Communications Regulatory Authority of the Republic of Lithuania

**Reference paper for creating model for calculation of bottom up long run average incremental costs (BU-LRAIC) for operator of public fixed communications network**

2013 June

# Glossary

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

| **No.** | **Abbreviation** | **Term** | **Explanation** |
| --- | --- | --- | --- |
|  | - | Access network | Part of a public electronic communications network that connects access nodes of core network to individual subscribers. |
|  | AETH | Access Ethernet switch | Ethernet switch in Access Node location, connecting the point to point subscribers to the core network. |
|  | ATM | Asynchronous Transfer Mode | Digital communication that is capable of very high speeds by using a standard switching technique designed to unify telecommunication and computer networks. It uses asynchronous time-division multiplexing and it encodes data into small, fixed-sized cells. |
|  | - | Benchmark | A standard or point of reference against which things may be compared or assessed |
|  | BBLL | Broadband leased line | Service contract between provider and customer, whereby provider agrees to deliver Broadband leased line service to handle data services |
|  | - | Broadband | Bandwidth in a communication channel not lower than 144 kbps. |
|  | BHCA | Busy hour call attempts | Number of call attempts in a busy hour. |
|  | BHE | Busy hour erlangs | Call traffic on busy hour traffic dimensioned by erlangs |
|  | BHT | Busy hour traffic | Amount of traffic in a busy hour. |
|  | - | Call | Connection established by means of a publicly available electronic communications service allowing two-way communication in real time. |
|  | CAPEX | Capital expenditure | Capital expenditure costs. CAPEX costs comprise depreciation and ROI. |
|  | - | Channel | Transmission channel |
|  | - | Circuit | Transmission line |
|  | - | Common and joint costs | Costs that are shared by several services |
|  | - | Core network | Group of network components switching and transmitting traffic. Core network comprises switches, local and remote subscriber units as well as transmission equipment between network nodes. |
|  | - | Cost driver | A factor that influences the existence and amount of costs. |
|  | CVR | Cost volume relationship | Relationship between total value of cost and cost driver. |
|  | - | Costs | Decrease in the economic value for a company due to usage of fixed assets, sale of assets, loss of assets, decrease in asset value or increase in liabilities over a period, which results in a decrease in equity capital. |
|  | CPE | Customer-premises equipment | Customer-premises equipment is any terminal and associated equipment located at a subscriber's premises and connected with a carrier's telecommunication channel(s) at the demarcation point. |
|  | DDF | Digital distribution frame | A device that switches incoming and outgoing signals. |
|  | DSLAM | Digital subscriber line access multiplexer | Network device which connects multiple customer digital subscriber line (DSL) interfaces to a high-speed digital communications channel using multiplexing techniques. |
|  | - | Duct | 100 mm or larger duct for laying cables built between two manholes or between a manhole and other equipment. |
|  | FA | Fixed assets | Tangible assets that give economic benefit to the company with a lifetime of more than a year and the minimal acquisition cost of the asset is not lower than the minimal value of tangible asset set by the company. |
|  | - | Fixed electronic communications network | Public electronic communications network having fixed end points. |
|  | GPON | Gigabit Passive Optical Network | A point-to-multipoint connection - fiber to the premises network architecture in which passive optical splitters are used to enable a single optical fiber to serve multiple premises. |
|  | HCC | Homogenous cost category | A set of costs, which have the same driver, the same cost volume relationship pattern and the same rate of technology change. |
|  | IC | Inter Connection | The linking of two networks for the mutual exchange of traffic. |
|  | IMS | IP multimedia sub-system | An architectural framework for delivering Internet Protocol (IP) multimedia services. |
|  | - | Incremental cost | Increase in costs due to increase in the volume of service. |
|  | - | Leased line | A dedicated telephone line connecting two end-points. |
|  | LN | Local Node | Node serving Local Zone |
|  | - | Local subscriber unit | Subscriber unit that is physically located in the same place as a switch. |
|  | LRAIC | Long run average incremental costing | The principle of long run average incremental costing – estimating change in costs as a result of change in cost driver volume and dividing them over a unit of service. The costs are measured in the long run, which means that the company based on the level of demand can change the amount of resources involved in providing a service i.e. all costs become variable. |
|  | - | Multiplexer | A device that enables more than one signal to be sent simultaneously over one physical channel. |
|  | MSAN | Multi Services Access Node | Device typically installed in Access Node which connects customers' access lines to the core network, to provide telephone, ISDN, and broadband such as DSL all from a single platform. |
|  |  | Narrowband | Bandwidth in a communication channel lower than 144 kbps. |
|  | NE | Network element | Any network object which physically or logically can be identified as an independent network unit. |
|  | - | Network interconnection | Physical and logical linking of public communications networks used by the same or a different undertaking in order to allow the users of one undertaking to communicate with the users of the same or another undertaking, or to access services provided by another undertaking. Interconnection is a specific type of access. |
|  | NGN | Next Generation Network | The concept of an electronic communications network, which is based on packet switching and separation of transport and network services. This concept also includes installation of optical fibers to access the public electronic communications networks. |
|  | NMS | Network Management System | An NMS manages the network elements. Management tasks include discovering network inventory, monitoring device health and status, providing alerts to conditions that impact system performance, and identification of problems, their source(s) and possible solutions. |
|  | - | Operator | An undertaking providing public communications network or an associated facility. |
|  | OPEX | OPEX | Operating expenditures that comprise salaries, material and other external service costs. |
|  | ODF | Optical distribution frame | Device that is used to physically group several cables to one cable. |
|  | OLT | Optical Line Terminal | Device which serves as the service provider endpoint of a passive optical network. |
|  | - | Origination | Transmission of a call from a network point where the call was originated to the switch (including switch) where interconnection can be established located closest to the subscriber originating the call. |
|  | - | Port | A socket in a computer or network into which a device can be plugged. |
|  | POTS | Plain Old Telephone Service | The basic single line switched access service offered by local exchange carriers to residential and business end users, using loop-start signaling. |
|  | PSTN | Public Switched Telephone Network | Public telephone network, based on circuit switching. |
|  | P2P | Point-to-Point connection | A direct communications connection between two nodes or endpoints |
|  | - | Rectifier | An electrical device that converts an alternating current into a direct one by allowing a current to flow through it in one direction only |
|  | ROI | Return on investment | Required return on investment calculated by multiplying WACC and capital employed. |
|  | - | Routing matrix | Matrix which represents the intensity of NE usage for different services. |
|  | - | Scorched node assumption | Assumption where you take everything as it is |
|  | - | Service | An electronic communications service which consists wholly or mainly in the conveyance of signals on electronic communications networks. |
|  | - | Subscriber | Person who or which is party to a contract with the provider of publicly available electronic communication services for the supply of such services. |
|  | RSU | Remote Subscriber unit | Functional network component from one side connected to an access network (via line card) and from the other side to a switch (via 2 mbps port). |
|  | - | Supporting activity | Supporting activity comprises administration, accounting, planning, human resource management and other supplementary activities. |
|  | - | Switch (switching host) | Network element that switches calls between two network nodes. |
|  | - | Switching network | Network of switches that ensures connection among separate nodes of electronic communications network. |
|  | - | Electronic communications network | An electronic communication network used to provide public telephone service including transmission of voice between network end points and other services such as fax or data transmission. |
|  | - | Termination | Transmission of a call from a switch (including switch) where interconnection can be established located closest to the subscriber receiving the call to the final network point where the call ends. |
|  | TN | Transit Node | Core IP router serving Transit Zone |
|  | - | Transit | Transmission of a call from a switch where interconnection can be established located closest to a subscriber initiating a call (excluding the switch ) to a switch where interconnection can be established located closest to a subscriber receiving a call (excluding the switch) via one or more switches. |
|  | Transit 1 | Type 1 Transit | Transmission of a call through single Transit switch (inclusive). This service is currently regulated PSTN service. |
|  | Transit 2 | Type 2 Transit | Transmission of a call from (to) Local switch (excluding that switch), located as near as possible to calling customer (called customer), where interconnection is already provided or can be provided, to (from) Transit switch (inclusive), where interconnection can be provided. This service is currently regulated PSTN service. |
|  | Transit 3 | Type 3 Transit | Transmission of a call from Transit switch (excluding that switch), where interconnection is provided or can be provided, to Transit switch (inclusive), where interconnection is provided or can be provided. This service is currently regulated PSTN service. |
|  | Transit 4 | Type 4 Transit | Transmission of international call through single International Transit switch (inclusive), when international call is originated in network in Lithuania. This service is currently regulated PSTN service. |
|  | Transit 5 | Type 5 Transit | Transmission of international call from Transit switch (excluding that switch) to International Transit switch (inclusive), when international call is originated in networks in Lithuania. This service is currently regulated PSTN service. |
|  | - | Transmission link | A link which ensures transmission of optical and electric signal between two remote geographic units. |
|  | - | Transmission network | Equipment of electronic communications which ensures transmission of optical and electric signals among separate core network components. |
|  | - | Tributary card | Component of a multiplexer constituting interface between multiplexer and other equipment of electronic communications. |
|  | - | Unsuccessful call | An attempted call which did not successfully proceed/was not answered. |
|  | WACC | Weighted average cost of capital | Cost of capital calculated as a weighted cost of borrowed and equity capital. |
|  | - | Wholesale billing system | Wholesale and invoice management information system. |
|  | 1GE or GE | 1 Gbps Ethernet interface | Interface capable to transmit Ethernet frames at a rate of a gigabit per second |
|  | 10GE | 10 Gbps Ethernet interface | Interface capable to transmit Ethernet frames at a rate of ten gigabits per second |
|  | – | Recommendation | European Commission Recommendation 2009/396/EC on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU as of 7 May 2009. |

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# Introduction

The purpose of this document is to present the main principles of BU-LRAIC model to be developed for the fixed line operator. Most of the principles have been already in place since 2005 when the BU-LRAIC[[1]](#footnote-1) model was introduced. Key changes to the previous approach:



The first key change to the document is the introduction of the NGN network topology which brought new network dimensioning. The second key change is the introduction of Pure LRAIC methodology. This brought new LRAIC methodology section where different methods of cost calculation are defined and compared. Overall, the structure of the document’ is completely new compared to the old document of 2005.

## Legal background

Elaboration of a tool for the calculation of cost-based interconnection prices of the Lithuanian fixed networks developed by bottom-up method of long-run incremental costs (hereinafter, BU-LRAIC ) method is maintained by these legal regulations:

* European Commission recommendation (2009/396/EC);
* European Union Electronic Communications Regulation System (directives);
* Law on Electronic Communications of the Republic of Lithuania;
* Market analysis conducted by the Communications Regulatory Authority of Republic of Lithuania (further – RRT);
* Executive orders and decisions of the Director of the RRT.

In 2005 RRT initiated the first project to estimate call costs for fixed-line networks. Ernst & Young created HY-LRAIC cost calculation model for fixed-line networks according to which the Director of the RRT in 2008 released an executive order No. 1V-101 and call termination, origination and transit prices were started to be regulated by RRT in 2008.

However, in 2009 the European Commission released a new recommendation (2009/396/EC) regarding call price regulation, and the aim of the project is to build a BU-LRAIC model to calculate costs of call termination in fixed-line networks in order to comply with the requirements set out in the recommendation, in particular the following:

* + Model the costs of an efficient service provider;
  + Calculations shall be based on current costs;
  + Implement a forward looking BU LRAIC model;
  + Comply with the requirements of "technological efficiency” – NGN;
  + May contain economic depreciation method;
  + Take into account the incremental costs (Pure LRAIC) of call termination in determining the per item cost.

## Document objective

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

* + To present the scope and the detailed principles of the BU-LRAIC modeling (guidelines and concept of the BU-LRAIC model).

