BU-LRIC methodology

Mobile network

Version 09-10-2015

Building a better
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1. Introduction

The objectives of this document are to present the theoretical background, scope and the principles of the BU-LRIC modelling. Document consists of three parts. Firs one presets theoretical background of BU-LRIC modelling, in specific:

- requirements set out in the recommendation of the European Commission,
- concept of the BU-LRIC modelling, including main principles and main steps of calculation.

Second part presents methodology and detailed assumptions related to BU-LRIC model for fixed operator, in particular:

- technology and topology of the network;
- scope of calculated services;
- network dimensioning principles;
- CAPEX and OPEX cost calculation principles.

2. Legal background

The interconnect charges have to provide fair economic information for the new entrants to the telecommunication market, who are about to decide, whether to build their own network, or to use the existing telecom infrastructure of the national incumbent. To provide information for correct economic decisions, interconnection charges set by the national incumbents – owners of existing telecom infrastructure – should:

- be based on current cost values,
- include only costs associated with interconnection service,
- not include those costs of the public operator, which are result of inefficient network utilization.

To meet the above-mentioned requirements the GNCC will elaborate a tool for the calculation of cost-based interconnection prices of the mobile and fixed networks based on the bottom-up long-run incremental costs methodology (hereinafter, BU-LRIC). The interconnection price control and methodology of price calculation is maintained by the following regulations:

- European Commission recommendation 2009/396/EC (hereinafter, Recommendation);
- European Union Electronic Communications Regulation System (directives);
- Law on Electronic Communications of the Republic of Georgia;
- Market analysis conducted by the GNCC;
- Executive orders and decisions of the Director of the GNCC.

The model will be built in order to comply with requirements set out in the Recommendation regarding price regulation of call termination prices on mobile and fixed networks, in particular the following:

- it must model the costs of an efficient service provider;
- it must be based on current costs;
- it must be a forward looking BU-LRIC model;
- It must comply with the requirements of "technological efficiency", hence the modeled network should be NGN based and take into account 2G and 3G technology mix;
- it may contain an amortization schedule. Recommended approach is economic depreciation; however other depreciation methods like straight-line depreciation, annuities and tiled annuities can be used.

- it must only take into account the incremental costs of call termination in determining the per item cost. The incremental costs of voice termination services should be calculated last in the order of services. Therefore in the first step the model should determine all the incurred costs related to all services expect voice termination and in the second step determine the costs related only to the voice termination services. The termination cost should include only traffic-related costs which are caused by the network capacity increase. Therefore only those costs, that would not arise if the service provider would cease to provide termination services to other service providers, can be allocated to termination services. Non-traffic related costs are irrelevant.

3. Main principles

Developing bottom-up LRIC model is a difficult process, requiring a multi-disciplinary approach across a number of diverse ranges of tasks and requires understanding of number of concepts. This section will outline the concepts behind the cost estimates used throughout the document.

Long run

Long run methodology assumes sufficiently long term of cost analysis, in which all costs may be variable in respect of volume changes of provided services – so the costs can be saved when the operator finishes providing the service.

Forward-looking

Forward looking methodology requires revaluation of costs based on historic values to future values as well as requires cost base adjustments in order to eliminate inefficient utilization of infrastructure. Further on the forward looking cost will be referred as current cost. Forward-looking costs are the costs incurred today building a network which has to face future demand for services and take into account the forecasted assets price change.

Depreciation method

According to the Recommendation there are four depreciation methods which can be implemented in the model:

- Straight-line depreciation
  The straight-line method allows calculating separately the cost of depreciation and cost of capital. The cost of depreciation is derived by dividing Gross Replacement Cost by its useful life.
- Annuities
  The annualized cost calculated with annuity method considers both: cost of depreciation and cost of capital related to fixed asset. The cost calculation is based on Gross Replacement Cost (GRC) of fixed asset.
- Tiled annuities
  The annualized cost calculated with tilted annuity method considers both: cost of depreciation and cost of capital related to fixed asset. The cost calculation is based on Gross Replacement Cost (GRC) of fixed asset. This method derives the cost that reflects the change in current price of fixed asset during financial year. Therefore, in conditions of rising/falling assets prices, capital maintenance cost is lower/higher than current depreciation.
- Economic depreciation

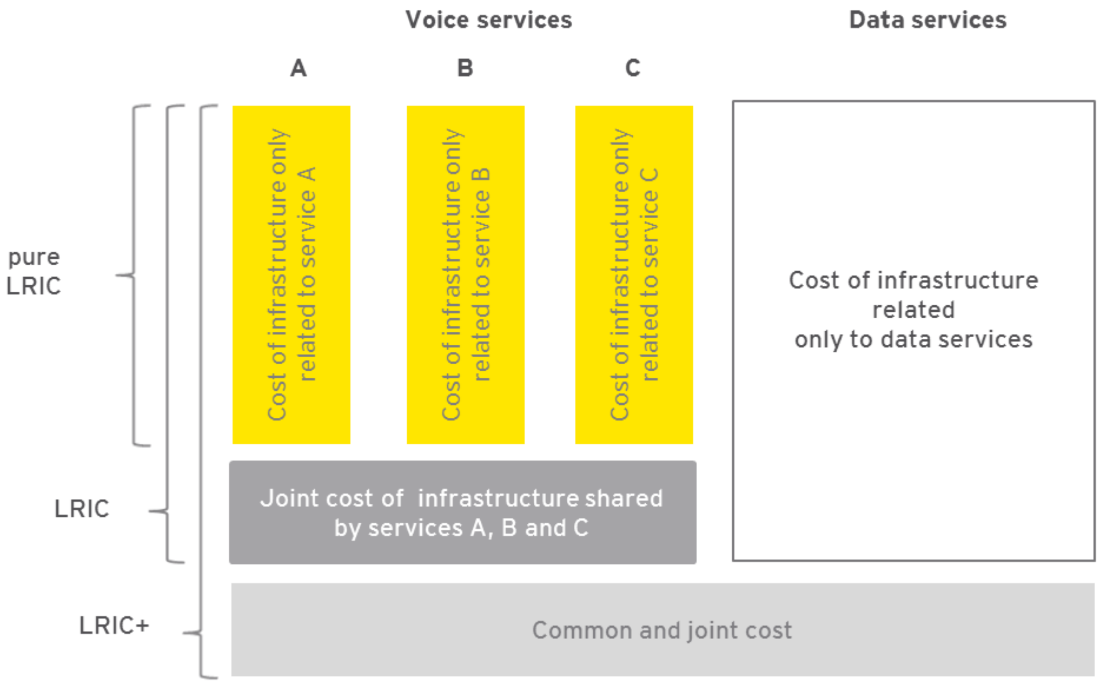
Economic depreciation method takes into account ongoing character of operator investments and change of prices of telecommunication assets. This method seeks to set the optimal profile of cost recovery over time and presents the change in economic assets value during year. Economic depreciation requires implementation of separate robust model which allow calculate network value for period of about 40 years.

Incremental costs of wholesale services

There are tree common approaches to calculate incremental cost of services:

- Pure LRIC method – includes only costs related to network components used in the provision of the particular service (e.g. call termination).
- LRIC method – includes only costs related to network components used in the provision of the particular group of services, which allows some shared cost of the group of services to become incremental as well. The group of service could be defined as voice services or data services.
- LRIC+ method – includes costs described in LRIC+ method description plus common and joint cost. The common and joint cost related to each group of service (total voice services and total data services) are calculated separately for each Network Component using an equally-proportional mark-up (EPMU) mechanism based on the level of incremental cost incurred by each group of service (total voice services and total data services).

Approaches in calculating using each method are illustrated in the picture below:



Calculating the incremental costs of wholesale services in telecommunication networks using pure LRIC method, it is necessary to identify only those fixed and variable costs that would not be incurred if the wholesale services were no longer provided to third-party operators (i.e. the avoidable costs only). The avoidable costs of the wholesale service increment may be calculated by identifying the total long-run cost of an operator providing its full range of services and then identifying the long-run costs of the same operator in the absence of the wholesale service being provided to third parties. This may then be subtracted from the total long-run costs of the business to derive the defined increment.

When calculating costs using LRIC method, it is necessary to identify only those fixed and variable costs that would not be incurred if the group of services were no longer provided to third-party operators and retail subscribers (i.e. the avoidable costs only). The avoidable costs of the group of services increment may be calculated by identifying the total long-run cost of an operator providing its full range of services and then identifying the long-run costs of the same operator in the absence of the group of services being provided to third parties retail subscribers. This may then be subtracted from the total long-run costs of the business to derive the defined increment.

When calculating costs using LRIC+ additional mark-ups are added on the primarily estimated increments to cover costs of all shared and common elements and activities which are necessary for the provision of all services.

Cost of capital

The required return on investment in the network and other related assets are defined as the cost of capital. The cost of capital should allow the investors to get a return on network assets and other related assets on a same level as from comparable alternative investments. The cost of capital will be calculated taking into account the weighted average cost of capital (WACC) set by GNCC.

Scorched earth versus scorched node

One of the key decisions to be made with bottom-up modeling is whether to adopt a "scorched earth" or a "scorched node" assumption. The scorched earth approach assumes that optimally-sized network devices would be placed at locations optimal to the overall network design. It assumes that the network is redesigned on a greenfield site. The scorched earth approach assumes that optimally-sized network devices would be placed at the locations of the current nodes of operators.

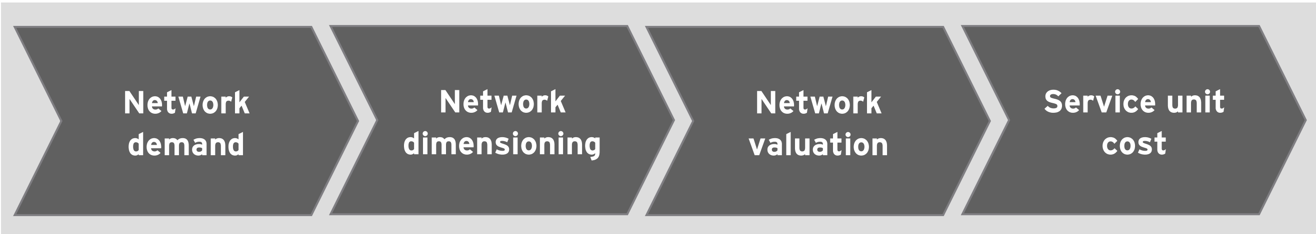
Bottom-up

A bottom-up approach involves the development of engineering-economic models which are used to calculate the costs of network elements which would be used by an efficient operator in providing telecommunication services. Bottom-up models perform the following tasks:

- Dimensioning and revaluation of the network.
- Estimate network costs.
- Estimate non-network costs.
- Estimate operating maintenance and supporting costs.
- Estimate services costs.

