

POI service one-off costs

POI one-off costs are related to the following one-off activities: receiving and proceeding of order, installation of transmission equipment, cross-connection of cables (on DDF and ODF), setting link on a switch and setting billing. Detailed description of one-off activities required for POI service is presented in the following table.

Table 19. POI service related one-off activities.

Activity	**Man-hours**	**Explanation**
Receiving and proceeding order	A hr	It is assumed that receiving and proceeding of POI order is not day-to-day procedure, it requires to co-ordinate a wide range of activities – ordering installation of additional transmission equipment, ordering cross-connections, ordering set-up on switch, ordering changes in billing system.
Installation of transmission equipment	B hr	It has to be noted that cost of installation is included in GRC of transmission devices and cost of supervising and receipt of installation work is included in mark-up for operation and maintenance. Therefore in the cost of IC link installation only additional administrative resources related to contact the supplier and ordering transmission devices are to be considered if any.
Setting link on switch, link tests	D hr	Setting and testing link on a switch.
Setting billing	E hr	Setting billing.
Total	**F hr**	

POI service one-off costs (CO_{POI}) are calculated according to the following formula:

$$CO_{POI} = t_{off} \times \alpha_{MH} \qquad (120)$$

Where:

t_{off} - Total time required to one-off activities (listed in table 19) per one POI, man-hours;

a_{MH} – Average activity man-hour costs (of required qualification), currency.

POI service periodical costs

POI service periodical costs include both cost related to network equipment and cost related to periodical POI-specific activities.

While calculating the equipment related cost for POI the following STM-1 equipment is required:

1. One STM-1 node (transmission node equipment);
2. One STM-1 optical interface (transmission node equipment);
3. One 32x2 Mbit/s tributary card;
4. 10 m of cable.

The cost of this service should represent incurred capital cost (CAPEX) together with mark-ups of:

1. Operational costs (OPEX) on network cost;
2. Network management system (CAPEX);
3. Administration and support (OPEX and CAPEX).

POI periodical equipment related annual costs are calculated according to the same principles and using the same mark-ups as described for transmission in section *8. Network valuation.*

The utilization rates for transmission equipment should correspond to an average number of 2Mbit/s circuits available per STM-1 link. It is assumed, that STM-1 at POI comprises of average 44 2Mbit/s circuits (operational allowance equal to 70%, assuming 63 circuits in one STM-1 node) and consequently annual POI equipment related annual costs per one POI (CC_{POI}) are calculated using the following formula:

$$CC_{POI} = \frac{CE_{POI}}{44} \quad (121)$$

Where:

CE_{POI} - POI periodical equipment related annual costs, currency.

Providing capacity for POI service one-off costs

Providing capacity for POI service one-off costs are related to the following one-off activities: receiving and proceeding of order, setting link on a switch and link tests. Detailed description of one-off activities required for providing capacity for POI service is presented in the following table. If the order is placed together with a POI order, no additional one-off costs for providing capacity in POI should be incurred – these costs are only incurred for additional capacity orders.

Table 20. Providing capacity for POI service related one-off activities.

Activity	Man-hours	Explanation
Receiving and proceeding order	A hr	It is assumed that receiving and proceeding of POI order is not day-to-day procedure, it requires to co-ordinate a wide range of activities – ordering installation of additional transmission equipment, ordering cross-connections, ordering set-up on switch, ordering changes in billing system
Installation of transmission equipment	B hr	It has to be noted that cost of installation is included in GRC of transmission devices and cost of supervising and receipt of installation work is included in mark-up for operation and maintenance. Therefore in the cost of IC link installation only additional administrative resources related to contact the supplier and ordering transmission devices are to be considered if any.
Setting link on switch and link tests	C hr	Setting link on a switch and link tests.
Total	**D hr**	

Providing capacity for POI service one-off costs ($CO_{capacity}$) is calculated according to the following formula:

$$CO_{capacity} = t_{off}^{c} \times \alpha_{MH} \qquad (122)$$

Where:

t_{off}^{c} - Total time required to one-off activities (listed in table 20) per one 2 Mbit/s link, man-hours;

α_{MH} – Average activity man-hour costs (of required qualification), currency.

Providing capacity for POI service periodical costs

As utilization rates for transmission equipment should correspond to an average number of 2Mbit/s circuits available per STM-1 link, it is assumed, that providing capacity for POI service periodical costs are equal to POI service periodical costs.