BU-LRAIC modeling is theoretical and might differ from the real market situation, however, it models operator of fixed electronic communications network operating efficiently in a competitive market.

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

# LRAIC methodology

All calculations in the model are based on Forward-Looking Long Run Average Incremental Cost (LRAIC) methodology, assuming Bottom-up approach and efficient operator operating in a fully competitive market. Below is provided a short introduction to the model of BU-LRAIC.

The meaning of the definition of BU-LRAIC is as follows:

1. **LRAIC costs:** There are 3 LRAIC methods of cost calculation: Pure LRAIC, LRAIC+ and LRAIC++.

* Pure LRAIC method – includes only incremental costs related to network components used in the provision of the particular service.
* LRAIC+ method – includes only incremental 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 service incremental as well. The group of service could be total voice services, total data services and access services.
* LRAIC++ method – includes costs described in LRAIC+ method description plus common and joint cost. The common and joint cost related to each group of service (total voice services, total data services and access services) are calculated separately for each Network Component using an equal-proportional mark-up (EPMU) mechanism based on the level of incremental cost incurred by each group of service (total voice services, total data services and access services).

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

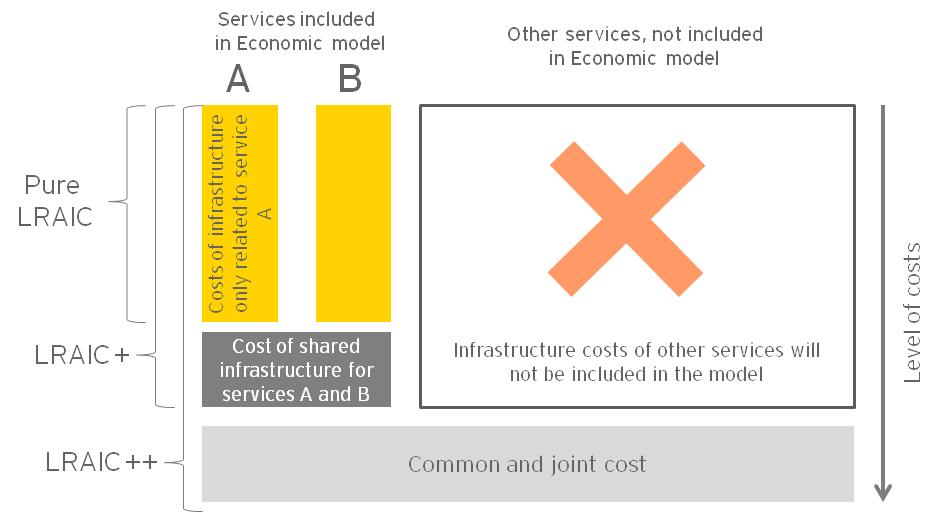
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Figure 1: Ilustration of LRAIC cost allocation methods

BU-LRAIC model will have functionality to calculate costs using all three methods.

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

Figure 2. Incremental and average incremental costs.

Average incremental costs

**Increment**

Output

Costs

**Incremental costs**

1. ***Forward looking.*** Forward-looking costs are the costs incurred today building a network which has to face future demand and asset prices. In practice this means that if modeling is done in a year X, the cost of services is calculated for the year up to X+10 (e.g. if modeling is done in 2009, service costs are calculated for the years 2010 - 2020).
2. ***Bottom-up.*** The 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 interconnection services.

Bottom-up models perform the following tasks:

* Dimension and revaluate the network;
* Estimate non-network costs;
* Estimate operating maintenance and supporting costs;
* Estimate services costs.

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

## Network modeling

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 objective of following either of the two approaches is to ensure that the incumbent operator has the right incentives to invest efficiently in its own network in the future, and that new entrants receive the correct economic signals that assist them in deciding between building their own networks or paying for interconnection with the incumbent’s network.

The scorched earth basis assumes that optimally-sized network devices would be employed at locations optimal to the overall transmission design, as if the network was being redesigned on a greenfield site. However, designing and agreeing an optimal network is not a straightforward or uncontentious task. Moreover, it may be considered reasonable to allow the operator to recover costs associated with the existing network configuration, given that it must in practice largely take it as given.

Following the network modeling principles described above, detailed calculations of required network elements are provided in section 6*. Dimensioning of the network*.

## Increments

In LRAIC methodology increments refer to elements that influence costs of objects subject to analysis (objects under analysis are provided in section *5.1 List of services*. Calculating the incremental costs of wholesale services in fixed line networks using Pure LRAIC 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 LRAIC+ method, it is necessary to identify only those fixed and variable costs that would not be incurred if the voice services were no longer provided to third-party operators and retail subscribers (i.e. the avoidable costs only). The avoidable costs of the voice 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 voice service 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 LRAIC++ 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.

Increments of current BU-LRAIC model are:

* Volume of services;
* Subscribers.

## Modeling period

In order to get a deeper insight into a fixed line network operator’s cost structure, it is common practice to calculate service costs for at least several periods. BU-LRAIC model will calculate nominal service costs for the 10-year period starting from 2010.

## Cost accounting

There are two methods of measuring costs in terms of replacement cost: historical cost accounting and current cost accounting. BU-LRAIC model will have a functionality to estimate costs using both methods.

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

The objective of the current cost accounting approach is to derive information what it would cost to acquire assets and other required resources now or in the near future. The current cost is calculated by using the current (or the latest) market prices (replacement cost) or adjusting the historical cost for asset specific inflation and therefore getting more realistic values of assets and other resources used in business. In the situation when fixed assets that are still in use are outdated or no longer available on the market, it may be difficult to assign their current price. In this situation the concept of modern equivalent asset (MEA) has to be adopted. MEA means an asset that would perform the same function as the asset to be replaced and is currently available on the market. Historical costs may also be used as a proxy for current costs when assets have been purchased quite recently and no better source for current costs (including MEA) is available.

## Cost of capital

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

Calculation and elaboration of WACC of an assumed efficient fixed line network operator in Lithuania will be provided in a separate report.

## Technological background

Ernst & Young will develop bottom-up engineering models that will allow revaluation based on current cost concept and allow modeling of cost to volume behavior including minimal network calculation.

According to the recommendation, “technological efficient" fixed operator should use NGN network with all services delivered over an IP core network. However, the model will also have the functionality to calculate interconnection costs following the PSTN network structure, which was dimensioned and approved with stakeholders in 2005 in the document “BU-LRAIC model documentation”.

This document will focus on the NGN network structure and its differences between PSTN. The main changes which are required to shift from PSTN to NGN fixed networks are listed below:

* Local points concentrating traffic in the fixed-operator network (RSU’s – Remote Subscriber Units, DSLAM’s - Digital Subscriber Line Access Multiplexers, LE’s - Local Exchanges including subscriber cards) should be replaced by MSANs – Multi Service Access Nodes and OLTs with Access Ethernet switches have to be modeled where fiber access is present;
* Transmission between nodes should utilize Ethernet transmission network instead of ATM/SDH transmission network;
* The switching functionality of Local and Transit exchanges should be moved to the IP routers and IMS system.
* NGN network needs to include Media Gateways to convert packet switched traffic to circuit switched traffic at points of interconnection;
* NGN network’s end user needs CPE equipment in order to receive internet access, VoIP and IPTV services.

A high level scheme illustrating these changes is presented below:

|  |  |
| --- | --- |
| PSTN network architecture | ODF / MDF |
| NGN network architecture |  |

Figure 3: Changes in network architecture.

**PSTN and NGN network logical structure**

Core PSTN switching network consists of separated switches and related equipment that ensures appearance and termination of temporary links among end points of the network. Switching network elements can be grouped into the following categories:

* Remote Subscriber Unit (RSU)
* Local Exchange (LE)
* Transit exchange (TE)

The local level of PSTN core network, which concentrates subscribers’ traffic, is formed by Remote Subscriber Units and Local Exchange. Geographical area served by one Local Exchange is called Local Zone.

The transit level of PSTN core network, which transmits traffic on long distances, is formed by Transit Exchanges. Geographical area served by one Transit Exchange is called Transit Zone.

The main differences in PSTN and NGN network structure are:

* NGN network utilizes Multi Service Access Nodes to concentrate subscriber traffic instead of Remote Subscriber Unit and Local Exchanges for copper access users and Optical Line Terminals as well as Access Ethernet switches with CPE equipment for fiber optics access users;
* NGN network utilizes IP routers to transit traffic instead of Transit Exchanges;
* PSTN network architecture consist of two or more network layers (local layer and transit layer) where NGN network architecture is flat and consist of one network layer, where traffic on local level can be aggregated by Ethernet Switches, and IP routers could be used only at the transit level.

PSTN and two layer NGN network logical structure is presented in the schemes below.



**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

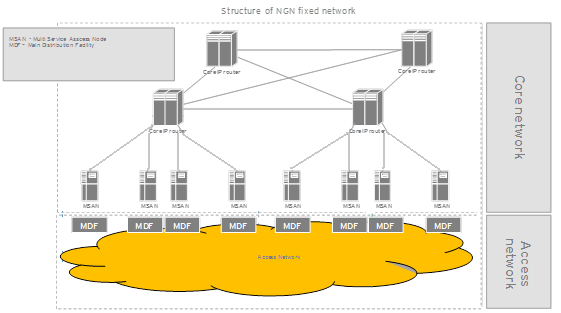
**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

Figure 4: PSTN network structure.



**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

**ODF/MDF**

Figure 5: Structure of NGN fixed network.

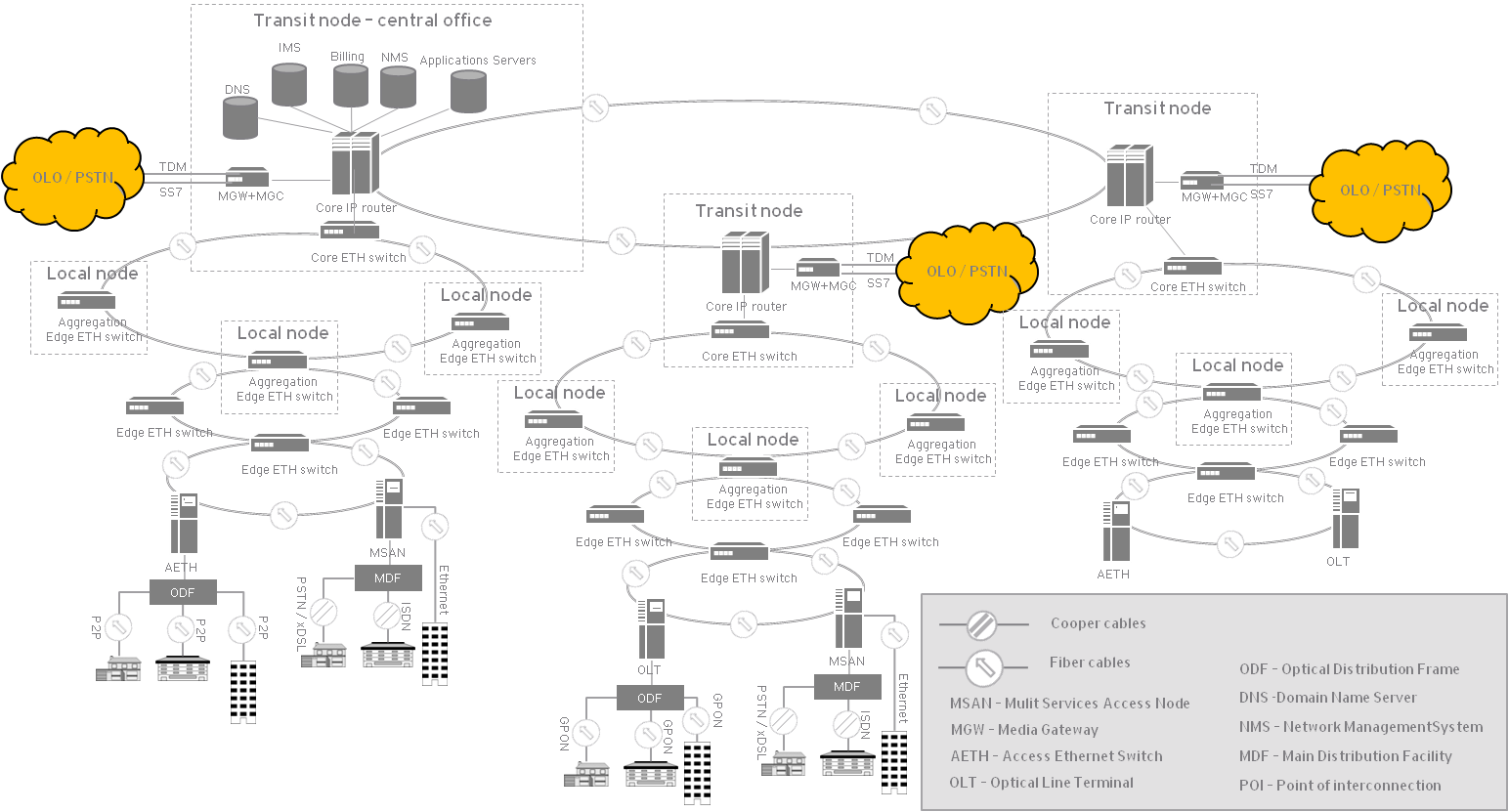


Figure 6. Structure of the modeled NGN network topology.