4. Flow of BU-LRIC model

Objective of BU-LRIC 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 built to meet current and forward looking demand. Figure below illustrates the overall flow of BU-LRIC methodology.



Step 1 - Network demand

Network demand section of the model is required to translate the relevant portfolio of service demand into required network capacity. As the dimensioned network should handle the traffic during the peak period, measured service volumes are translated into busy-hour demand on network elements. Networks are constructed to meet future demands, therefore In order to reflect this requirement the planning horizon for networks elements 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.

Step 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 allows variable cost structures to determine the costs on an element-by-element basis.

Step 3 - Network valuation

After all the necessary network equipment it valuated and its cost are attributed to Homogenous Cost Categories (HCC) are derived. 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. Network equipment identified during network dimensioning is revalued at Gross Replacement Cost (GRC). The revaluation is done by multiplying the number of network equipment physical units by current prices of the equipment.

GRC is the basis to calculate the annual cost for each HCC which includes both:

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

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

Step 4 - Service cost calculation

To calculate the unit cost of services costs grouped under HCC are allocated to network components, and then network components are allocated to services.

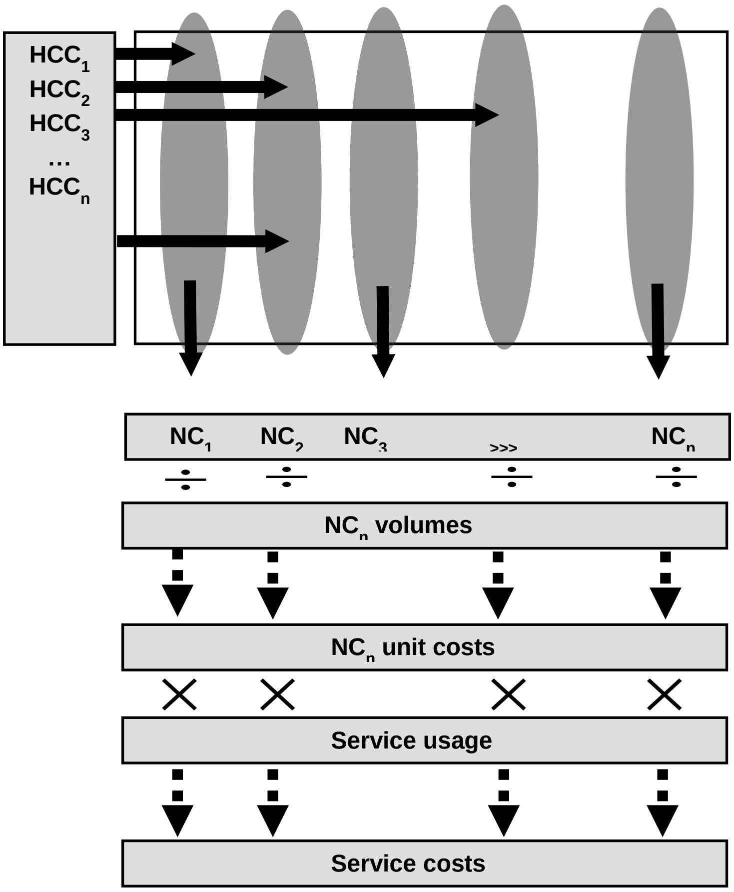
Homogeneous cost category → **Network components** → **Services**

Network Component is a synonym of the cost of a logical network hierarchy element. They are functionally consistent blocks, out of which telecom services are combined. In this regard every different telecommunication network should be represented by a different group of network elements. There are different network elements for fixed-telephony core network, for mobile-telephony core network, for data transmission core network, etc.

All telecommunication networks represent a kind of hierarchy. Such network hierarchy consists of nodes (i.e.: in fixed-telephony core network nodes are switches) and paths between them (i.e.: transmission links in fixed-telephony core network). Such hierarchical view enables analysis of traffic flows going through specific logical network elements. Besides nodes and transmission links there is a number of supplementary network elements that represent service centers or other specialized devices (e.g. number portability, pre-selection etc.).

Due to the hierarchical structure of nodes and transmission links, different network components are defined for different hierarchical levels – either nodes or transmission links.

From the perspective of cost calculation of interconnection services only network elements representing fixed-telephony core network and mobile network are of interest. It means that all network elements representing other networks can be grouped together into one.



The figure on the left presents the process of calculation of service unit costs. HCC costs are allocated to Network components (NC) directly or using allocation drivers. Further total NC costs are calculated by summing appropriate HCC. Total NC costs are divided by the NC volumes (service volume on particular Network Component) and Network Component unit costs are calculated. Finally Network Component unit costs are multiplied by routing factor to calculate the service unit costs.

5. Network technology and structure

5.1 Network technology and structure

According to the recommendation the BU-LRIC model for calculation of the mobile termination services should use:

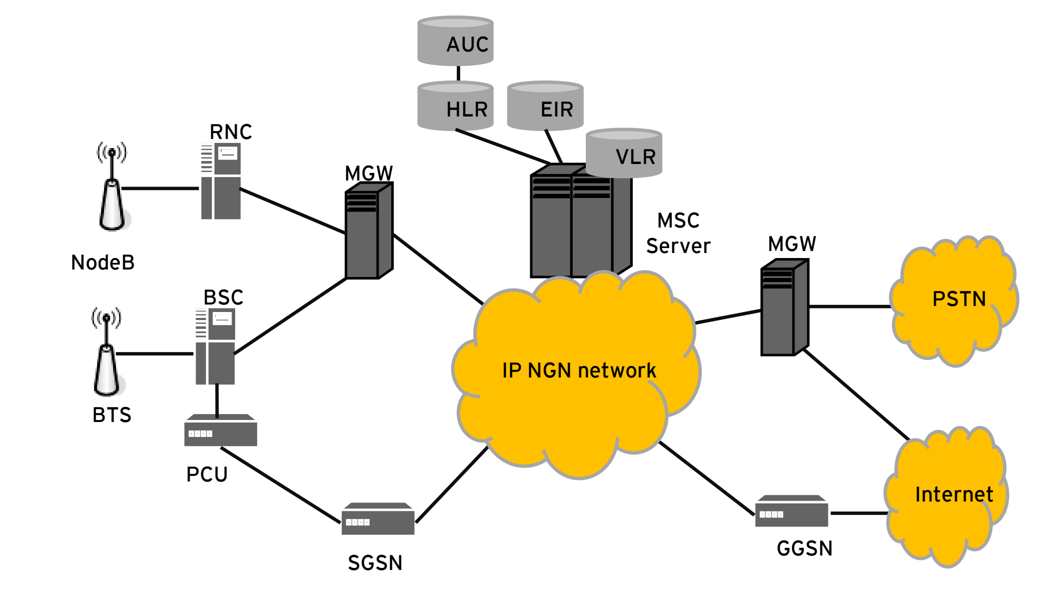
- Mix of the 2G and 3G technologies in the radio access network;
- NGN core network which is IP based.

Takin this into account the modelled network will utilize:

- Mobile Switching Server and Media Gateways instead of circuit switched Mobile Switching Centre;
- IP and Ethernet based core network instead of ATM and SDH core network.

The modelled network structure is presented on the scheme below.

Network architecture according to EU (2009/396/EC)



5.2 Mobile network elements

The table below presents the list of network elements and method of their revaluation. We assume three possible approaches of network elements cost calculation:

- Direct – capital cost of network elements will be calculated based on engineering models.
- Mark-up - capital cost of network elements will be calculated based on operators accounting data as a rate of CAPEX cost to network cost.
- Non calculated - elements do not participate in provision of wholesale termination traffic, therefore it cost do not have to be calculated.

Network element	Dimensioned elements	Description	Revaluation method
Network sites	Tower	Base station location including detached mast or tower (concrete or steel)	Direct
	Roof-top	Base station location including the infrastructure mounted on the roof or rented site (e.g. chimney)	Direct
	Micro-site	Base station location including the infrastructure required for installation of micro-cell	Direct
	Pico-site	Base station location including the infrastructure required for installation of pico-cell	Direct
Base station cabinet – macrocell	Small – up to 6 radio units	Single RAN (common for 2G, 3G, 4G) base station main unit including cabinet, management unit, interface units, power supply, batteries for site configuration up to 6 radio units.	Direct
	Large – up to 12 radio units	Single RAN (common for 2G, 3G, 4G) base station including cabinet, management unit, interface units, power supply, batteries for site configuration up to 12 radio units.	Direct
BTS macrocell	Main unit	Radio unit and antenna system per one carrier. All remaining elements, including software and licenses, not included in the base station cabinet and extension units.	Direct
	Extension unit: sector	Radio unit extension per one sector	Direct
	Extension unit: TRX	Radio unit extension per one TRX	Direct
BTS microcell	Main unit	Complete microcell equipment	Direct
	Extension unit: TRX	Radio unit extension per one TRX	Direct
BTS picocell	Main unit	Complete pikocell equipment	Direct
	Extension unit: TRX	Radio unit extension per one TRX	Direct
NodeB	Main unit	Radio unit base unit and antenna	Direct

macrocell		system per one carrier	
	Extension unit: sector	Radio unit extension per one sector	Direct
	Extension unit: CE	Radio unit extension per one CE	Direct
NodeB microcell	Main unit	Complete microcell equipment	Direct
	Extension unit: CE	Radio unit extension per one CE	Direct
NodeB picocell	Main unit	Complete pikocell equipment	Direct
	Extension unit: CE	Radio unit extension per one CE	Direct
BSC	Main unit	Main unit including cabinet, management unit, interface units, power supply	Direct
	Extension unit: TRX	Main unit capacity extension perTRX	Direct
TRC	Main unit	Main unit including cabinet, management unit, interface units, power supply	Direct
	Extension unit: E1	Main unit capacity extension perE1	Direct
RNC	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension units: Iub link	Main unit capacity extension per Iub link	Direct
	Extension units: sectors	Main unit capacity extension per sector	Direct
	Extension units: sites	Main unit capacity extension per site	Direct
MSS	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BHCA	Main unit capacity extension per BHCA	Direct
MGW	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BHCA	Main unit capacity extension per BHCA	Direct
	Extension unit: E1	Main unit capacity extension per E1	Direct
VMS	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: subscribers	Main unit capacity extension per subscriber	Direct
HLR	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: subscribers	Main unit capacity extension per subscriber	Direct
CUDA	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct

SMSC	Extension unit: subscribers	Main unit capacity extension per subscriber	Direct
	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BH SMS	Main unit capacity extension per BH SMS	Direct
SMSC	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BH MMS	Main unit capacity extension per BH MMS	Direct
IN	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: subscribers	Main unit capacity extension per subscriber	Direct
	Extension unit: BH transactions	Main unit capacity extension per BH transaction	Direct
PCU	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: Gb link throughput	Main unit capacity extension per subscriber	Direct
SGSN	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: Gb link throughput	Main unit capacity extension per subscriber	Direct
GGSN	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
IMS	Main unit	Main unit including frame, management unit, software, interface units, power supply	Direct
	Service card MRCF/CCTF	Shelf to include the service cards	Direct
	Service card - A-SBG	Service cards providing A-SBG functionality	Direct
	Service card - VoIP AS	Service cards providing VoIP Application Server	Direct
	Service card - BGCF	Service cards providing BGCF functionality	Direct
	Service card - DNS server	Service cards providing DNS functionality	Direct
	Service card - Service delivery AS	Service cards providing Service delivery application server	Direct

	Service card - HSS - Control card	Service cards providing HSS - Control card	Direct
	Service card - HSS – database	Service cards providing HSS - database	Direct
	IMS - Licenses - subscriber	IMS licences per subscriber	Direct
	IMS - Licenses - traffic	IMS licences per traffic (BHCA, BHE)	Direct
	HSS – Licenses	HSS licences per subscriber	Direct
Billing system	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BHCA	Main unit capacity extension per BHCA	Direct
Number portability	Main unit	Main unit including cabinet, management unit, software, interface units, power supply	Direct
	Extension unit: BHCA	Main unit capacity extension per BHCA	Direct
NMS	N/A	N/A	Mark-up
Transmission backhaul	Radioline 10 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
	Radioline 20 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
	Radioline 50 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
	Radioline 100 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
	Radioline 150 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
	Radioline 200 Mbit/s	The complete radioline including IDU, ODU, antenna system, software and licences, interface unit and power supply	Direct
Core transmission	Data transmission service 1Gbit/s	The rental fee of data transmission service	Direct
	Data transmission service 10Gbit/s	The rental fee of data transmission service	Direct

6. Scope of calculated services

The BU-LRIC model will calculate the unit cost of the following services:

- Call origination
- Call termination
- National roaming

The cost of services will be calculated using the following approaches:

Service	Calculation approach
Call termination	▶ Pure LRIC
Call origination	▶ Pure LRIC ▶ LRIC ▶ LRIC+
National roaming: ▶ On -net ▶ Call termination ▶ Call origination	▶ Pure LRIC ▶ LRIC ▶ LRIC+

7. Dimensioning of the network

The critical step in dimensioning the network is developing the engineering models for network active elements and passive infrastructure. In case of BU-LRIC model the engineering models cannot be filled with aggregate data transferred from inventory register of the operator. In order to overcome this problem the dimensioning of the network has to be applied based on easily accessible data like annual service and subscriber volumes.

Technological model will only model these infrastructure components that are required for the delivery of wholesale voice services. However the capacity of these components will be set according to all relevant services. Costs of other services, using same infrastructure, will not be calculated.

7.1 Calculation of network 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-LRIC model comprises the following type of information:

- Service demand in terms of voice call minutes, SMS and MMS quantities, data minutes and bytes;
- Number of subscribers;
- Traffic flows, network element usage factors;

Service profiles in terms of set-up time, rate of unsuccessful call attempts.

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

- LTE network;
- 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 provided by mobile network are presented further in this section.

Voice calls minutes are analyzed in seven groups:

- On-net minutes - call minutes originated by own subscriber on own mobile network and terminated in own subscriber on own mobile network including, calls to short telephone numbers;
- Off-net minutes - call minutes originated by own subscriber on own network and terminated on other networks (including international networks), including calls to short telephone numbers;

- Incoming minutes - call minutes originated on other networks (including international networks) and terminated on own subscriber on own mobile network, including calls to short telephone numbers;
- Transit minutes - traffic, which is neither originated nor terminated in the own network, bridge traffic between different operators;
- Inbound roaming services – on-net call - call minutes originated and terminated in own mobile network including calls to short telephone numbers, provided to roaming subscribers (national and international);
- Roaming services – off-net - call minutes originated on own network and terminated on other network (including international networks) including calls to short telephone numbers, provided to roaming subscribers (national and international);
- Roaming services – incoming - call minutes originated on other networks (including international networks) and terminated on own mobile network, including calls to short telephone numbers, provided to roaming subscribers (national and international);

SMS is split into three groups:

- On-net SMS - SMS sent from own mobile network to own mobile network;
- Outgoing SMS - SMS sent from own mobile network to international networks and to other mobile networks;
- Incoming SMS - SMS sent from international networks and from other mobile networks to own mobile network;

MMS is split into three groups:

- On-net MMS - MMS sent from own mobile network to own mobile network;
- Outgoing MMS - MMS sent from own mobile network to international networks and to other mobile networks;
- Incoming MMS - MMS sent from international networks and from other mobile networks to own mobile network;

Packet data traffic volumes comprise yearly total up-link and yearly total down-link traffic loads in MB.

7.2 Service demand conversion

7.2.1 Conversion of annual volumes to Busy Hour traffic

The average traffic load conversion to peak loads is needed for the 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. The amount of network elements is calculated according to the estimated BHE. 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.

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

1. Calculating the number of call attempts;
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.

The annual volume of successful call-attempt is calculated according to the following formula:

$$N_{CA} = \frac{T_{call}}{\alpha_{CD}}$$

Where:

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

α_{CD} – Average call duration, minutes.

Successful call-attempts in are converted to busy hour call-attempts. Busy hour call-attempts present the total volume of call attempts (successful and unsuccessful) in busy-hour and it is calculated according to the following formula:

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

Where:

N_{CA} – Annual volume of successful call-attempts, units.

f_R – Routing factor for particular service traffic in a particular network element.

f_{DA} – De-averaging factor,%;

r_u – Ratio of unsuccessful calls compared to successful calls, %

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.

The da-averaging factor is calculated according to the following formula:

$$f_{DA} = r_{BA} \times f_H$$

Where:

r_{BA} – Busy hour traffic to average hourly traffic ratio. This factor shows proportion of busy and average traffic.

f_H – Inhomogeneity factor for peak load distribution. This factor shows traffic aggregation level in the network element.

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:

$$T_W = T \times f_R$$

Where:

T – Traffic volume, minutes, messages or MB;

f_R – Routing factor.

Routing factors show how intensively each network element is used for each type of service. For example, an on-net call may on average use two BTS, two BSC and one MSC, which means on-net call in its path from user device to user device flows through BTS element two times on average, through BSC two times on average, and through MSC one times on average.

The adjustment for unbilled traffic in the network is calculated for voice calls. Billed minutes traffic or just billed minutes are defined as call duration from a connection start, when a phone is picked up to a connection end, when a phone is hung up. Performing calculations of 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 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:

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

$$f_A = \frac{S_s}{\alpha_{CD} \times 60} + \frac{S_u \times r_u}{\alpha_{CD} \times 60}$$

Where:

f_A – Adjusting factor;

T_W – Weighted calls traffic for particular network element, minutes.

S_s – Call set-up duration for successful calls, seconds.

S_u – Call set-up duration for unsuccessful calls, seconds.

r_u – Ratio of unsuccessful calls compared to successful calls, %.

α_{CD} – Average call duration, seconds.

Division by 60 is second conversion to minute volume.

7.2.2 Conversion of traffic to homogenous service volume

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. SMS (SMS);
2. MMS (MMS);
3. Packet data traffic for GSM network:
   - GPRS transmission technology;
   - EDGE transmission technology.

4. Packet data traffic for UMTS network:
   - UMTS R99 transmission technology;
   - HSDPA transmission technology.
5. Packet data traffic and VoIP calls for LTE network:
   - LTE transmission technology;

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

$$T_C = T_W \times f_C$$

Where:

T_C – Converted particular service traffic, minutes;

T_W – Weighted particular service traffic - messages or MB.

f_C – Conversion factor for a particular service SMS, MMS, packet data services.

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

7.2.2.1 Conversion of SMS and MMS

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

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

Where:

L_{SMS} – Average length of SMS message, Bytes.

ρ_{ch} – SDCCH channel bit rate, kbit/s.

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:

$$f_{MMS} = \frac{f_G \times L_{MMS}}{10^6}$$

Where:

f_G – GPRS MB to minute conversion factor.

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

Division by 10^6 is bytes conversion to megabytes.

7.2.2.2 Conversion of GSM packet data

The 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 the 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:

$$f_{G\,or\,E} = 1024 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{G\,or\,E}}$$

Where:

ρ_G – GPRS bit rate, kbit/s;

ρ_E – EDGE bit rate, kbit/s;

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1024 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:

$$f_{GSM} = 1024 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_G \times (P_G + P_{GW}) + \rho_E \times (P_E + P_{EW})}$$

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;

ρ_E – EDGE bit rate, kbit/.

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1024 is megabyte conversion to kilobytes.

7.2.2.3 Conversion of UMTS data

The 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 the 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:

$$f_{umts} = 1024 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{umts}}$$

$$f_{HSDPA} = 8 \times \frac{1}{60} \times \frac{1}{\rho_{HSDPA}}$$

Where:

ρ_{umts} - UMTS bit rate, kbit/s;

ρ_{HSDPA} - HSDPA bit rate, Mbit/s.

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1024 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:

$$f_{UMTS} = 1024 \times 8 \times \frac{1}{60} \times \frac{1}{\rho_{umts} \times P_{umts} + 1024 \times \rho_{HSDPA} \times P_{HSDPA}}$$

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;

ρ_{HSDPA} - HSDPA bit rate, Mbit/s.

Division by 60 is second conversion to minute, multiplication by 8 is bytes conversion to bits and multiplication by 1024 is megabyte conversion to kilobytes.

7.2.2.4 Conversion of LTE packet data

LTE data traffic conversion factor (f_{LTE}) in megabytes to minute equivalent takes into account the amount of the data (Mbytes) required to send one minute of call using VoLTE (Voice over LTE services) technology. The amount of the data required for a minute of call for VoLTE is calculated based on the VoIP channel bandwidth. Calculation of VoIP channel bandwidth requires determining some assumptions regarding VoIP (Voice over IP) technology:

- Voice codec used;
- Payload of each network layer protocols: RTP / UDP / IP / Ethernet.