## Mark – ups

As already discussed in section *2.2 Increments,* a mark-up approach is provided in the BU-LRAIC model to estimate network related operational cost, administration and support operational and capital costs, network management system capital cost. The major driver of network structure and development is service demand. Increasing service demand requires additional network capacity and appropriate network elements. This results in increased network related operational costs (e.g. more designing engineers are needed to built and supervise network). Network related operational cost (headcount) is a driver for administration and support operational and capital costs. Service demand and mark-up relation is illustrated in Figure 7:

**Network demand**

**Network infrastructure**

**Network related operational costs**

**Admin/support operational and capital costs**

%

%

Figure 7: Service demand and mark-up relation.

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

1. Questionnaire data provided by Operators.

If data provided by the Operators is not sufficient for modeling purposes, following data sources will be used:

1. Reports published by the Information Society Directorate of the European Commission related to bottom-up costing models used for the interconnection cost calculation in the European Union member states;
2. Reports and documents published by the Federal Communication Commission related to bottom-up costing models used for the interconnection cost calculation in the European Union member states;
3. Public reports on LRAIC projects, LRAIC models that are used in other EU member states;
4. Ernst & Young knowledge of the telecommunications sector.

# Outline of the modeling principles

## Sub-models

The current BU-LRAIC model consists of two separate sub-models. Each of them includes different services (see Table 1). The sub-models are physically separated into two independent (not inter-linked) MS Excel models.

Table 1. Sub-models of the BU-LRAIC model

|  |  |
| --- | --- |
| **First sub-model – services included** | **Second sub-model – services included** |
| Call origination  Call termination  Call transit  Capacity based services | Provision of auxiliary services for network interconnection |

In the First sub-model the following costs are calculated:

* capex related network costs;
* opex related network costs;
* CAPEX – administration and support;
* OPEX – administration and support.

CAPEX related network costs cover network components listed in section *5.3 List of network components*[[2]](#footnote-2). CAPEX related network management system costs, OPEX related network costs, OPEX and CAPEX for administration and support, are listed and discussed in section *7.2 Mark-up allocation*.

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

## Model scenarios

There are 10 operators of fixed electronic communications network with significant market power – TEO LT, AB is the historical incumbent and 9 alternative fixed network operators. RRT regulates call termination prices of all operators, but prices of call termination services on 9 alternative fixed network operators are linked to price level of TEO LT, AB. Therefore, only one cost calculation model scenario will be developed.

# Flow of BU-LRAIC modeling

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

Figure 8 illustrates the overall flow of BU-LRAIC modeling. Accordingly, the structure of this reference paper is aligned with the provided flow as well.

**Network demand**

**Network dimensioning**

**Service costs calculation**

**Network valuation**

Figure 8: The overall flow of BU-LRAIC methodology.

## Network demand

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

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

The detailed explanation of network demand principles is provided in section *6.1 Calculating network demand*.

## Network dimensioning

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

The detailed explanation of network dimensioning principles is provided in section 6 *Dimensioning of the network*.

## Network valuation

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

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

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

CAPEX costs consist of Return on Investment (ROI) and depreciation. OPEX costs consist of salaries (including social insurance), material and costs of external services (external services – transportation, security, utilities, etc).

The detailed analysis of methodologies to annualize CAPEX costs is provided in section *7.1 Cost annualization.*

A detailed explanation of Mark-ups used to recover network related operational cost, administration and support operational and capital costs and network management system capital cost is provided in sections *2.7 Mark – ups* and *7.2 Mark-up allocation*.

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

## Service cost calculation

The fundamental principle of LRAIC methodology – costs are allocated to network components, network components are mapped with network services and in this way the costs are calculated (see Figure 9).

**Homogeneous cost categories**

**Network components**

**Services**

Figure 9: Cost allocation principles.

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

The detailed explanation of service cost calculation is provided in section 8 *Service cost calculation.*

# Scope of the model

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

## List of services

As migration to NGN flattens the network topology, a network model contains only single level of the network hierarchy. Therefore there might be no need to differentiate call origination and call termination into local and national level and there might be no need to have 5 types of transit as it is currently in regulation of PSTN services. As a result, list of services included in the first BU-LRAIC sub-model comprise:

1. Call origination;
2. Call termination;
3. Call transit (7 types):

* Transit of national calls:

a) Transit of call via network thought single switch (operators are interconnected at the same switch) originated and terminated in Lithuania – Transit 1

b) Transit of a call originated and terminated in Lithuania from switch (excluding that switch), where interconnection is provided or can be provided, to switch (inclusive), where interconnection is provided or can be provided (operators are interconnected at different switches) – Transit 3

c) Transit of call originated and terminated in Lithuania via network – Transit 1/3

* Transmission of international call through (Transit) switch (inclusive), when international call is originated in network in Lithuania – Transit 4;
* Transmission of international call from (Transit) switch (excluding that switch) to International (Transit) switch (inclusive), when international call is originated in networks in Lithuania – Transit 5.
* Transit of call via network originated in Lithuania and terminated abroad –Transit 4/5;
* Transit of call originated abroad and terminated in Lithuania via network– Transit 6.

1. Capacity based services.

Cost calculation of capacity based services is described in section *8.3 Service cost*.

All services have peak and off-peak hours. Service averaging to peak and off peak hours will be calculated using the ratios provided by the operators.

The list of services included in the second BU-LRAIC sub-model comprises provision of auxiliary services for network interconnection.

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

Table 2. Outcome of the first BU-LRAIC sub-model

| **Service name** | **Service accounting unit** | **Unit costs** | **Network Components** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Access Node (AN) | Transit node (TN) | Transmission AN-TN | Transmission TN-TN | IMS | IC Billing | MGW - POI | IE[[3]](#footnote-3) | Transmission TN-IE\* | CPE |
| Call origination | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call termination | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 1 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 3 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 1/3 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 4 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 5 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 4/5 | Minutes |  |  |  |  |  |  |  |  |  |  |  |
| Call transit 6 | Minutes |  |  |  |  |  |  |  |  |  |  |  |

## List of homogeneous cost categories

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

Table 3 indicates the list of homogeneous cost categories (HCC) in BU-LRAIC model.

Table 3. List of HCC in BU-LRAIC model

| **HCC name** | **HCC sub-components** |
| --- | --- |
| **Infrastructure** | *Trench*  *Primary duct - 1 hole*  *Primary duct - 2 holes*  *Primary duct - 6 holes*  *Primary duct - 12 holes*  *Primary duct - 24 holes*  *Primary duct - 48 and more holes*  *Manholes* |
| **Ground reconstruction** | *Grass reconstruction*  *Sidewalk reconstruction*  *Asphalt pavement reconstruction*  *Concrete pavement reconstruction* |
| **Passages under obstacles** | *Passage under road (up to 15m)*  *Passage under road (above 15m)*  *Passage under railway tracks*  *Passage under rivers and channel*  *Passage under other obstacles* |
| **Additional works** | *Project works*  *Consent of the landowners*  *Geodetic service* |
| **Fiber cable** | *Fiber cable – 12 fibers*  *Fiber cable – 24 fibers*  *Fiber cable – 48 fibers*  *Fiber cable – 72 fibers*  *Fiber cable – 96 fibers*  *Fiber cable – 144 fibers* |
| **Joints for fiber cables** | *Joint for 12 fibers*  *Joint for 24 fibers*  *Joint for 48 fibers*  *Joint for 72 fibers*  *Joint for 96 fibers*  *Joint for 144 fibers*  *Section measurement* |
| **MSAN** | *Chassis - Type 1*  *Chassis - Type 2*  *Chassis - Type 3*  *Chassis - Type 4*  *Chassis - Type 5*  *Subscriber cards - Type 1 - ADSL*  *Subscriber cards - Type 2 - SHDSL*  *Subscriber cards - Type 3 - POTS*  *Subscriber cards - Type 4 - ISDN - BRA*  *Trunking card - Type 1*  *Optical module - 10GE Type 1 - LR (Long Range)* |
| **OLT** | *Chassis - Type 1*  *Chassis - Type 2*  *Chassis - Type 3*  *Subscriber cards - Type 1 - GPON*  *Optical module- Subscriber cards*  *Trunking card - Type 1*  *Optical module - 10GE Type 1 - LR (Long Range)* |
| **Access Ethernet Switch** | *Chassis - Type 1*  *Subscriber cards - Type 1 - P2P*  *Subscriber cards - Type 2 - P2P*  *Trunking cards - GE - Type 1*  *Trunking cards - GE - Type 2*  *Optical module - Subscriber cards*  *Optical module - Trunking cards - GE* |
| **Edge Ethernet Switch** | *Chassis - Type 1*  *Chassis - Type 2*  *Chassis - Type 3*  *Switching cards*  *Trunking cards - GE - Type 1*  *Trunking cards - GE - Type 2*  *Trunking cards - 10GE - Type 3*  *Trunking cards - 10GE - Type 4*  *Optical module - GE- Type 1 - SR - (Short Range)*  *Optical module - GE- Type 2 - LR (Long Range)*  *Optical module - 10GE Type 1 - SR - (Short Range)*  *Optical module - 10GE Type 2 - LR (Long Range)* |
| **Aggregation Edge Ethernet Switch** | *Chassis - Type 1*  *Chassis - Type 2*  *Chassis - Type 3*  *Switching cards*  *Trunking cards - GE - Type 1*  *Trunking cards - GE - Type 2*  *Trunking cards - 10GE - Type 3*  *Trunking cards - 10GE - Type 4*  *Optical module - GE- Type 1 - SR - (Short Range)*  *Optical module - GE- Type 2 - LR (Long Range)*  *Optical module - 10GE Type 1 - SR - (Short Range)*  *Optical module - 10GE Type 2 - LR (Long Range)* |
| **Core Ethernet Switch** | *Chassis - Type 1*  *Chassis - Type 2*  *Chassis - Type 3*  *Switching cards*  *Trunking cards - GE - Type 1*  *Trunking cards - GE - Type 2*  *Trunking cards - 10GE - Type 3*  *Trunking cards - 10GE - Type 4*  *Optical module - GE- Type 1 - SR - (Short Range)*  *Optical module - GE- Type 2 - LR (Long Range)*  *Optical module - 10GE Type 1 - SR - (Short Range)*  *Optical module - 10GE Type 2 - LR (Long Range)* |
| **Transit Node - IP router** | *Chassis - Type 1*  *Chassis - Type 2*  *Switching cards*  *Trunking cards - 10GE - Type 1*  *Trunking cards - 10GE - Type 2*  *Optical module - 10GE Type 1 - SR - (Short Range)*  *Optical module - 10GE Type 2 - LR (Long Range)* |
| **MGW** | *Chassis - Type 1*  *Voice processing card*  *Trunking cards - GE - Type 1*  *Trunking card - Type 1*  *Trunking card - Type 2*  *Trunking card - Type 3*  *Trunking card - Type 4*  *Optical module - 1GE Type 1 - SR - (Short Range)* |
| **MGC** | *Main unit – MGC*  *Expansion unit – MGC* |
| **IMS** | *IMS – Cabinet*  *IMS core - Service frame*  *IMS core - Service card - Type 1 – A-SBG*  *IMS core - Service card - Type 2 - VoIP AS*  *IMS core - Service card - Type 3 - CSCF & MRCF*  *IMS core - Service card - Type 4 - BGCF*  *IMS core - Service card - Type 5 - DNS server*  *IMS core - Service card - Type 6 - Service delivery AS*  *HSS - Service card - Type 1 - Control card*  *HSS - Service card - Type 2 - Database card*  *IMS - Licenses - Type 1 – subscriber*  *IMS - Licenses - Type 2 – traffic*  *HSS – Licenses* |
| **Billing IC System** | *Main unit*  *Expansion unit* |
| **Regulatory costs** | *Regulatory costs* |
| **Optical CPE equipment** | *Optical CPE equipment* |

## List of network components

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

* Access Node (AN)
* Transit Node (TN)
* Transmission - AN – TN
* Transmission - TN – TN
* IMS
* IC Billing
* MGW / MGC
* IE
* TN - IE
* CPE

# Dimensioning of the network

As mentioned in section *2.6 Technological background,* the following dimensioning will only incorporate NGN network structure.

The critical step in dimensioning the network is developing the engineering models for network elements transmission systems and cable infrastructure. In case of bottom-up LRAIC 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:

* Based on voice and data traffic volume, gathered from operators, the dimensioning of MSAN network will be performed;
* Based on traffic switched and routing factors, the dimensioning of Ethernet and IP transmission nodes will be performed.

Technical – Technological model will only model these infrastructure components that are required for the delivery of wholesale services, calculated in Economic model. 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.

## Calculating network demand

The starting point for the model is the existing demand, which is measured by:

* On net calls (except calls to short telephone numbers) to VoIP and PSTN;
* Off net calls (except calls to short telephone numbers) to VoIP, PSTN, mobile networks;
* International calls (except calls to short telephone numbers) to VoIP, PSTN and mobile networks in foreign countries;
* Calls to short telephone numbers (free of charge and charged) to VoIP, PSTN and mobile networks to short telephone numbers;
* Call termination of calls which were initiated on VoIP, PSTN and mobile networks;
* Call origination;
* Call transit 1;
* Call transit 2;
* Call transit 3;
* Call transit 4;
* Call transit 5;
* Call transit 6;
* Internet access services to businesses and residents;
* IPTV services;
* Other voice and data transmission services;
* Access to network provided at fixed location.

## Conversion of circuit switched traffic into packet data traffic

Since NGN network is a packet based network, all circuit switched traffic (volume of billed minutes) must be converted into packet data traffic (volume of kbps). This calculation consists of the following steps:

1. Calculation of volume of ports utilized by subscribers of voice services

Based on the engineering model of MSAN, the number of ports utilized by the subscribers of voice services would be calculated. For detailed calculations see formula (3).

1. Calculation of BHT (Busy Hour Traffic) per subscriber ports

Based on busy hour traffic demand on MSANs (described further in the document) and the volume of ports utilized by subscribers of voice services from the first step, the volume of BHmE (Busy Hour mili Erlangs) per subscriber port would be calculated. For detailed calculations see formula (2).

1. Calculation of volume of BHE (Busy Hour Erlangs) for each MSAN

For each MSAN the volume of BHE would be calculated. This would be done multiplying the volume of ports utilized by subscribers of voice services by volume of BHmE (Busy Hour mili Erlangs) per subscriber port.

The volume of BHE determines how many VoIP channels are required to handle the voice traffic in the busy hour. For detailed calculations see formula (11), where BHE calculation is incorporated in estimating voice bandwidth volume.

1. Calculation of VoIP cannel bandwidth.

This calculation 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:

|  |  |
| --- | --- |
|  | (1) |

Where,

- IP header (bytes);

- UDP header (bytes);

- RTP header (bytes);

- Ethernet header (bytes);

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

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

- Priority factor.

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

Table 4. VoIP codecs and their required channel bandwidth

|  |  |  |
| --- | --- | --- |
| **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*

1. Calculation of busy hour voice bandwidth for each MSAN.

For each MSAN busy hour bandwidth is calculated multiplying the volume of BHE by the bandwidth of voice channel. For detailed calculations see formula (11).

Volume of data transmission services with guaranteed throughputs will be calculated based on the nominal capacities of these services.

The volume of the best effort data transmission services will be calculated based on the total annual traffic of these services.

## Calculating traffic demand on network elements

The demand for services then needs to be adjusted to include allowance for growth, and an allowance for capacity utilization. Taken together, these give the total demand for traffic on each network element. Once the existing demand has been adjusted to include the above factors, the total demand is attributed to each network element through the use of “routing factors”.

Table 5. Routing factors

|  | **Service type** | | | **Routing factors** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|  |  | |  | Access Node (AN) | Transit Node (TN) | Transmission - AN - TN | Transmission - TN - TN | Transmission - TN - POI | IE - International Exchange[[4]](#footnote-4) | Transmission - TN – IE\* |
|  | | Local calls – on-net calls (in the network of incumbent operator) | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | National calls – on-net calls (in the network of incumbent operator) | | 2,00 | 2,00 | 2,00 | 1,00 | 0,00 | 0,00 | 0,00 |
|  | | International calls (except calls to short telephone numbers) to VoIP, PSTN and mobile networks in foreign countries; | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 1,00 | 1,00 |
|  | | Calls to short telephone numbers | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Interconnection calls – outgoing on local level | | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 0,00 | 0,00 |
|  | | Interconnection calls – outgoing on national level | | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 0,00 | 0,00 |
|  | | Interconnection calls – incoming on local level | | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 0,00 | 0,00 |
|  | | Interconnection calls – incoming on national level | | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 0,00 | 0,00 |
|  | | Interconnection calls – transit 1 | | 0,00 | 1,00 | 0,00 | 0,00 | 2,00 | 0,00 | 0,00 |
|  | | Interconnection calls – transit 2 | | 0,00 | 1,00 | 0,00 | 1,00 | 2,00 | 0,00 | 0,00 |
|  | | Interconnection calls – transit 3 | | 0,00 | 1,00 | 0,00 | 1,00 | 2,00 | 0,00 | 0,00 |
|  | | Interconnection calls – transit 4 | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 0,00 |
|  | | Interconnection calls – transit 5 | | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 | 1,00 | 1,00 |
|  | | Interconnection calls – transit 6 | | 0,00 | 1,00 | 0,00 | 0,00 | 1,00 | 1,00 | 1,00 |
|  | | Other connections | | 1,00 | 1,00 | 1,00 | 0,00 | 1,00 | 0,00 | 0,00 |
|  | | Internet access services - residential subscribers | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Internet access services - business subscribers | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Internet access services - wholesale subscribers | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | IPTV services | | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | ATM/Ethernet data transmission - IP corporate | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | ATM/Ethernet data transmission - IP Access | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Other | | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end analog leased lines - 64 Kbit/s | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end digital leased lines - nx64 Kbit/s | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end digital leased lines - 2 | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end leased lines - STM-0 | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end leased lines - STM-1 | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |
|  | | Year end leased lines - STM-4 | | 2,00 | 1,00 | 2,00 | 0,00 | 0,00 | 0,00 | 0,00 |

Routing factors show how intensively each network element is used for each type of service. For example, a call may on average use between one and two MSANs, and less than one transit IP router. The network, however, does not need to be dimensioned for total traffic, but must be able to meet the demand at the busiest hour of the year. To that end, the model requires information on:

* Voice and data traffic in the conventional busiest hour of the year; and
* Annual realized voice and data traffic.

From these two estimates, a percentage to apply to the total traffic to estimate the dimensioned busy hour can be derived.

## Vocabulary of formulas

In the table below the vocabulary of formulas used to dimension network elements is described:

Table 6. Vocabulary for the formulas

| **Abbreviation** | **Explanation** |
| --- | --- |
|  | Number of x elements |
|  | Volume of x traffic |
|  | Number of subscribers/services |
|  | Throughput of x element |
|  | Headroom allowance |
|  | Proportion expressed in percentage |
|  | Capacity of x element |

Moreover, formulas marked in a frame represent the main formulas, which dimension elements under the topic and formulas without the frame are additional in order to derive the values needed for dimensioning.

## Dimensioning of the Access Nodes

The approach to dimensioning for the Access Nodes takes the following respects:

* It uses the number of ports required for the provisioning of defined services;
* It uses billed minutes and data traffic as the starting point;

**ODF**

* It incorporates holding times and an allowance for growth;
* It uses routing factors to determine the intensity with which each network element is used;
* It dimensions the network to meet the busy hour demand;
* It then adjusts this capacity to allow for flows between nodes and to provide resilience.

**ODF**



Figure 10. Transition from PSTN to NGN and place of MSAN/OLT/Access Ethernet switch

Dimensioning of the Access Nodes will be performed according to the scorched node approach. Scorched earth approach is not used in dimensioning Access Network in order not to affect the market of wholesale access services currently provided at access node locations. Assumptions of Scorched Node approach are as follows:

* For each Access Node location collect geographical data (address, coordinates) – scorched node approach, which will not affect wholesale access services;
* For each Access Node location collect volume of connected services. Specifically: voice services provided over cooper access network, voice services provided over optical access network, ISDN BRA services, ISDN PRA services, Internet access services provided over cooper access network, Internet access services provided over optical access network using GPON or P2P architecture, TDM leased lines, TDM leased lined – high speed, ATM/Ethernet data transmission services;
* It is assumed that leased lines will be provided based on SDSL /HDSL technology;
* It is assumed that high speed TDM leased lines will be provided based on Ethernet technology;
* ATM data transmission services will be provided based on Ethernet technology;
* MSANs will be dimensioned where support of subscribers connected to the network over POTS, ISDN and xDSL technologies is necessary;
* Access Ethernet Switches will be dimensioned where support of subscribers connected to the network over Point to Point technology is necessary;
* Optical Line Terminals will be dimensioned where support of subscribers connected to the network over GPON technology is necessary.

After the information is collected and the stated assumption takes place, dimensioning the number of required equipment in Access Nodes is calculated in these steps:

1. Calculation of the average throughput per port utilized by subscribers of voice services and the average throughput per port utilized by the subscribers of data services for each network component;
2. Calculation of number of subscriber and trunking ports needed at each Access Node location, using the calculated throughputs to estimate the demand of traffic through the mentioned ports;
3. Determination of network element’s main unit type (chassis) for each Access Node location depending on the number of subscriber and trunking cards needed at each Access Node location;

#### Calculation of average throughput of Access Node network elements

Average throughput per ports utilized by the subscribers of voice services based on network demand calculation is calculated using the following formula:

|  |  |
| --- | --- |
|  | (2) |

Where,

 - Average throughput per port for each network component (NC);

- Total realized services volume;

- Busy Hour to Average Hour traffic ratio. This factor shows the proportion of busy and average traffic;

 - Average utilization of network component. See formula (4);

- Volume of equivalent voice lines. See formula (3);

 - Number of GPON and Point to Point voice subscribers.