The VoIP channel bandwidth is calculated according to the following formula:

$$VoIP_{bit-rate} = (IP + UDP + RTP + ETH + PLS) \times PPS \times PF \times \frac{8}{1024}$$

Where,

IP - IP header (bytes);

UDP - UDP header (bytes);

RTP - RTP header (bytes);

ETH - Ethernet header (bytes);

PLS - Voice payload size (bytes) – VoIP codec related value;

PPS - Packets per second (packets) – codec bit rate related value;

PF - Priority factor.

The results of the calculation are presented in the table below.

Codec & Bit Rate (Kbps)	Bandwidth in Ethernet layer (Kbps)	Voice Payload Size (bytes)
G.711 (64 Kbps)	87.2 Kbps	160,00
G.729 (8 Kbps)	31.2 Kbps	20,00
G.723.1 (6.3 Kbps)	21.9 Kbps	24,00
G.723.1 (5.3 Kbps)	20.8 Kbps	20,00
G.726 (32 Kbps)	55.2 Kbps	80,00
G.726 (24 Kbps)	47.2 Kbps	60,00
G.728 (16 Kbps)	31.5 Kbps	60,00
G722_64k(64 Kbps)	87.2 Kbps	160,00
ilbc_mode_20 (15.2Kbps)	38.4Kbps	38,00
ilbc_mode_30 (13.33Kbps)	28.8 Kbps	50,00

Source: *"Voice Over IP - Per Call Bandwidth Consumption", Cisco*

7.3 Network dimensioning

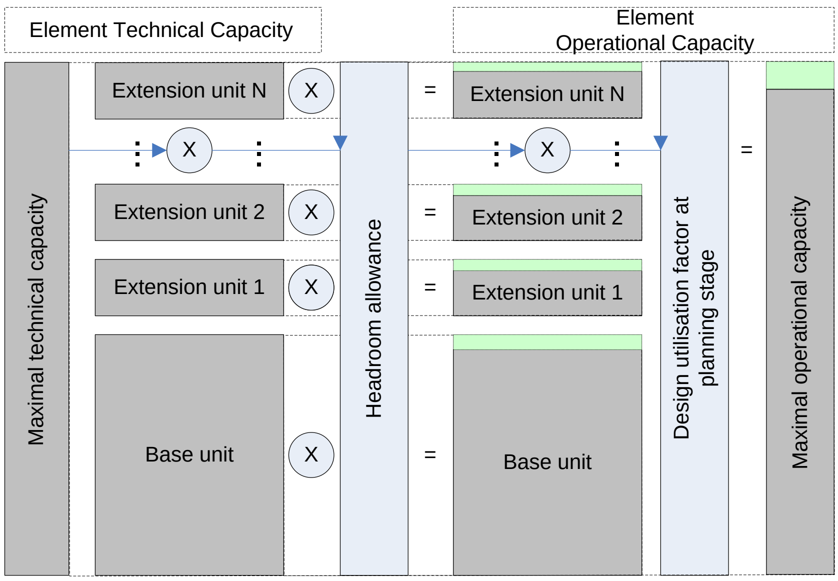
Having in mind the complexity of network dimensioning, the algorithms are further divided into separate phases according to GSM, UMTS and LTE network architectures, respectively:

1. Base Station System (BSS) for GSM, Radio Network System (RNS) for UMTS and Packet Switching System (PSS) for LTE;
2. Core network;

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

7.3.1 Base and extension units concept

Having in mind the modular nature of telecommunication 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 a 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 the resources needed. It is cost effective to install an extension unit in a base unit, then to install an additional base unit as long as the required traffic is served. Algorithms for the calculation of the amounts of BU and EU are general for all network elements analyzed in the scope of BU-LRIC model. Figure below represents BU and EU calculation algorithm.



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

$$BU = \left\lceil \frac{DV}{C^{\psi}} \right\rceil$$

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.

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

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

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

Where:

C^{ψ} – Maximal operational capacity of a network element, measurement unit is the same as for *DV*.

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:

$$C^{\psi} = C^{\tau} \times OA$$

BU and EU operational capacity (C^{o}_{i}, BHCA, subscribers, etc.) are calculated according to the principle given in the following formula by applying capacity values respectively.

$$C^{o}_{i} = C_{i} \times OA_{i}$$

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*.

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

i – Specifies BU or EU.

OA – Operational allowance, %.

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:

$$OA = HA \times f_U$$

Where:

HA – Headroom allowance, %. HA shows what part of BU or EU capacity is reserved for future traffic growth.

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

$$HA = \frac{1}{r_{SDG}}$$

Where:

r_{SDG} – Service demand growth ratio.

r_{SDG} determines the level of under-utilization 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.

The service demand growth ratio is calculated for each one of the 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, UMTS and LTE traffic sum of up-link or down-link traffic subject to greater value.

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

7.3.2 Vocabulary of formulas

In the table below a vocabulary of formulas used to dimension network elements and calculate the demand is described:

Abbreviation	Explanation
N	Number of x elements
V	Volume of x traffic
S	Number of subscribers/services
T	Throughput x element
HA	Headroom allowance
ρ	Proportion expressed in percentage
C	Capacity of x element

7.3.3 Dimensioning of GSM network

7.3.3.1 Base Transceiver Station

The first step in dimensioning the Base Station Subsystem (BSS) layer is modeling 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 the territory of the Republic of Georgia (for coverage) and traffic (for capacity) into the following geographical areas:

1. Urban – Built up city or large town with large buildings and houses. Building heights above 4 stores (about 10m).
2. Suburban – Village, highway scattered with trees and houses. Some obstacles near the mobile, but not very congested.
3. Rural – Open space, forests, no tall trees or building in path.

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

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

Coverage requirements

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

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

$$A_C^c = 1.5 \times \sqrt{3} \times R^2 = 2.6 \times R^2$$

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.

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 area types. The traffic is also split by geographical area type .

Consequently, the 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:

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

Where:

N_{900} – Amount of 900 MHz spectrum, 2 x MHz.

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

λ_{TRX} – Bandwidth of a transceiver, MHz.

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

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

Where:

C_{Ss} – Spectrum capacity for single band cell, TRXs.

N_{1800} – Amount of 1800 MHz spectrum, 2 x MHz.

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

λ_{TRX} – Bandwidth of a transceiver, MHz.

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:

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

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), TRX. This value describes maximal TRX amount, which can be physically installed in mikro, pico or makro cells.

It is assumed, 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:

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

Where:

N_{TRX} – Number of TRXs, TRX.

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%.

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

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

Where:

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

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

$$N_{CAP}^{Si} = \frac{N_{CAP}^{Se}}{N_{Se/Si}}$$

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

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 by multiplying total number of sites 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

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

$$N^{Si}_{Total} = Max(N^{Si}_{COV}; N^{Si}_{CAP})$$

Where:

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

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

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

7.3.3.2 Transceiver

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

Similarly to BTS modeling case, all of the TRX calculations are executed by subdividing the territory of the Republic of Georgia into geographical areas.

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

$$BHE^{Se}_{GSM} = \frac{BHE^{A}_{GSM}}{N^{Si}_{Total} \times N_{\mathrm{Se/Si}}}$$

Where:

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

N^{Si}_{Total} – Total BTS sites in a mobile network, units.

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

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

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

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

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

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

Where:

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

N_{TRX} - TRX number, TRX.

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.

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

$$N_{TRX} = \left\lceil N_{TRX/Se} \times N_{Total}^{Se} \right\rceil$$

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

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

Where:

$N_{TRX/Se}$ - Average number of TRXs per sector, units.

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 by multiplying total number of sites with proportions (%) of i sectored sites in the network.

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

7.3.3.3 Base Station Controller

Base station controller comprises 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 the number of TRXs.

The total amount of BSC base units and extension units is calculated according to the algorithm provided in section 7.3.1 presenting Base and extension units concept.

7.3.3.4 Transcoder Controller

Transcoder controller (TRC) comprises 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 with respect to these parts. The dividend variable for both parts is total 2 Mbit/s link capacity (C_L, E1 A interface). The total 2 Mbit/s link capacity is calculated according to the following formula:

$$C_L = \rho_C \times \frac{TH_{GSM}}{C_b} \times \frac{BHE_{GSM} - BHE_{PD}}{BHE_{GSM}}$$

Where:

TH_{GSM} – Throughput in TRC, kbit/s;

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_{PD} – Packet data demand for GSM network, BHE.

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

Next, as in BSC calculations, TRC base units and extension units are calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with E1 number (A interface) as dividend variable for both parts.

7.3.4 Dimensioning of UMTS network

7.3.4.1 Node B

In UMTS network, the first step in dimensioning RNS layer is modeling 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.

UMTS macrocell range and sector capacity are calculated separately for different area types. In UMTS system the cell range is dependent on current traffic, the footprint of CDMA cell is dynamically expanding and contradicts according to the number of users. This feature of UMTS is called "cell breathing". Implemented algorithm calculates optimal UMTS cell range with regard to the cell required capacity (demand). This calculation is performed in four steps:

1) Required UMTS network capacity by cell types

In this step the required UMTS network capacity for uplink and downlink channel is calculated based on voice and data traffic demand. The UMTS network capacity is calculated separately for different area type.

2) Traffic BH density per $1km^2$

In this step traffic BH density per $1km^2$ is calculated based on the required UMTS network capacity and required coverage of UMTS network. The UMTS traffic BH density per 1 km^2 is calculated separately for uplink and downlink channel for each area type.

3) Downlink and uplink calculation

In this section implemented algorithm finds the relationship (function) between cell area and cell capacity, separately for uplink and downlink channel and different area type. To find relationship (function) formula algorithm uses two function extremes:

1. x: Maximal UMTS cell range assuming minimal capacity consumption
   y: Minimal site capacity volume (single data channel)
2. x: Maximal UMTS cell range assuming full capacity consumption
   y: Maximal site capacity volume

Then according to traffic BH density per 1 km^2 and found relationship (function) formula, the optimal cell area and sector capacity is calculated separately for different area type.

4) Total

In this last step the optimal UMTS macrocell range and sector capacity is calculated separately for uplink and downlink channel and different area type.

The values presenting:

1. x: Maximal UMTS cell range assuming minimal capacity consumption
   y: Minimal site capacity volume (single data channel)
2. x: Maximal UMTS cell range assuming full capacity consumption
   y: Maximal site capacity volume

will be gathered from operators and verified based on link budget calculation.