The volume of equivalent voice lines is calculated using the following formula:

|  |  |
| --- | --- |
|  | (3) |

Where,

- Number of equivalent voice lines;

 - Number of voice lines;

 - Number of ISDN-BRA lines;

 - Number of ISDN-PRA lines;

 - Equivalent voice channels – POTS;

 - Equivalent voice channels - ISDN-BRA;

 - Equivalent voice channels - ISDN-PRA.

The average utilization of network component is calculated using the following formula:

|  |  |
| --- | --- |
|  | (4) |

Where,

- Total weighted voice service volume on network component;

- Total realized voice service volume;

- Average utilization of network component.

The total weighted service volumes for each network component are calculated using the following formula:

|  |  |
| --- | --- |
|  | (5) |

Where,

- Total weighted voice services volume on network component;

- Service volume of *i* -voice service;

- Routing factor of i voice service defined for particular network component. See Table 5;

- Voice service;

- Number of voice services.

The average throughput per ports utilized by subscribers of data services based on average throughputs and overbooking factors is calculated using the following formula:

|  |  |
| --- | --- |
|  | (6) |

Where,

 - Average data throughput per port;

 - Data service Busy Hour traffic;

 - Total amount ofservices;

 - Priority factor forservice;

#### Calculation of number of ports in Access Nodes

For each Access Node location the number of services (POTS, xDSL, GPON, P2P) is calculated using the following formula:

|  |  |
| --- | --- |
|  | (7) |

Where,

 - Number ofservices;

 - Volume of services at access node location;

 - Total amount of users/subscribers;

 - Total amount of services provided at access nodes.

For each Access Node location the calculation of trunking ports (GE, 10 GE) based on the required capacity and technical assumptions (ring structure, redundancy) is done using the following formulas:

* For OLT and Access Ethernet Switches:

|  |  |
| --- | --- |
|  | (8) |

Where,

- Demand from voice services provided over fiber in Mbit/s. It is calculated by multiplying the traffic generated by voice services in Erlangs provided over GPON and P2P technologies in Access Node location by  VoIP channel bit rate (see formula (12));

- Demand from data services provided over fiber in Mbit/s. It is calculated using formula (13), except number of GPON and P2P services is taken.

- Headroom allowance;

- Demand from IPTV services provided over fiber in Mbit/s.

Demand from IPTV services is calculated using the following formula:

|  |  |
| --- | --- |
|  | (9) |

Where,

- Number of IPTV services present at Access Node location;

- Average throughput of IPTV service. See formula (6);

 - Average throughput of VOD service. See formula (6);

- Maximal amount of channels provided to the subscribers;

- Average throughput required to show one channel via IPTV.

* For MSAN:

|  |  |
| --- | --- |
|  | (10) |

Where,

- Number of trunking ports;

- Headroom allowance;

 - Demand from voice services in Mbit/s. See formula (11);

 - Demand from data services in Mbit/s. See formula (13).

Traffic demand created by voice services is calculated using the following formula:

|  |  |
| --- | --- |
|  | (11) |

Where,

 - Number of lines in the access node location. See formula (3);

- Average throughput of Access Node ports. See formula (2);

- VoIP channel bit rate.

The bit rate depends on codec used and is calculated using the following formula:

|  |  |
| --- | --- |
|  | (12) |

Where,

- IP header (bytes);

- UDP header (bytes);

- RTP header (bytes);

- Ethernet header (bytes);

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

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

- Priority factor.

Traffic demand created by data services is calculated using the following formula:

|  |  |
| --- | --- |
|  | (13) |

Where,

- Throughput of data service (internet access service, analog or nx64 or 2Mbit/s leased lines);

- Number of data service volume. See formula (7).

#### Determination of unit types (chassis) of network elements in Access Node

For each Access Node location, determine main unit type (chassis) based on the calculated required capacity of subscriber and trunking cards.

Main unit type (chassis) is dimensioned using the following formula:

|  |  |
| --- | --- |
|  | (14) |

Where,














Where,

 - Volume of network element’s at Access Node chassis Type x, where x for MSAN = {1, 2, 3, 4, 5} and for OLT and Access Ethernet Switch = {1, 2, 3};

- Number of subscriber cards at Access Node location. See formula (17);

- Number of trunking cards at Access Node location. See formula (18);

 - Volume of traffic to be handled by network element in Access Node location defined in Mbit/s. The value is retrieved by summing  and values. See formulas (11) and (13);

- Volume of voice service defined in BHCA. See formula (19);

- Capacity of network element’s chassis Type x, defined in volume of subscriber cards;

- Capacity of network element’s chassis Type x, defined in volume of trunking cards;

- Switching capacity of network element’s chassis Type x, defined in Mbit/s;

- Voice processing capacity of network element’s chassis Type x, defined in BHCA.

For OLT and Access Ethernet Switches, the main unit types are estimated without including the parts of the formula.

Calculation of the required subscriber cards per Access Node location is done using the following formulas:

* For OLT:

|  |  |
| --- | --- |
|  | (15) |

Where,

 - Number ofservices (voice, internet access and IPTV) provided over GPON technology. See formula (7);

- Headroom allowance for ports;

- Split ratio of the GPON fiber;

- Capacity of ports in subscriber card.

* For Access Ethernet Switch:

|  |  |
| --- | --- |
|  | (16) |

Where,

 - Number ofservices (voice, internet access and IPTV) provided over Point-to-Point technology. See formula (7);

- Headroom allowance for ports;

- Capacity of ports in subscriber card.

* For MSAN:

|  |  |
| --- | --- |
|  | (17) |

Where,

- Volume of subscriber cards;

- Capacity of services/ports in subscriber card;

 - Number of services at access node location. See formula (7);

- POTS, internet access services;

- Headroom allowance for services.

Calculation of the required trunking cards per Access Node location is done using the following formula:

|  |  |
| --- | --- |
|  | (18) |

Where,

 - Number of trunking cards;

 - Number of trunking ports in Access Node location. See formula (10) and (8) depending on the network element present in the AN;

 - Capacity of trunking ports in trunking card.

Voice busy hour call attempts at Access Node location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (19) |

Where,

 - Busy hour call attempts at Access Node location;

 - Number of lines in the access node location. See formula (3);

- Headroom allowance for voice processing elements;

 - Average busy hour call attempts per port for in Access Node (AN). See formula (20).

 is calculated using the following formula:

|  |  |
| --- | --- |
|  | (20) |

Where,

 - Average BHCA per port for each network component (NC);

- Total realized services volume;

- Busy Hour to Average Hour traffic ratio.

 - Ratio of unsuccessful call attempts to total call attempts;

 - Number of lines in the access node location. See formula (3);

 - Average call length.

From the traffic-related costs only Access Node equipment costs, which would be avoided in the absence of a service being provided, should be allocated to the relevant increment, excluding subscriber’s access cards for call termination and origination.

## Dimensioning transit network

Transit node can be calculated in as-is state (scorched node) or optimize state (scorched earth). In as-is state (scorched node) Transit IP routers will replace Transit Exchanges at the existing locations. In optimized state (scorched earth) Transit IP routers will be located in the main cities where POI is provided. However, the following calculation formulas apply in dimensioning using both approaches – scorched earth and node.

In order to dimension Transit nodes, the following assumptions have to be taken:

* Locate Core IP routers in the main city of Transit Zones.
* Assign Aggregation Edge Ethernet Switches to Transit Zones.

After an assumption takes place, dimensioning the number of the required Core IP routers is calculated in these steps:

1. Calculation of required number of ports for each Core IP router. See formula (21)
2. Calculation of volume of IC traffic for each Core IP router and MGW, based on services traffic volume and routing factors. See formula (42) where voice IC traffic is estimated in erlangs and formula (23) where data traffic is dimensioned in the amount of GE ports
3. Determination of main unit (chassis) types of each MGWs based on the number and required capacity IC ports. See formula (39)
4. Calculation of number of expansion cards (E1, STM-1, GE) for each MGW. See formulas (40) - (47)
5. Determination of main unit (chassis) types for each Core IP router based on the number of ports and the required capacity. See formula (51)
6. Calculation of number of expansion cards (GE, 10 GE, routing expansion, management) for each Core IP router. See formulas (52) - (54)

#### Calculation of number of ports of Core IP router

There are two types of ports in Core IP routers: 10GE short range and 10GE long range. Therefore, the total amount of required ports is the sum of 10GE ports for TN location. It is calculated using the following formula:

|  |  |
| --- | --- |
|  | (21) |

Where,

 - Total required number of 10GE ports in Core IP router at TN location;

 - Number of long range 10GE ports in TN location. See formula (28);

 - Number of short range 10GE ports in TN location. See formula (22).

**a) Calculation of 10GE short range ports:**

The number of required of 10GE short range ports in TN location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (22) |

Where,

 - Number of GE interfaces used in TN for transferring data to peering points. See formula (23);

 - Number of GE interfaces required for MGW for IC traffic handling. See formula (38);

 - Headroom allowance of IP router trunking cards;

 - Number of GE interfaces present at Core Ethernet switching network connected to TN location. See formula (27).

Number of GE interfaces used for data transfer to peering points is calculated using the following formula:

|  |  |
| --- | --- |
|  | (23) |

Where,

 - Average utilization of the appropriate network component. See formula (4);

 - Volume of traffic from high speed leased lines in Gbit/s. See formula (24);

 - Volume of services at TN location. See formula (26);

 - Volume of traffic from data transmission services in Gbit/s. See formula (24).

Volumes of traffic of the mentioned services are calculated using the following formula:

|  |  |
| --- | --- |
|  | (24) |

Where,

 - Average throughput per port of appropriate data service in Kbit/s. See formula (6);

 - Volume of services (STM-LL or ATM) provided at TN location.

The services volume is calculated using the following formula:

|  |  |
| --- | --- |
|  | (25) |

Where,

 - Volume of services (STM-LL or ATM) provided at TN location (input data);

 - Total volume of services (STM-LL or ATM) provided at TN location (input data);

 - Total amount of service (STM-LL or ATM) subscribers (input data).

Volumes of ,  and  will be gathered via questionnaire from the operator.

Volume of Wholesale Internet Access services traffic outgoing the network () is calculated using the following formula:

|  |  |
| --- | --- |
|  | (26) |

Where,

 - Proportion of internet access services to wholesale subscribers;

 - Average throughput per port of appropriate data service. See formula (6);

 - Number of Internet Access services present at TN location;

- Proportion of POI traffic outgoing at IP routers level.

The number of short range GE interfaces required for Core Ethernet switch connected to TN location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (27) |

Where,

 - Traffic incoming from Ethernet switching layer to Transit Nodes. This traffic is calculated by summing the volume of traffic incoming into Ethernet Switches minus the volume of traffic which is outgoing from the Ethernet switch layer;

 - Headroom allowance of Ethernet switches trunking cards.

**b) Calculation of 10GE long range ports:**

The number of required of 10GE long range ports in TN location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (28) |

Where,

 - Headroom allowance of IP router trunking cards;

 - Number of 10GE ports required in TN location to handle traffic generated by voice and data services.

The number of required 10GE ports in TN location to transfer data between Transit Nodes is calculated using the following formula:

|  |  |
| --- | --- |
|  | (29) |

Where,

- Volume of traffic generated by voice services and traveling through TN. It is calculated using formula (30);

 - Volume of traffic generated by data services and traveling through TN. It is calculated using formula (31).

Traffic generated by voice services is calculated using the following formula:

|  |  |
| --- | --- |
|  | (30) |

Where,

 - Number of equivalent voice lines. See formula (3);

 - Number of GPON and Point to Point voice subscribers;

 - VoIP channel bit rate. See formula (12);

 - Average throughput per port for appropriate network component (NC). In this case for TN-TN network component. See formula (2).

Traffic generated by data services in Gbit/s going from TN location to other TN location () is calculated by the following formula:

|  |  |
| --- | --- |
|  | (31) |

Where,

- Average utilization of appropriate network component. See formula (4);

 - Volume of traffic from leased lines (analog, 2mb and nx64 leased lines) present at TN location. See formula (34);

 - Volumes of traffic of data services in Gbit/s present at TN location. See formula (24);

 - Volume of traffic of IPTV services, estimated by converting the average throughput of IPTV services into Gbit/s;

 - Volume of Internet Access services traffic in Gbit/s present at TN location. See formula (32).

Volume of Internet Access services traffic () is calculated using the following formula:

|  |  |
| --- | --- |
|  | (32) |

Where,

 - Volume of traffic generated by internet access services for residents;

 - Volume of traffic generated by internet access services for businesses;

 - Volume of traffic generated by internet access services for wholesale.

These internet access service volumes are calculated using the following formula:

|  |  |
| --- | --- |
|  | (33) |

Where,

- Volume of traffic generated by internet access services for residents, businesses or wholesale;

 - Proportion of Internet Access services provided for appropriate user (resident, business, wholesale);

 - Average throughput per port of appropriate data service. See formula (6);

 - Number of Internet Access services at TN location.

The volume of traffic aggregated from leased lines is calculated using the following formula:

|  |  |
| --- | --- |
|  | (34) |

Where,

 - Volume of traffic coming from lines (analog, nx64 or 2mb). See formula (35).

This volume is calculated using the following formula:

|  |  |
| --- | --- |
|  | (35) |

Where,

 - Average throughput per port of appropriate data service;

 - Number of leased lines (analog, nx64 or 2mb) present at TN location. See formula (36).

The number of leased lines present at TN location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (36) |

Where,

 - Total amount of leased lines service provided by the operator (input parameter);

- Rank of the lines (see formula (3)) present at TN location with leased lines services;

- Preliminary amount of leased lines service present at TN location. See formula (37).

Amounts of leased lines will be gathered from operator via questionnaire.

The preliminary amount of leased lines at TN location is calculated using the following formula:

|  |  |
| --- | --- |
|  | (37) |

Where,

- Volume of leased line services in the selected year;

 - Number of leased line services present at TN location with leased lines services.

#### Calculation of IC ports of MGW

For each MGW calculate the required number of IC ports.

The number of GE interfaces is calculated using the following formula:

|  |  |
| --- | --- |
|  | (38) |

Where,

 - Number of GE interfaces required for MGW for IC traffic handling;

 - Minimal number of TN-MGW interfaces, it is assumed that at least one GE interface is required between TN and MGW.

 - Traffic from TN to POI in erlangs. See formula (42);

 - VoIP channel bit rate. See formula (12).

* + - 1. **Determination of MGW main units**

For each MGW the main unit (chassis) type based on IC ports number and the required capacity is determined. Chassis type and amount is determined using the following formula:

|  |  |
| --- | --- |
|  | (39) |

Where,

 - Number of MGW chassis;

 - Slot capacity of MGW chassis;

 - Number of type cards;

- Type of expansion card for MGW chassis, one of five types;

* + - 1. **Calculation of expansion cards of MGWs**

For each MGW calculate volume of expansion cards (E1, STM-1, GE). There are 5 types of trunking/expansion cards which support different interfaces and voice processing card. Below formulas for dimensioning of each Type of cards are provided.

1. **Dimensioning of MGW expansion cards Type 1:**

|  |  |
| --- | --- |
|  | (40) |

Where,

 - Number of Type 1 MGW trunking cards;

- Headroom allowance for MGW trunking cards;

 - Capacity of Type 1 trunking card measured in E1 interfaces;

 - Capacity of Type 2 trunking card measured in E1 interfaces;

 - Proportion of E1 interfaces joining MGW and POI;

- Number of E1 interfaces connecting MGW and POI. This element is calculated in formula (41);

 - Number of Type 2 MGW trunking cards. See formula (43).

The number of E1 interfaces () is calculated using the following formula:

|  |  |
| --- | --- |
|  | (41) |

Where,

 - Capacity of 2Mbit/s link in Erlangs;

 - Traffic in erlangs between TN and MGW. See formula (42).

This traffic is calculated using the following formula:

|  |  |
| --- | --- |
|  | (42) |

Where,

 - Volume of traffic in ERL between appropriate network components;

 - Number of MSAN equivalent voice lines (see formula (3)) aggregated by TN;

 - Number of GPON and Point to Point voice lines aggregated by TN ;

 - Average throughput of the appropriate network component. See formula (2).

**b) Dimensioning of MGW expansion cards Type 2:**

|  |  |
| --- | --- |
|  | (43) |

Where,

;

- Number of E1 interfaces connecting MGW and POI. See formula (41);

 - Proportion of E1 interfaces joining MGW and POI;

 - Capacity of Type 1 trunking card measured in E1 interfaces;

 - Capacity of Type 2 trunking card measured in E1 interfaces;

- Headroom allowance for MGW trunking cards;

**c) Dimensioning of MGW expansion cards Type 3:**

|  |  |
| --- | --- |
|  | (44) |

Where,

 - Number of Type 3 MGW trunking cards, rounded up to the nearest integer;

- Number of E1 interfaces connecting MGW and POI. See formula (41);

 - Proportion of STM-1 interface joining MGW and POI;

- Headroom allowance for media gateway trunking cards;

 - Capacity of Type 3 trunking card measured in STM-1 interfaces;

 - Capacity of SMT-1 interfaces in POI measured in E1 interfaces.

**d) Dimensioning of MGW expansion cards Type 4:**

|  |  |
| --- | --- |
|  | (45) |

Where,

 - Number of Type 4 MGW trunking cards;

- Number of E1 interfaces connecting MGW and POI. See formula (41);

 - Proportion of STM-4 interface joining MGW and POI;

- Headroom allowance for media gateway trunking cards;

 - Capacity of Type 4 trunking card measured in STM-4 interfaces;

 - Capacity of SMT-4 interfaces in POI measured in E1 interfaces.

**e) Dimensioning of MGW expansion cards to support GE interfaces:**

|  |  |
| --- | --- |
|  | (46) |

Where,

 - Number of GE MGW trunking cards in MGW;

 - Capacity of GE trunking card measured in GE interfaces;

 - Number of GE interfaces connecting MGW with TN, rounded up to integer. See formula (38).

**f) Dimensioning of MGW voice processing cards:**

|  |  |
| --- | --- |
|  | (47) |

Where,

 - Capacity of voice processing card to handle erlangs;

 - Volume of traffic in ERL between appropriate network components. See formula (42);

- Headroom allowance for MGW switching cards.



#### Media Gateway Controller

Media Gateway Controller (MGC) is dimensioned to provide control function for the dimensioned MGW.

MGC comprises of the following parts:

* Base unit and software;
* MGC extension.

The number of MGC base units (, units) is calculated according to the following formula:

|  |  |
| --- | --- |
|  | (48) |

Where,

- Number of MGC main units;

 - MGC main unit slot capacity;

- Number of MGC expansion cards.

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

|  |  |
| --- | --- |
|  | (49) |

Where,

 - Expansion unit capacity in BHE;

- Headroom allowance for MGC hardware and software;

 - Volume of traffic in ERL between appropriate network components. See formula (42);

#### Determination of main unit types of Core IP router

For each Core IP router the main unit (chassis) type based on the number of ports and the required capacity is determined. The amount of each chassis is calculated using the following formula:

**Dimensioning of Ethernet core IP Router chassis Type 1:**

|  |  |
| --- | --- |
|  | (50) |

Where,





Where,

 - Number of core IP router chassis Type 1;

 - Number of core IP router chassis Type 2. See formula (51);

- Sum of Type 1 and Type 2 trunking cards with 10 GE interfaces. See formulas (59) - (62);

- Sum of switching cards. See formula (58);

- Capacity of core IP router chassis Type 2, defined in volume of 10 GE cards;

- Capacity of core IP router chassis Type 1, defined in volume of 10 GE cards;

- Capacity of core IP router chassis Type 2, defined in volume of switching cards;

- Capacity of core IP router chassis Type 1, defined in volume of switching cards.

**Dimensioning of Ethernet core IP Router chassis Type 2:**

|  |  |
| --- | --- |
|  | (51) |

Where,




Where,

 - Number of core IP router chassis Type 2;

- Sum of Type 1 and Type 2 trunking cards with 10 GE interfaces. See formulas (53) - (54);

- Sum of switching cards. See formula (52);

- Capacity of core IP router chassis Type 2, defined in volume of 10 GE cards;

- Capacity of core IP router chassis Type 1, defined in volume of 10 GE cards;

- Capacity of core IP router chassis Type 2, defined in volume of switching cards;

- Capacity of core IP router chassis Type 1, defined in volume of switching cards.

#### Calculation of Core IP router expansion cards

It is assumed that there is on type of switching card and two types of trucking cards.

**a) Dimensioning of Core IP routers Switching cards:**

|  |  |
| --- | --- |
|  | (52) |

Where,

- Capacity of core IP routes switching card in Gbit/s;

- Sum of all the traffic going through the Core IP router in Transit Node location in Gbit/s divided by headroom allowance (HA). It consists of traffic outgoing to MGW and peering points as well as voice and data traffic between TNs;

- Headroom allowance for core IP routes switching cards.



**b) Dimensioning of core IP router Type 2 10GE card:**

|  |  |
| --- | --- |
|  | (53) |

Where,

- Number of Type 2 10GE cards;

- Capacity of Type 1 10GE cards, defined in 10GE interfaces;

- Capacity of Type 2 10GE cards, defined in 10GE interfaces;

 - Required volume of 10GE ports. See formula (21);

**c) Dimensioning of core IP router Type 1 10GE cards:**

|  |  |
| --- | --- |
|  | (54) |

Where,

 - Number of Type 1 10GE cards;

 - Number of Type 2 10GE cards. See formula (53);

- Capacity of Type 1 10GE cards, defined in 10GE interfaces;

- Capacity of Type 2 10GE cards, defined in 10GE interfaces;

 - Required volume of 10GE ports. See formula (21).

## Dimensioning the transmission network

The approach we take to dimension the transmission network is similar to that taken for the Access Nodes in the following respects:

* It uses billed minutes and data traffic as the starting point;
* It incorporates holding times and an allowance for growth;
* It uses routing factors to determine the intensity with which each network element is used. See Table 5. Routing factors;
* It dimensions the network for the same busy hour as the Access Node’s network;
* It then adjusts this capacity to allow for flows between nodes and to provide resilience.

The main assumptions of dimensioning the Transmission Network are:

1. **Architecture of transmission network**

For the purpose of network dimensioning we will define three levels of transmission network:

* Local level – covering the part of transmission network between Access Nodes, Edge Ethernet Switches and Aggregation Ethernet Switches. In each Local Zone all Access Nodes will be connected to Edge Ethernet Switches and Aggregation Ethernet Switches which concentrate traffic from those Access Nodes.
* Transit 1 level – covering the part of transmission network between Aggregation Edge Ethernet switches and Core Ethernet Switches. In each Transit Zone all Aggregation Edge Ethernet Switches concentrating traffic from Edge Ethernet Switches are connected to the Core Ethernet Switches which concentrates traffic from whole Transit Zone.
* Transit 2 level - covering the part of transmission network between Core Ethernet Switches. All Core Ethernet Switches concentrating traffic towards Core IP routers in Transit Zones are connected to each other.

1. **Technology of transmission network**

The total capacity required on each transmission route can be allocated over Gigabit Ethernet or 10 Gigabit Ethernet transmission link. In such a network, we would expect lower capacity links in the lower part of the network and higher capacity links in the higher part (core part) of the network. As with the utilization rates for the switches, we would expect lower utilization rates for the transmission network elements lower down in the network architecture.