Coverage

UMTS network area coverage is split by geographical areas urban, suburban and rural.

The minimal number of Node B sites required to satisfy coverage requirements (N_{COV}^{SiB} , units) are determined separately for uplink and downlink, by the following formulas:

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

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

Where:

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

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

R_{UMTS} – Optimal cell range for uplink/downlink, km.

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

Traffic demand

The required capacity of UMTS network is calculated separately for uplink and downlink channel as well as voice traffic and packet data traffic.

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

$$C_{UMTS} = \frac{BHMB_{UMTS}}{60 \times 60} \times 8 \times 1024$$

Where:

$BHMB_{UMTS}$ – Capacity to be handled by UMTS network, MB. It is a busy hour traffic part In a particular geographical area and cell type (macro, micro and pico) in UMTS network.

Division by 60 and 60 is hour conversion to seconds, multiplication by 8 is a bytes conversion to bits and multiplication by 1024 is megabyte conversion to kilobytes.

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

$$N_{CAP}^{SeB} = \frac{C_{UMTS}}{C_{\min}^{Se}} + \frac{BHE_V}{C_V^{Erl}}$$

Where:

C_{UMTS} – Capacity required to handle the packet data traffic in UMTS network, kbit/s.

$C_{\min}^{Se}$ – Sector capacity in BHT, kbit/s.

BHE_V – Capacity required to handle the voice, video, SMS, MMS traffic in UMTS network

C_V^{Erl} - Sector capacity in BHT, ERL.

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

$$N_{CAP}^{SiB} = \sum_{i=1}^{3} N_{iSeB}^{SiB}$$

$$N_{iSeB}^{SiB} = \frac{N_{iCAP}^{SeB}}{i}$$

Where:

N_{iCAP}^{SeB} – Sectors number to meet capacity requirements in UMTS network, distinguished by particular sectorization, units. This size is calculated by multiplying the total number of sectors (N_{CAP}^{SeB} , 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 number of Node B sites (N_{Total}^{SiB}, units) is calculated according to the following formulas:

$$N_{Total}^{SiB} = N_{CAP}^{SiB} + Adj$$

$$Adj = \frac{N_{COV}^{SiB} - N_{CAP}^{SiB}}{2}$$

Where:

N_{CAP}^{SiB} – Sectors to meet capacity requirements, units;

N_{COV}^{SiB} – Sectors to meet coverage requirements, units;

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

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

It is assumed that each UMTS site handles HSDPA/HSUPA.

7.3.4.2 Radio Network Controller

In UMTS network, the next step in dimensioning BSS layer is modeling 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 the minimum number of RNC base units required is a function of requirements to meet particular number of Iub links, particular number of sectors and sites.

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

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

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

Where:

TH_{Iub} – Iub link throughput, Mbit/s. The same as UMTS throughput.

C_{Iub} – RNC maximal operational capacity to satisfy Iub interface throughput, Mbit/s;

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

C_{RNC}^{Se} – RNC maximal operational capacity to satisfy number of sectors, units

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;

N_{iSe}^{SiB} – i sectored sites in UMTS network, units. This parameter is calculated multiplying the 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 7.3.1 presenting Base and extension units concept. RNC Iub link throughput, sectors number and Node B sites number are the respective dividend variables.

7.3.5 Dimensioning of LTE network

7.3.5.1 eNodeB

In LTE network, the first step in dimensioning PSS layer is modeling the eNode B element. The outcome of the algorithms presented in this section is the number of eNode B sites. All eNode B calculations are divided by geographical area proportions.

The optimal LTE cell range regarding to the cell required capacity (demand) will be performed in the same way as for NodeBs, taking into account the technical parameters specific for LTE technology.

In the model eNode B is dimensioned for handling both data and voice traffic. Since LTE network is a packet based network, all the volume of voice traffic in billed minutes must be converted into packet data traffic (volume of kbps). This calculation consists of the following steps:

1. Calculate the average volume of BHE (Busy Hour Erlangs) for each eNodeB.

   The volume of BHE determines how many VoIP channels are required to handle the voice traffic in the busy hour.

2. Calculate VoIP cannel bandwidth.

   This calculation requires to determine some assumptions regarding VoIP (Voice over IP) technology:

   - Voice codec used;
   - Payload of each network layer protocols: RTP / UDP / IP / Ethernet.

   The VoIP channel bandwidth is calculated according to the following formula:

$$VoIP_{bit-rate} = (IP + UDP + RTP + ETH + PLS) \times PPS \times PF \times \frac{8}{1000}$$

   Where,

   IP - IP header (bytes);

   UDP - UDP header (bytes);

   RTP - RTP header (bytes);

   ETH - Ethernet header (bytes);

   PLS - Voice payload size (bytes) – VoIP codec related value;

   PPS - Packets per second (packets) – codec bit rate related value;

   PF - Priority factor.

The results of calculation are presented in the table below.

Codec & Bit Rate (Kbps)	Bandwidth in Ethernet layer (Kbps)
G.711 (64 Kbps)	87.2 Kbps
G.729 (8 Kbps)	31.2 Kbps

G.723.1 (6.3 Kbps)	21.9 Kbps
G.723.1 (5.3 Kbps)	20.8 Kbps
G.726 (32 Kbps)	55.2 Kbps
G.726 (24 Kbps)	47.2 Kbps
G.728 (16 Kbps)	31.5 Kbps
G722_64k(64 Kbps)	87.2 Kbps
ilbc_mode_20 (15.2Kbps)	38.4Kbps
ilbc_mode_30 (13.33Kbps)	28.8 Kbps

Source: *"Voice Over IP - Per Call Bandwidth Consumption", Cisco*

3. Calculate busy hour voice bandwidth for eNodeB.

For eNodeB modeling the busy hour bandwidth will calculated by multiplying volume of BHE by bandwidth of voice channel.

Coverage

LTE network area coverage is split by geographical areas urban, suburban and rural.

The minimal number of eNode B sites required to satisfy coverage requirements (N_{COV}^{SiE} , units) is determined by the following formulas:

$$N_{COV}^{SiE} = \left\lceil \frac{eA_C}{eA_C^c} \right\rceil$$

$$eA_C^c = 1.5 \times \sqrt{3} \times R_{LTE}^2 = 2.6 \times R_{LTE}^2$$

Where:

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

eA_C^c – Coverage area of one eNode B cell, km^2;

R_{LTE} – Maximal cell range, km. (will be gathered from the operators).

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

Traffic demand

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

$$C_{LTE} = \frac{BHMB_{LTE}}{60 \times 60} \times 8 \times 1024$$

Where:

$BHMB_{LTE}$ – Capacity to be handled by LTE network, MB. It is a busy hour traffic part in a particular geographical area and cell type (macro, micro and pico) in LTE network;

Division by 60 and 60 is hour conversion to seconds, multiplication by 8 is a bytes conversion to bits and multiplication by 1024 is megabyte conversion to kilobytes.

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

$$N_{CAP}^{SeE} = \left(\frac{C_{LTE}}{C_{\min}^{Se}} \right) \times LU$$

Where:

C_{LTE} – Capacity required to handle the traffic in LTE network, kbit/s.

$C_{\min}^{Se}$ – Sector capacity in BHT, kbit/s.

LU – Cell capacity utilization in BHT, %.

The number of LTE sites (N_{CAP}^{SiE} , units) to meet capacity requirements is calculated according to the following formulas:

$$N_{CAP}^{SiE} = \sum_{i=1}^{3} N_{iSeB}^{SiE}$$

$$N_{iSeE}^{SiE} = \frac{N_{iCAP}^{SeE}}{i}$$

Where:

N_{iCAP}^{SiE} – the number of sectors to meet capacity requirements in LTE network, distinguished by particular sectorization, units. This size is calculated total sectors number (N_{CAP}^{SiE}) multiplying by respective sectorization proportions (%).

N_{CAP}^{SiE} – the number of LTE sites to meet capacity requirements, units;

N_{iSeB}^{Si} – *i* sectored sites in LTE network, units;

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

Total amount of eNode B sites

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

$$N_{Total}^{SiE} = N_{CAP}^{SiE} + Adj$$

$$Adj = \frac{N_{COV}^{SiE} - N_{CAP}^{SiE}}{2}$$

Where:

N_{CAP}^{SiE} – Sectors to meet capacity requirements, units;

N_{COV}^{SiE} – Sectors to meet coverage requirements, units.

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

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

7.3.5.2 Evolved Packet Core

Evolved packet core (EPC) handles all traffic in LTE network. EPC consists of two main groups of components: Mobility management entity (MME), which handles control functions, and Packet gateway (PGW) which is responsible for the actual transmission of data.

The number of MME basic units is calculated as S1-U link number of sessions [BH sessions / sec] divided by maximal capacity of MME physical location. The MME extension unit is calculated according to the formula:

$$EU(\mathrm{MME}) = \left\lceil BU(\mathrm{MME}) \times \frac{\frac{CAP(A)}{BU(\mathrm{MME})} - OC(base)}{OC(ext)} \right\rceil$$

Where:

EU(MME) – number of MME extension units

BU(MME) – number of MME basic units

CAP(A) – S1-MME link number of sessions [BH sessions / sec]

OC(base) – base unit operational capacity of MME

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

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

The number of PGW base units (BU_{PGW}^{C} , units) to meet network requirements is calculated as S1-U link throughput [BH packets / sec] divided by maximal capacity of PGW physical location. The PGW extension unit is calculated according to formula:

$$EU(\mathrm{PGW}) = \left\lceil BU(\mathrm{PGW}) \times \frac{\frac{CAP(A)}{BU(\mathrm{PGW})} - OC(base)}{OC(ext)} \right\rceil$$

Where:

EU(PGW) – number of PGW extension units

BU(PGW) – number of PGW basic units

CAP(A) – S1-U link throughput [BH packets / sec]

OC(base) – base unit operational capacity of PGW

7.3.6 Dimensioning of sites

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

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

Where:

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

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

N_i^{Sic} – Particular i type sites in LTE network, units.

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

7.3.7 Dimensioning of core network

7.3.7.1 Mobile Switching Centre Server

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

The outcome of the algorithms presented in this section is the amount of MSS base and extension units. Estimation of the minimum number of MSS base units required is a function of requirements to meet minimal network configurations and switching capacity. For the requirements to meet the minimal network configuration demand there is an assumption adopted in model that the minimal number of MSS in a mobile network is two (1+1 redundancy).

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

$$BU_{MSS}^{C} = \frac{N_{BHCA}}{C_{CPU}}$$

$$C_{CPU} = C_{MSS,s}^{\psi} \times N_{CPU/MSS}$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA.