1. **The treatment of non-voice traffic**

The provision of transmission requires an investment in infrastructure, much of which is shared between the varieties of services. If the entire investment was borne by the voice services, the charge would be too high. We achieve this cost sharing in part by dimensioning the transmission network for both voice and data traffic. A number of networks use the transmission system such as leased line, public data networks and special service networks introduced to meet specialized demands of customers.

A detailed description of transmission network elements dimensioning is presented below.

#### Local level

Dimensioning of the Local (Edge) Ethernet switching network is done in the following steps:

* Access Node’s equipment has Ethernet interfaces for backhaul purposes;
* Access Nodes are connected with Ethernet rings to Edge Ethernet switch which is located at the location of Local Node (scorched node approach) or in the previous location of the Local/Primary Exchange (scorched earth approach).



Figure 11: Local Ethernet swithing network according to scorched node and scorched earth approaches.

* Volume and capacity of Ethernet rings will be calculated based on the traffic volume generated by Access Nodes;
* Ethernet switch main unit (chassis) and expansion cards (GE, 10GE) volume will be calculated based on rings volume and capacity.

Dimensioning Edge Ethernet switching network is calculated in these steps:

1. For each Edge Ethernet switch determine the main unit (chassis) type;
2. Calculate the volume of expansion cards (GE, 10 GE, switching cards) for each Edge Ethernet switch.
   * + 1. **Determination of Edge Ethernet switch main unit types**

The main unit (chassis) type of Edge Ethernet switch is determined based on the required capacity. It is assumed that there are 3 Types of chassis and calculations are provided below.

**a) Dimensioning of Ethernet Switches chassis Type 3:**

|  |  |
| --- | --- |
|  | (55) |

Where,




Where,

 - Number of Ethernet Switch chassis Type 3;

- Sum of Type 1, Type 2, Type 3 and Type 4 trunking cards with 1/10 GE interfaces. See formulas (59) - (62);

- Sum of switching cards. See formula (58);

- Capacity of Ethernet Switch chassis Type 3, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 3, defined in volume of switching cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of switching cards.

**b) Dimensioning of Ethernet Switches chassis Type 2:**

|  |  |
| --- | --- |
|  | (56) |

Where,







Where,

 - Number of Ethernet Switch chassis Type 2;

 - Number of Ethernet Switch chassis Type 3. See formula (55);

- Sum of Type 1, Type 2, Type 3 and Type 4 trunking cards with 1/10 GE interfaces. See formulas (59) - (62);

- Sum of switching cards. See formula (58);

- Capacity of Ethernet Switch chassis Type 3, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 1, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 3, defined in volume of switching cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of switching cards;

- Capacity of Ethernet Switch chassis Type 1, defined in volume of switching cards.

**c) Dimensioning of Ethernet Switches chassis Type 1:**

|  |  |
| --- | --- |
|  | (57) |

Where,





Where,

 - Number of Ethernet Switch chassis Type 1;

 - Number of Ethernet Switch chassis Type 3. See formula (55);

 - Number of Ethernet Switch chassis Type 2. See formula (56);

- Sum of Type 1, Type 2, Type 3 and Type 4 trunking cards with 1/10 GE interfaces. See formulas (59) - (62);

- Sum of switching cards. See formula (58);

- Capacity of Ethernet Switch chassis Type 3, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 1, defined in volume of 1/10 GE cards;

- Capacity of Ethernet Switch chassis Type 3, defined in volume of switching cards;

- Capacity of Ethernet Switch chassis Type 2, defined in volume of switching cards;

- Capacity of Ethernet Switch chassis Type 1, defined in volume of switching cards.

* + - 1. **Calculation of expansion cards of Edge Ethernet switch**

Calculation of volume of expansion cards (GE, 10 GE, switching cards) for each Edge Ethernet switch is based on the volume of traffic and the required amount of 1-10GE ports.

**a) Dimensioning of Ethernet Switches Switching cards:**

|  |  |
| --- | --- |
|  | (58) |

Where,

- Capacity of Ethernet switching card in Gbit/s;

- Total volume of traffic passing Edge Ethernet switching network. Total traffic consists of traffic generated by Access Nodes, high speed leased lines, data traffic outgoing to POI, traffic going to upper layer Ethernet Switches;

- Headroom allowance for Ethernet switch switching cards.

**b) Dimensioning of Ethernet Switches Type 2 1GE cards:**

|  |  |
| --- | --- |
|  | (59) |

Where,

- Number of Type 2 1GE cards;

- Capacity of Type 1 1GE cards, defined in 1GE interfaces;

- Capacity of Type 2 1GE cards, defined in 1GE interfaces;

 - Required volume of 1GE ports. See formula (63).

**c) Dimensioning of Ethernet Switches Type 1 1GE cards:**

|  |  |
| --- | --- |
|  | (60) |

Where,

- Number of Type 1 1GE cards;

- Number of Type 2 1GE cards. See formula (59);

- Capacity of Type 1 1GE cards, defined in 1GE interfaces;

- Capacity of Type 2 1GE cards, defined in 1GE interfaces;

 - Required volume of 1GE ports. See formula (63).

**d) Dimensioning of Ethernet Switches Type 4 10GE card:**

|  |  |
| --- | --- |
|  | (61) |

Where,

- Number of Type 4 10GE cards;

- Capacity of Type 3 10GE cards, defined in 10GE interfaces;

- Capacity of Type 4 10GE cards, defined in 10GE interfaces;

 - Required volume of 10GE ports. See formula (63).

**e) Dimensioning of Ethernet Switches Type 3 10GE cards:**

|  |  |
| --- | --- |
|  | (62) |

Where,

 - Number of Type 3 10GE cards;

 - Number of Type 4 10GE cards. See formula (61);

- Capacity of Type 3 10GE cards, defined in 10GE interfaces;

- Capacity of Type 4 10GE cards, defined in 10GE interfaces;

 - Required volume of 10GE ports. See formula (63).

* + - 1. **Calculation of amount of 1GE and 10GE ports**

The amount of 1GE and 10GE ports is calculated in a few steps described below.

* + - * 1. **Calculation of amount of 1GE ports**

Calculation of 1GE ports for each Edge Ethernet location is done using the following formula:

|  |  |
| --- | --- |
|  | (63) |

Where,

 - Number of GE ports required by the leased line and data transmission services provided from Edge Ethernet switching network. See formula (65);

 - Number of GE ports required by the POI services provided from Edge Ethernet switching network. See formula (66);

 - Number of GE ports required at Edge Ethernet switching network to connect ANs. See formula (67).

 - Number of GE ports required at Edge Ethernet switching network to transfer traffic to upper layer Ethernet Switches. The number is calculated using formula (64);

The number of GE ports required at Edge Ethernet switching network to connect to Aggregation Edge Ethernet switches is calculated:

|  |  |
| --- | --- |
|  | (64) |

Where,

 - Backhaul ring’s throughput (1 Gbit/s);

 - Volume of traffic outgoing from all AN connected to the LN in Gbit/s. This traffic consists of voice, internet access and leased lines services, with routing factors applied, provided at AN in Local Zone minus traffic outgoing at POI in LN area.

The amount of GE ports required for leased line services provided from Edge Ethernet switching network is calculated:

|  |  |
| --- | --- |
|  | (65) |

Where,

- Volume of SMT-LL services provided in LN area;

 - Volume of data transmission services provided in LN area;

- Average utilization of network component. See formula (4).

The amount required by the POI services provided from Edge Ethernet switching network is calculated:

|  |  |
| --- | --- |
|  | (66) |

Where,

 - Proportion of total POI bandwidth outgoing at Ethernet switching networks;

 - Volume of internet access services to wholesale subscribers. See formula (33);

The number of GE ports required at Edge Ethernet switching network to connect ANs is calculated:

|  |  |
| --- | --- |
|  | (67) |

Where,

 - Number of rings connecting ANs. See formula (68).

The number of rings connecting AN is calculated using the following formula:

|  |  |
| --- | --- |
|  | (68) |

Where,

 - Number of ANs connected to the LN location;

 - Maximal number of ANs connected to a ring at Local Node area. See formula (69).

 - Predefined maximal number of ANs connected to a ring at Local Node area

The maximal number of ANs connected to a ring at Local Zone is calculated using the following formula:

|  |  |
| --- | --- |
|  | (69) |

Where,

 - Backhaul ring’s throughput (1 Gbit/);

 - Headroom allowance for backhaul ring;

 - Number of MSANs/OLT/AETH connected to the LN location;

 - Volume of traffic outgoing from all AN connected to the LN in Gbit/s. This traffic consists of voice, internet access and leased lines services, with routing factors applied, provided at AN in Local Zone minus traffic outgoing at POI in LN area.

* + - * 1. **Calculation of amount of 10GE ports**

The number of 10GE ports required at Edge Ethernet switching network is using same alghoritms as described in paragraph above, taking into account volumes of 10 GE ports.

#### Transit 1 level

Dimensioning of the Transit 1 (Aggregation) Ethernet switching network is done in the following steps:

* Edge Ethernet Switches are connected with Ethernet rings to the Aggregation Edge Ethernet switch which aggregates the traffic and forwards it to Core Ethernet Switch.
* Aggregation Edge Ethernet Switches are connected with Ethernet rings to the Core Ethernet Switch which is located at the location of Core IP router.
* Volume and capacity of Ethernet rings will be calculated based on the traffic volume generated by Edge Ethernet Switches.
* Ethernet switch main unit (chassis) and expansion cards (GE, 10GE) volume will be calculated based on the rings volume and capacity.

Dimensioning Aggregation Ethernet switching network is calculated in the following steps:

1. For each Aggregation Edge Ethernet switch determine the main unit (chassis) type. It is performed using analog formulas (55) - (57)
2. Calculate the volume of expansion cards (GE, 10 GE, switching cards) for each Aggregation Edge Ethernet switch. It is performed using analog formulas (58) - (62)

#### Transit 2 level

Dimensioning of the Transit 2 (Core) Ethernet switching network is done in the following steps:

* Ethernet core switches located by core IP routers are connected with Ethernet Ring.
* The volume and capacity of Ethernet rings will be calculated based on the traffic volume generated by Core IP router.
* Ethernet switch main unit (chassis) and expansion cards (GE, 10GE) volume will be calculated based on the rings volume and capacity. See formulas (55) - (57) and (70) - (71).
  + - 1. **Calculation of expansion cards for Core Ethernet switch**

Calculation of volume of expansion cards (GE, 10 GE, switching cards) for each Core Ethernet switch is based on the volume of traffic and the required amount of 1-10GE ports

**a) Dimensioning of Core Ethernet Switches Type 3 10GE cards:**

|  |  |
| --- | --- |
|  | (70) |

Where,

 - Number of Type 4 expansion cards required for Core Ethernet switching network in TN area. See formula (71).

 - Number of Type 3 expansion cards required for Core Ethernet switching network in TN area. See formula (71).

 - Capacity of Type 4 expansion cards expressed in number of optical modules;

 - Capacity of Type 3 expansion cards expressed in number of optical modules;

 - Number of 10GE interfaces at Core Ethernet switching network in TN area. See formula (72).

**b) Dimensioning of Ethernet Switches Type 4 10GE cards:**

|  |  |
| --- | --- |
|  | (71) |

Where,

 - Capacity of Type 4 expansion cards expressed in number of optical modules;

 - Capacity of Type 3 expansion cards expressed in number of optical modules;

 - Number of 10GE interfaces at Core Ethernet switching network in TN area. See formula (72).

**c) Calculation of 10GE interfaces at Core Ethernet switching network in TN location:**

|  |  |
| --- | --- |
|  | (72) |

Where,

 - Number of 10GE short range interfaces in Core Ethernet switching network at TN location. See formula (75);

 - Number of 10GE long range interfaces in Core Ethernet switching network at TN location. See formula (73).