$C_{MSS,s}^{\psi}$ – Maximal MSS operational capacity to satisfy call attempts in BHT, BHCA.

C_{CPU} - MSS extension unit - switching capacity, BHCA;

$N_{CPU/MSS}$ – extension units per MSS, units.

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

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

Where:

$BU_{MSS}^{\min}$ – 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 and equals to 2 units.

BU_{MSS}^{C} – Number of MSS base units to meet switching capacity requirements;

The amount of MSS extension units is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept.

7.3.7.2 Media Gateway

MGW comprises of the following parts:

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

Estimation of the 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 the minimal network configuration demand there is an assumption adopted in BU-LRIC model that the minimal number of MGWs in a mobile network is two.

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

$$BU^{C}_{MGW} = \frac{N_{BHCA}}{C_{CPU}}$$

$$C_{CPU} = C^{\psi}_{MGW,s} \times N_{CPU/MGW}$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA;

$C^{\psi}_{MGW,s}$ – Maximal MGW operational capacity to satisfy call attempts in BHT, BHCA;

C_{CPU} – CPU capacity of MGW, BHCA;

$N_{CPU/MGW}$ – CPUs per MGW, units.

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

$$BU^{p}_{MGW} = \frac{N^{p}_{MGW}}{C^{\psi}_{MGW,p}}$$

Where:

N^{p}_{MGW} – Total ports required in MGW, units;

$C^{\psi}_{MGW,p}$ – Maximal MGW operational capacity to satisfy number ports, ports.

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

$$N^{p}_{MGW} = p_{RNC} + p^{mgw}_{ic} + p^{mgw}_{is}$$

Where:

p_{RNC} – RNC-facing ports in MGW, units;

p^{mgw}_{ic} – Interconnect-facing ports in MGW, units;

p^{mgw}_{is} – Inter-switch 2 Mbit/s ports in MGW, units;

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

$$p_{RNC} = T_{RNC} \times \frac{1}{0.7} \times \frac{1}{31}$$

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:

$$T_{RNC} = M_{Total} + VM_{Total} + SMS_{Total} + MMS_{Total}$$

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.

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

$$p_{ic}^{mgw} = T_{ic}^{mgw} \times \frac{1}{0.7} \times \frac{1}{31}$$

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:

$$T_{ic} = M_{Total} + MV_{Total} + SMS_{Total} + MMS_{Total}$$

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 MMS 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:

$$p_{is}^{mgw} = T_{is}^{mgw} \times \frac{1}{0.7} \times \frac{1}{31}$$

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:

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

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 MMS messages traffic in MGW, BHE;

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

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

Where:

$BU_{MGW}^{\min}$ – Number of MGW base units to meet minimal network requirements, units.

BU_{MGW}^{C} – Number of MGW base units to meet switching capacity requirements;

BU_{MGW}^{p} – Number of MGW base units to meet port number requirements, units.

The amount of MGW extension units for both processor and ports part is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with the number of BHCA and the total number of ports required in MGW as dividend variables respectively.

7.3.7.3 Voice Mail Service and Home Location Register

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

- Base unit;
- Extension units.

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

The amount of VMS and HLR base units and extension units is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with mailboxes and the number of subscribers as dividend variables.

7.3.7.4 Service Control Point (Intelligent Network)

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

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

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

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

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

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

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;

$C^{\psi}_{SCP,Tr}$ – Maximal operational capacity to satisfy number of transactions, BH transactions/s;

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

N_{BHCA} – Call attempts in BHT, BHCA;

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

The amount of SCP extension units for subscribers and transactions part is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with the number of subscribers and BH transactions per second dividend variables.

7.3.7.5 Packet control unit (PCU) / Serving GPRS support node (SGSN)

In this section the PCU basic and extension units is calculated. The number of PCU basic units (BU_{PCU}) is calculated as follows:

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

Where:

TH_{Gb} – Gb link throughput [Mbps]

C_{PCU}^{ψ} – Maximal operational capacity of PCU [Mbps]

BU_{RNC} – number of RNC base units

BU_{BSC} – number of BSC base units

Gb link throughput [Mbps] is calculated as follows:

$$TH_{Gb} = \frac{1}{60} \times \left(\frac{\max(T_{GSMu}; T_{GSMd})}{f_{GSM}}\right)$$

Where:

T_{GSMu} – Total minute equivalent for up-link packet data megabytes in the GSM network element per minute in busy hour

T_{GSMd} – Total minute equivalent for down-link packet data megabytes in the GSM network element per minute in busy hours

f_{GSM} – GSM data traffic to minute equivalent conversion factor

The PCU extension unit is calculated according to formula:

$$EU(\mathrm{PCU}) = \left\lceil BU(\mathrm{PCU}) \times \frac{\frac{CAP(A)}{BU(\mathrm{PCU})} - OC(base)}{OC(ext)} \right\rceil$$

Where:

EU(PCU) – number of PCU extension units

BU(PCU) – number of PCU basic units

CAP(A) – Gb link throughput [BH packets / sec]

OC(base) – base unit operational capacity of PCU

OC(ext) – extension step operational capacity of PCU

Later in this section the SGSN basic and extension units is calculated. The number SGSN basic units is calculated as Gb link throughput [BH packets / sec] divided by maximal capacity of SGSN physical location. The SGSN extension unit is calculated according to the formula:

$$EU(\mathrm{SGSN}) = \left\lceil BU(\mathrm{SGSN}) \times \frac{\frac{CAP(A)}{BU(\mathrm{SGSN})} - OC(base)}{OC(ext)} \right\rceil$$

Where:

EU(SGSN) – number of SGSN extension units

BU(SGSN) – number of SGSN basic units

CAP(A) – Gb link throughput [BH packets / sec]

OC(base) – base unit operational capacity of SGSN

7.3.7.6 Short messages service center (SSMC)

SMSC comprises two parts:

- Base unit;
- Extension units.

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

SMSC is 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 messages) per second ($M_{MS/s}$, messages/s) and is calculated according to the following formula:

$$N_{MS/s} = \frac{1}{60} \times \frac{T_{MS}}{f_{MS}}$$

Where:

f_{MS} – Message to minute equivalent conversion factor.

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

Amount of SMSC base units and extension units is calculated according to algorithm provided in section 7.3.1 Base and extension units with busy hour SMS messages as dividend variable.

7.3.7.7 Multimedia messaging service center (MMSC)

The number MMSC basic units is calculated as the number of BH MMS per second divided by maximal capacity of MMSC physical location. The MMSC extension unit is calculated according to the formula:

$$EU(\mathrm{MMSC}) = \left\lceil BU(\mathrm{MMSC}) \times \frac{\frac{CAP(A)}{BU(\mathrm{MMSC})} - OC(base)}{OC(ext)} \right\rceil$$

Where:

EU(MMSC) – number of MMSC extension units

BU(MMSC) – number of MMSC basic units

CAP(A) – number of BH MMS per second

OC(base) – base unit operational capacity of MMSC

OC(ext) – extension step operational capacity of MMSC

Amount of MMSC base units and extension units is calculated according to algorithm provided in section 7.3.1 Base and extension units with busy hour MMS messages as dividend variable.

7.3.7.8 IP multimedia Sub-System

The IP multimedia Sub-System is required to provide VoLTE services.

The volume of IMS extension cards (TDM processing, VoIP processing) are calculated according to the following algorithm:

The number of required IMS Type 1, 2, 3, 4, 5, 6 cards is calculated using the following formula:

$$N_{Type-x}^{IMS} = \max(\left\lceil \frac{V_z}{C_{x-capacity}} \right\rceil ;2)$$

Where,

$C_{x-capacity}$ -Type x IMS service card handling capacity;

V_z - Total network volume z handled by x type of component;

z - Total network volume of BHE or $BHCA$ or S_{total};

x - IMS service card Type: 1 or 2 or 3 or 4 or 5 or 6.

The number of required HSS service cards is calculated using the following formula:

$$N_{Type-1/2}^{HSS} = MAX(\left\lceil \frac{S_{total}}{C_{x-capacity}} \right\rceil ;2)$$

Where,

S_{total} - Total amount of voice subscribers in the network;

$C_{x-capacity}$ - Type x HSS service card handling capacity;

x - Type of the service card. There are two types in total.

7.3.7.9 Centralized User Database (CUDB)

Centralized User Database is required to provide interface between VLR and HSS.

Each Centralized User Database (CUDB) comprises two parts:

- Base unit;
- Extension units.

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

Amount of CUDB base units and extension units is calculated according to algorithm provided in section 7.3.1 Base and extension units concept with mailboxes and subscribers number as dividend variables.

7.3.7.10 Billing IC system

The model will dimension only the network elements that participate in the provision of wholesale termination, origination and transit services; therefore, only the wholesale related part of the billing system will be dimensioned.
Wholesale billing system encompasses the infrastructure from traffic data collection to invoicing and payment monitoring in particular hardware and software required for:

- Collecting and processing wholesale billing records;
- Warehousing of wholesale traffic data;
- Invoicing of wholesale customers.

The billing system is dimensioned using the following steps:
Calculate the number of servers to support the required CDR. Calculations is done using the following formula:

$$N^{IC} = \left\lceil \frac{N_{IC-\exp}}{C_{IC-M.capacity}} \right\rceil$$

Where,

N^{IC} - Number of billing system main units;

$C_{IC-M.capacity}$ - Billing system main unit's slot capacity;

$N_{IC-\exp}$ - Number of IC system's expansion cards.

The required amount of expansion cards is calculated using the following formula:

$$N_{IC-\exp} = \left\lceil \frac{CDR}{HA \times C_{IC-Exp.capacity}} \right\rceil$$

Where,

$C_{IC-Exp.capacity}$ - Expansion unit's handling o capacity;

HA - Headroom allowance for IC hardware and software;

CDR - Call detail records to be handled by the billing system. This amount is estimated by summing the amount of interconnection traffic multiplied by its CDR statistics.

The amount of Billing IC system extension units is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with the number of BHCA required in Billing IC system as dividend variable.

7.3.7.11 Number portability system

Number portability system should present a part of number portability system utilized by wholesale services.

Number portability system comprises of the following parts:

- Number portability system: basic unit
- Number portability system: extension

Estimation of the minimum number of Number portability system base units required is a function of requirements to meet:

1. Minimal network configurations;
2. Processing capacity.

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

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

The number of Number portability system base units (BU_{NPS}^{C} , units) to meet processing capacity requirements are calculated according to the following formulas:

$$BU_{NPS}^{C} = \frac{N_{BHCA}}{C_{CPU}}$$

$$C_{CPU} = C_{NPS,s}^{\psi} \times N_{CPU/NPS}$$

Where:

N_{BHCA} – Call attempts in BHT, BHCA.

$C_{NPS,s}^{\psi}$ – Maximal Number portability system operational capacity to satisfy call attempts in BHT, BHCA.

C_{CPU} – Processing capacity of BHCA;

$N_{CPU/NPS}$ – Maximal number of extension units per Number portability system, units.

The amount of Number portability system extension units is calculated according to the algorithm provided in section 7.3.1 Base and extension units concept with the number of BHCA required in Number portability system as dividend variable.

7.3.8 Transmission

7.3.8.1 Backhaul transmission

Transmission network connects physically separated nodes in a mobile network (BTSs/NodeB/eNodeB, BSCs/RNC/EPC, MSCs or MSS/MGWs or SGGSN/GGSN) and allows transmission of communication signals over far distances. Transmission network, according to the mobile network topology in BU-LRIC model, is split into the following hierarchical levels:

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

BU – LRIC model also assumes two different transmission technologies:

- Ethernet technology in backhaul transmission.
- Ethernet technology in core transmission. Data transmission services are modeled in core transmission as well.

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

Backhaul transmission

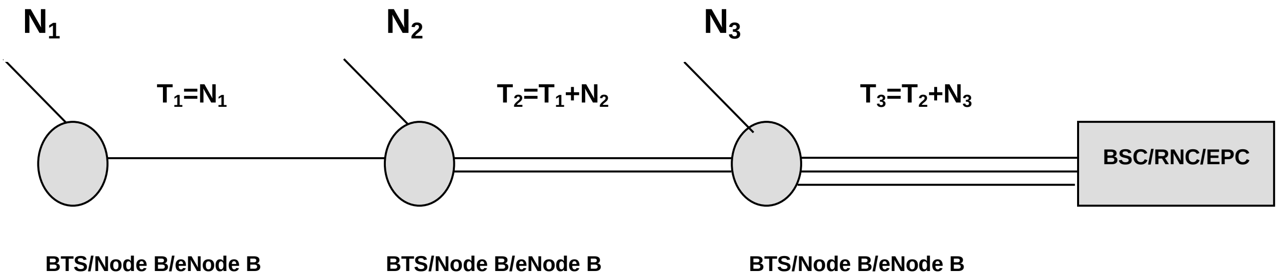
Backhaul transmission connects BTSs with BSCs (GSM network), NodeBs with RNCs (UMTS network) or eNodeBs to EPC. Ethernet technology is used to transport data between the mentioned nodes of mobile network. Ethernet comprise the following transmission modes:

- Ethernet radio link 10 Mbit/s microwave link;
- Ethernet radio link 20 Mbit/s microwave link;
- Ethernet radio link 50 Mbit/s microwave link;
- Ethernet radio link 100 Mbit/s microwave link.
- Ethernet radio link 150 Mbit/s microwave link.
- Ethernet radio link 200 Mbit/s microwave link.

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

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

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



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

Key characteristics for backhaul transmission modeling are:

- Transmission network equipment is built with minimal capacity level to assure BTS/Node B/ eNodeB – BSC/RNC/EPC transmission on the level sufficient to serve the traffic demand.
- Each BTS/NodeB/eNodeB that belongs to a particular transmission line put additional volume of data to the transmission line. It results in higher loading of the transmission line coming up to BSC/NodeB/eNodeB and lower loading moving backwards.
- Assumption that the average number of sites per transmission line is three is set.

Below, the algorithm of Ethernet radio links number calculation by different transmission modes (10 Mbit/s step) is provided. As all Ethernet radio link modes are calculated with reference to one algorithm, a common Ethernet radio link number calculation algorithm is provided.

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

$$\alpha_{TH} = \frac{TH_{UMTS} + TH_{GSM} + TH_{LTE}}{N_{SI}}$$

Where:

TH_{UMTS} – Total throughput 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;

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

N_{SI} – Total number of sites (GSM, UMTS and LTE networks), units;

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

$$TH_{UMTS} = \sum_{i,j,k} TH_{i,j,k}^{UMTS} \times N_{i,j,k}^{UMTS}$$

Where:

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

$N_{i,j,k}^{UMTS}$ – 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:

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

Where:

N_{CAP}^{SeB} - Number of sectors to meet capacity requirements in all types of area and cell, 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.

C_{HSDPA}^{Se} - Sector capacity – HSDPA, in BHT in all types of area and cell, kbit/s;

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

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

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

$$TH_{GSM} = \sum_{i,j,k} TH_{i,j,k}^{GSM} \times N_{i,j,k}^{GSM}$$

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:

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

Where:

$N_{TRX/Se}$ - Number of TRXs per sector (taking in account all types of area and cell), 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:

$$C_i^l = C_b \times OA \times N_i^{lc}$$

Where:

C_b – Basic 2 Mbit/s link capacity, kbit/s; Mbit/s will be translated into kbit/s using 1024 multiple.

OA – Operational allowance, %;

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

i – Ethernet links at 10 Mbit/s, 20 Mbit/s, 50 Mbit/s, 100 Mbit/s, 150 Mbit/s and 200 Mbit/s.

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

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

Where:

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

α_{TH} – average throughput per site, kbit/s.

The number of transmission modes sections per transmission line is calculated for different types of Ethernet radio links. The number of sections of *i* Ethernet links per transmission line is calculated according to the following formula:

$$N_i^{\sec} = MIN(N_i^{MAX,\sec}; \alpha_{BTS}) - \sum_{x=2}^{x=i} N_x^{\sec}$$

Where:

$N_i^{MAX,\sec}$ – Maximum number of *i* sections per transmission line, units;

α_{BTS} – Average number of BTS sites per transmission line, units.

$N_x^{\sec}$ – Number of *x* sections per transmission line, units.

i – Ethernet links at 10 Mbit/s, 20 Mbit/s, 50 Mbit/s, 100 Mbit/s, 150 Mbit/s and 200 Mbit/s.

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

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

Where:

$N_i^{\sec}$ – Number of transmission mode sections per transmission line, units.

i – Ethernet links at 10 Mbit/s, 20 Mbit/s, 50 Mbit/s, 100 Mbit/s, 150 Mbit/s and 200 Mbit/s.

α_{BTS} – Average number of BTS sites per transmission line, units.

$N^{\sec}$ – Total number of transmission modes sections per transmission line, units.

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

$$N_i^{ETH} = P_i^{\sec} \times N_{Total}^{Si}$$

Where:

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

i – Ethernet links at 10 Mbit/s, 20 Mbit/s, 50 Mbit/s, 100 Mbit/s, 150 Mbit/s and 200 Mbit/s.

N_{Total}^{Si} – Total number of sites in mobile network, units.

7.3.8.2 Core transmission

As mentioned before, core transmission connects BSCs/RNCs/EPC and MSCs or MGWs or GGSNs.

First of all, the number of Ethernet radio links in BSC/RNC – MSC, BSC/RNC – MGW or EPC - GGSN hierarchy level is calculated. Below, the calculation algorithm is provided.

The number of BSC/RNC-MSC, BSC/RNC – MGW or EPC - GGSN sections to meet capacity demand ($N_{SDH}^{\sec}$, units) is calculated according to the following formula:

$$N_{ETH}^{\sec} = \left\lceil \frac{D_C}{N_{BR} \times C_{ETH}^{\psi}} \right\rceil$$

Where:

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

N_{BR} – Number of BSCs, RNCs and EPC, units;

C_{ETH}^{ψ} – Maximal operational capacity of Ethernet radio link, E1.

The total number of Ethernet links (N_{ETH}, units) is calculated according to the following formula:

$$N_{ETH} = N_{BR} \times P_m^t \times \alpha_{BSC} \times N_{ETH}^{\sec}$$

Where:

N_{BR} – Number of BSCs, RNCs and EPC units;

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

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

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

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

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

Alternative technology for transporting data in BSC/RNC – MSC,BSC/RNC – MGW or EPC - GGSN hierarchy level is data transmission services. Kilometers as additional measure besides pieces of data transmission services are calculated, as the costs of data transmission services increase together with the increasing distance between BSC/RNC and MSC/MGW or EPC and GGSN. Having in mind the pricing model the 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 data transmission services for 1 km.

The number of data transmission services BSC/RNC-MSC, BSC/RNC-MGW or EPC - GGSN ($N_{BSC-MSC/MGW}^{l}$, units) is calculated according to the following formula:

$$N_{BSC-MSC/MGW}^{l} = N_{BR} \times P_L^t$$

Where:

N_{BR} – Number of BSCs RNCs and EPC, units.

P_L^t – Share of transmission covered by data transmission services, %.

The total length of data transmission services in BSC/RNC – MSC, BSC/RNC – MGW or EPC - GGSN ($L_{BSC-MSC/MGW}$, km) is calculated according to the following formula:

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

Where:

$N^{l}_{BSC-MSC/MGW}$ – Number of data transmission services BSC/RNC-MSC, BSC/RNC – MGW or EPC - GGSN units;

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

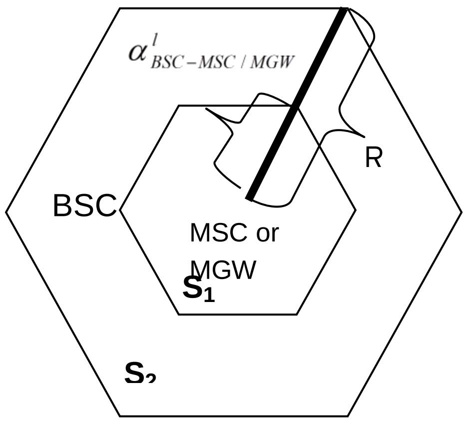
The average distance of leased line between BSC/RNC/EPC and MSC or MGW or GGSN ($\alpha^{l}_{BSC-MSC/MGW}$, km) is calculated according to the following formula:

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

Where:

R – Radial distance of hexagon, km.

The area of hexagon equals to Area of Republic of Georgia divided by the number of MSS or MGW. The figure below illustrates the calculation of the average distance of leased line between BSC/RNC/EPC and MSC or MGW or GGSN.



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 smaller hexagon, km^2;

S_2 – Area of bigger hexagon, km^2.

In MSC-MSC, MGW – MGW or GGSN - GGSN hierarchy level two types of measure of data transmission services are calculated as well. The number of data transmission services MSC-MSC, MGW – MGW or GGSN - GGSN ($N^l_{MSC-MSC/MGW-MGW}$, units), assuming each MSC/MGW/GGSN is connected with each of the rest of MSC/MGW/GGSN, is calculated according to the following formula:

$$N^l_{MSC-MSC/MGW-MGW} = BU_{MSC/MGW} \times (BU_{MSC/MGW} - 1)$$

Where:

$BU_{MSC/MGW}$ – Number of MSC/MGW/GGSN.

The total length of data transmission services MSC-MSC, MGW – MGW or GGSN - GGSN ($L_{MSC-MSC/MGW-MGW}$, units) is calculated according to the following formula:

$$L_{MSC-MSC/MGW-MGW} = N^l_{MSC-MSC/MGW-MGW} \times \alpha^l_{MSC-MSC/MGW-MGW}$$

Where:

$N^l_{MSC-MSC/MGW-MGW}$ – Number of data transmission services MSC/MSS/MGW/GGSN-MSC/MSS/MGW/GGSN, units;

$\alpha^l_{MSC-MSC/MGW-MGW}$ – Average distance of data transmission services between MSCs/MGWs/GGSN, km.

The average distance of data transmission services between MSCs/MGWs/GGSNs ($\alpha^l_{MSC-MSC/MGW-MGW}$, km) is calculated according to the following formula:

$$\alpha^l_{MSC-MSC/MGW-MGW} = \frac{R_{MSC/MGW}}{\sqrt{2}}$$

Where:

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

The area of hexagon is equal to the area of the Republic of Georgia.

Stand-alone transmission radio link: tower and site preparation

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

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

$$N_{S-A}^{t} = N_{B}^{S-A} + N_{C}^{S-A}$$

Where:

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

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

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

$$N_{B}^{S-A} = N^{ETH} \times P_{S-A}^{ETH}$$

$$N^{PDH} = \sum_{i} N_{i}^{PDH}$$

Where:

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

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

N_{i}^{PDH} – 10 Mbit/s, 20 Mbit/s, 50 Mbit/s, 100 Mbit/s, 150 Mbit/s, 200 Mbit/s Ethernet radio links.

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

$$N_{C}^{S-A} = N_{ETH} \times P_{S-A}^{ETH}$$

Where:

N_{ETH} – Total number of Ethernet radio links (calculated in formula No. **Error! Reference source not found.**), units;

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

8. Network valuation

8.1 Cost annualization

All fixed line 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-LRIC model there are four alternative methods that are used to calculate annual CAPEX costs:

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

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

Straight-line method

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

$C = CD - HG + ROI$

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 the annuity method are calculated according to the following formula:

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

Tilted annuity method

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

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

Economic depreciation method

The economic depreciation algorithm involves a cash-flow analysis to answer the question: what time-series of prices consistent with the trends in the underlying costs of production (e.g. utilization of the network, price change of asset elements) yield the expected net present value equal to zero (i.e. normal profit).

Economic depreciation requires forecasting the key variables:

- Cost of capital;
- Changes in the price of Modern Equivalent Asset;
- Changes in operating cost over time;
- Utilization profile.
- The impact of key variables on depreciation is as follows:
- The lower the cost of capital, the lower the cost of investment that needs to be recovered in any year;
- The grater the future MEA price reductions, the more depreciation needs to be front-loaded;
- The deprecation should be brought forward, according to the increase of operating cost of an asset.

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 favored in theory. However, in the current BU-LRIC model the use of economic depreciation is excluded from modeling scope due to some reasons. Firstly, results from this method are highly dependable on various forecast assumptions. Forecasted revenue, cost of capital, changes in the price of Modern Equivalent Asset, changes in operating cost over time, utilization profile are essential for calculations, though having in mind the dynamic nature of the electronic communications market, forecasts may be subjective. Secondly, using alternative cost annualization methods, such as straight-line, annuity or tilted annuity, enables to reach comparable results.

The tilted annuity method will be used as the main method to calculate annual CAPEX costs due to simplicity and a fact that it generates a depreciation profile similar to that of economic depreciation – method recommended by Recommendation. It is worth mentioning that the model will have a possibility to calculate annual CAPEX using straight line, annuity and tilted annuity methods.

8.2 Mark-ups

BU-LRIC models operational, NMS, administration and support costs as mark-ups of the network costs.

In particular the following cost categories will be covered in the model as a cost rates:

Operational cost categories

- Network operation, maintenance and planning expenses - operational costs of planning, management, on—site visits, inspections, configuration and maintenance works, for particular network elements:
  - Access nodes
  - Core network
  - Transmission network
- Operational cost of general administration, finance, human resources, information technology management and other administration and support activities (salaries, materials, services).

Capital cost categories

- Network management system - general
- Network management system – dedicated to network elements
  - Access nodes
  - Core network
  - Transmission network
- Capital costs of general administration, finance, human resources, information technology management and other administration and support activities (buildings, vehicles, computers, etc.)

The above cost categories will be covered by calculating:

- Mark-ups on network capital cost, or
- Mark-ups on network operational cost.

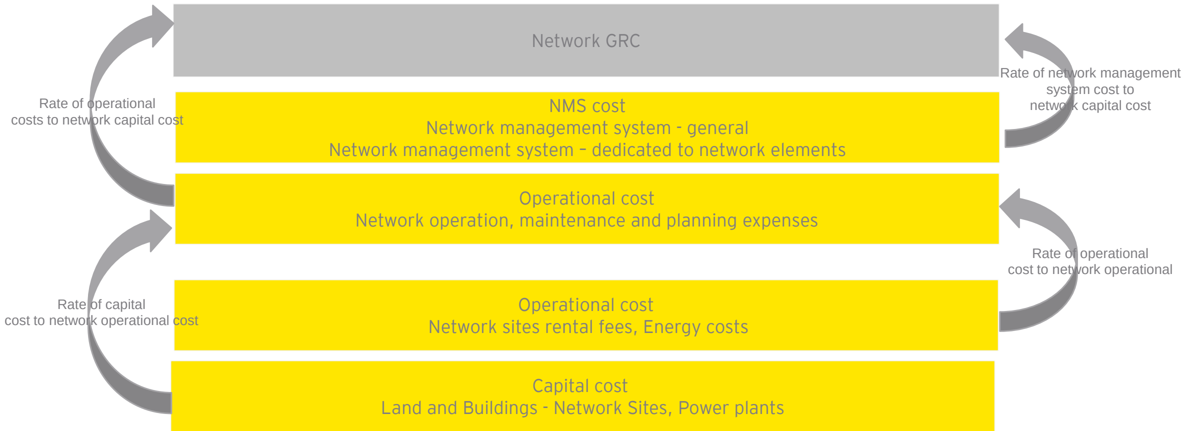
Markups on network capital cost would be calculated for the following cost categories:

- Network operation, maintenance and planning expenses (operational cost)
- Network management system – general (capital cost)
- Network management system – dedicated to network elements (capital cost)

Markups on network operational cost, previously allocated on corresponding network elements, would be calculated for the following cost categories:

- Capital costs of general administration, finance, human resources, information technology management and other administration and support activities.
- Operational cost of general administration, finance, human resources, information technology management and other administration and support activities.

The scheme below present mechanism of calculating cost which are based on cost rates.



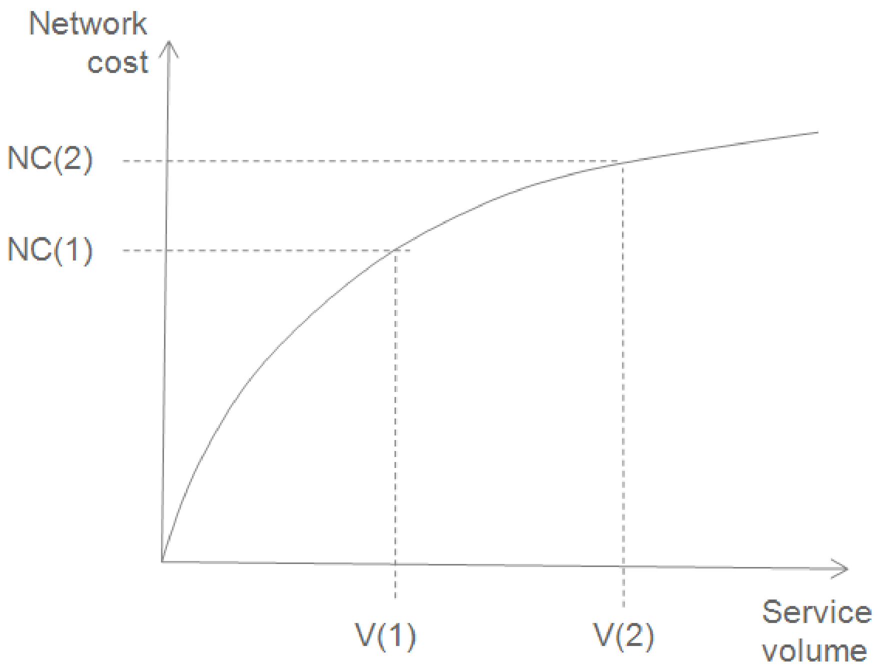
The mark-ups value will be calculated based on the financial data of operators.

9. Services costs calculation

9.1 Pure LRIC and LRIC approach

The avoidable costs of service (e.g. call termination) or group of services (e.g. voice calls) increment may be calculated by identifying the total long-run cost of an operator providing its full range of services and then identifying the long-run costs of the same operator in the absence of the service or group of services being provided to third parties and subscribers. This may then be subtracted from the total long-run costs of the business to derive the defined increment.

The diagram below illustrates methodology of incremental cost calculation.



The incremental cost is calculated as follows:

$$U = \frac{NC(2) - NC(1)}{V(2) - V(1)}$$

Where,

U – incremental cost

NC(1) – cost of network planned to utilize demand for V(1) service volume

NC(2) – cost of network planned to utilize demand for V(2) service volume

NC(2) – NC(1) – incremental cost of network (avoidable cost)

V(2) – total service volume

V(1) – total service volume less service or group of services volume

V(2) –V(1) – service or group of services volume

9.2 LRIC+ approach

When calculating costs using LRIC+ additional mark-ups are added on the primarily estimated increments to cover costs of all shared and common elements and activities which are necessary for the provision of all services.

After establishing the incremental costs of Network Components (NC), the common and join cost (CJC) are allocated to the Network Components (NC) using equally-proportional mark-up (EPMU) mechanism based on the level of incremental cost incurred by each Network Component. 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 routing factor and service costs are calculated.