The amount of 10GE LR interfaces in Core Ethernet switching network at TN area is determined using the following formula:

|  |  |
| --- | --- |
|  | (73) |

Where,

 - Number of long range 10GE interfaces required for LN area. See formula (74);

- Headroom allowance for Ethernet switch trunking cards.

|  |  |
| --- | --- |
|  | (74) |

Where,

- Headroom allowance for Ethernet switch trunking cards;

 - Number of ports required to connect switching network ant IP routers. It is performed using analog formula as (64).

The amount of 10GE SR interfaces in Core Ethernet switching network at TN area is calculated using the following formula:

|  |  |
| --- | --- |
|  | (75) |

Where,

 - Traffic incoming from Aggregation Edge Ethernet Switches connected to TN location. It is calculated by summing the volume of traffic outgoing from Aggregation Edge Ethernet Switches to TN for the Transit Node location minus the volume of traffic outgoing at the POI present in the Aggregation Edge Ethernet Switch layer;

- Headroom allowance for Ethernet switch trunking cards.

## Dimensioning the fiber cables

Dimensioning of the fiber cables requires to calculate the length of the fiber cables in each defined level of the transmission network (local, transit 1 and transit 2). Fiber cables length will be obtained from the operator (as is state) and verified based on the geographical coordinates of network nodes and logical topology of the network (optimized state). For fiber cable costs the fixed (e.g. cost of laying) and variable part (e.g. cost of fiber cable) would be established based on the economical data on individual network elements gathered from operators.

From the traffic-related costs only the variable part of the fiber cable cost which would be avoided in the absence of a service being provided should be allocated to the relevant increment proportionally to the traffic volume.

**Fiber cables CVR – Cost Volume Relationship**

The cost of fiber cables will be driven by the required throughput of cable section. To simplify the model, a linear relationship between the fiber cables cost and the fiber cables throughput is assumed. To find the relationship, two boundary points are defined:

1. Minimal network cost – cost of fiber network dimensioned to fulfill only topology requirements, traffic volume is not taken into account. The minimal fiber network cost may consist of: fiber cables (with the minimal number of fibers)) cost, joints cost and installing cost.
2. Nominal network cost – cost of fiber network dimensioned to fulfill the topology and traffic requirements. The nominal fiber network cost may consist of: fiber cables (with the nominal number of fibers)) cost, joints cost and installing costs (these statistics are to be provided by the operator).

The graph presenting CRV of fiber cables is presented below.



Figure 12: CRV of fiber cables.

Therefore the costs of fiber cables in the operating network would be the difference between the two scenarios listed above.

## Dimensioning the ducts

Ducts length will be obtained from the Operator (as is state) and verified based on the geographical coordinates of network nodes and the logical topology of the network (optimized state). For duct costs the fixed (e.g. cost of digging, surface reconstruction) and variable part (e.g. cost of ducts) would be established based on the economical data on individual network elements gathered from operators. From the traffic-related costs only the variable part of ducts cost, which would be avoided in the absence of a service being provided, should be allocated to the relevant increment proportionally to the fiber cable incremental cost.

#### Ducts CVR – Cost Volume Relationship (rural)

The cost of ducts in rural genotypes will be driven by the cost of fiber cables. The CVR function defined for fiber cables would be used, however, two boundary points for ducts cost must be defined:

1. Minimal network cost – cost of ducts dimensioned to fulfill only topology requirements, traffic volume is not taken into account. The minimal ducts cost may consist of: trench cost, ground reconstruction cost and other earth work cost.
2. Nominal network cost - cost of ducts dimensioned to fulfill topology and traffic requirements. The nominal ducts cost may consist of: primary duct cost (nominal number of bores in rural) manholes cost, ground reconstruction cost and other earth works cost (these statistics are to be provided by the operator).

#### Ducts CVR – Cost Volume Relationship (urban)

Cost of ducts in an urban geotype will be driven by the cost of fiber cables. The CVR function defined for fiber cables would be used, however, two boundary points for ducts cost must be defined:

1. Minimal network cost – cost of ducts dimensioned to fulfill only topology requirements, traffic volume is not taken into account. The minimal ducts cost may consist of: trench cost, ground reconstruction cost and other earth work cost.
2. Nominal network cost - cost of ducts dimensioned to fulfill topology and traffic requirements. The maximal ducts cost may consist of: primary duct cost (nominal number of bores in urban) manholes cost, ground reconstruction cost and other earth works cost (these statistics are to be provided by the operator). The graph presenting CRV of ducts is presented below.



Figure 13: CRV of ducts.

## Other network elements

#### IMS – IP multimedia subsystem

Dimensioning of IMS – IP multimedia sub-system, is done using the following steps:

* For the whole network calculate the volume of BHCA. The total BHCA for the network is calculated using the following formula:

|  |  |  |  |
| --- | --- | --- | --- |
| |  |  | | --- | --- | |  |  | | (76) |

Where,

 - Total busy hour call attempts in the network;

- Total realized services volume;

- Busy Hour to Average Hour traffic ratio.

 - Ratio of unsuccessful call attempts to total call attempts;

- Average call length;

- Headroom allowance for IMS voice processing elements.

* For the whole network calculate the volume of BHE. Total volume of Busy hour erlangs is calculated using the following formula:

|  |  |
| --- | --- |
|  | (77) |

Where,

 - Busy hour erlangs;

 - Average throughput per port in Access Node. See formula (1);

 - Total amount of voice lines in Access Node network. See formula (2);

- Headroom allowance for IMS voice processing elements.

* For the whole network calculate the number of voice services. The following formula is used to calculate the total amount of voice services:

|  |  |
| --- | --- |
|  | (78) |

Where,

 - Total amount of voice services in the network;

 - Total amount of voice lines in Access Node network. It is calculated by summing all of the voice lines (which are calculated using formula (3)) in the Access Node network;

- Headroom allowance for IMS subscriber serving elements.

* The number of IMS cabinets and service frames is assumed to be one.
* 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:

|  |  |
| --- | --- |
|  | (79) |

Where,

 -TypeIMS service card handling capacity;

 - Total network volumehandled bytype of component;

- Total network volume of oror;

- Total network volume of oror;

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

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

|  |  |
| --- | --- |
|  | (80) |

Where,

 - Total amount of voice subscribers in the network;

 - Total busy hour call attempts in the network;

 - TypeHSS service card handling capacity;

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

#### Billing 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 are done using the following formula:

|  |  |
| --- | --- |
|  | (81) |

Where,

- Number of billing system main units;

 - Billing system main unit’s slot capacity;

- Number of IC system’s expansion cards.

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

|  |  |
| --- | --- |
|  | (82) |

Where,

 - Expansion unit’s handling of BHE capacity;

- Headroom allowance for IC hardware and software;

 - 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.

#### Customer Premise Equipment (CPE)

It is assumed, that one CPE is required for subscriber connected to the network over GPON or P2P technology. Also, the same CPE is capable to provide internet access, VoIP and IPTV services.

# Network valuation

Two possible approaches of network elements cost calculation are assumed:

1. Direct – the capital cost of network elements will be calculated based on engineering models;
2. Rate of CAPEX cost to network cost – capital cost of network elements will be calculated based on the operators accounting data;

The table below presents participation of network elements in the provision of services and the method of each element cost calculation:

Table 7. Assignment of network elements to services

| Network element | Involvement in services provision | | | Cost calculation | |
| --- | --- | --- | --- | --- | --- |
| Voice -wholesale origination | Voice - wholesale termination | Voice transit | Direct | Mark up |
| CPE | X | X |  | X |  |
| MSAN | X | X |  | X |  |
| OLT | X | X |  | X |  |
| AETH | X | X |  | X |  |
| IMS | X | X | X | X |  |
| Media Gateway | X | X | X | X |  |
| MGC | X | X | X | X |  |
| NMS | X | X | X |  | X |
| Aggregation Edge Ethernet switch | X | X | X | X |  |
| Edge Ethernet switch | X | X | X | X |  |
| Core Ethernet switch | X | X | X | X |  |
| IP router | X | X | X | X |  |
| Billing system | X | X | X | X |  |
| Fiber cables and related elements | X | X | X | X |  |

## 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-LRAIC model there are four alternative methods that are used to calculate annual CAPEX costs:

* Straight-line method;
* Annuity method;
* Tilted Annuity method;
* Economic depreciation 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:

|  |  |
| --- | --- |
|  | (83) |

Where:

*  - current depreciation (l – useful life of an asset (data will be gathered from Operators); GRC –gross replacement cost of an asset);
* , holding gain (loss);
*  - 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:

|  |  |
| --- | --- |
|  | (84) |

**Tilted annuity method**

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

|  |  |
| --- | --- |
|  | (85) |

**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-LRAIC 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.

A detailed analysis of straight-line, annuity, tilted annuity and economic depreciation and annualization methods is presented in Annex No. 2. Recommendation allows to use different depreciation method than economic depreciation if feasible. 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. The comparison of those methods is presented in Annex 2. It is worth mentioning that the model will have a possibility to calculate annual CAPEX using straight line, annuity and tilted annuity methods.

## Mark-up allocation

The BU-LRAIC model allows recovering costs that are incurred in real life but that are difficult to model as incremental activities. BU-LRAIC model includes the network related operational cost, administration and support operational and capital costs and network management system capital cost as a percentage of the network costs. In the current BU-LRAIC model the following mark-ups are calculated:

Table 8. Mark-ups in BU-LRAIC modeling

| **Parameter name** | **Activities and equipment included** |
| --- | --- |
| **Mark ups on GRC** | |
| *Mark-ups of operational costs on network cost* | |
| Access node | Network operation, maintenance and planning expenses - operational costs of planning, management, on—site visits, inspections, configuration and maintenance works, for particular network elements. |
| Transmission network |
| Switching network |
| Fiber cables and ducts |
| *Mark-ups of network management system on network costs* | |
| Access node | CAPEX of network management system equipment. |
| Transmission network |
| Switching network |
| **Mark-ups on operational costs** | |
| *Mark-ups of administration and support operational cost* | |
| Access node | Operational cost of general administration, finance, human resources, information technology management and other administration and support activities (salaries, materials, services). |
| Transmission network |
| Switching network |
| *Mark-ups of administration and support capital cost* | |
| Access node | CAPEX of general administration, finance, human resources, information technology management and other administration and support activities (buildings, vehicles, computers, etc.). |
| Transmission network |
| Switching network |

General table of mark-ups that would be used in calculations are provided in Table 9.

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

.

Table 9. Mark-ups

|  | **Mark-ups of operational costs on network cost** | **Mark-ups of network management system on network components** | **Mark-ups of administration and support operational cost** | **Mark-ups of administration and support capital cost** |
| --- | --- | --- | --- | --- |
| **Infrastructure** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **Ground reconstruction** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **Passages under obstacles** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **Additional works** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **Fiber cable** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **Joints for fiber cables** | | | | |
| All sub-components | Fiber cables and ducts  (% on HCC GRC value) | - | - | - |
| **MSAN / OLT / AETH** | | | | |
| All sub-components | Access node  (% on HCC GRC value) | Access node  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **Edge Ethernet Switch** | | | | |
| All sub-components | Transmission network  (% on HCC GRC value) | Transmission network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **Core Ethernet Switch** | | | | |
| All sub-components | Transmission network  (% on HCC GRC value) | Transmission network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **Transit Node - IP router** | | | | |
| All sub-components | Switching network  (% on HCC GRC value) | Switching network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **MGW / MGC** | | | | |
| All sub-components | Switching network  (% on HCC GRC value) | Switching network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **IMS** | | | | |
| All sub-components | Switching network  (% on HCC GRC value) | Switching network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |
| **Billing IC System** | | | | |
| All sub-components | Switching network  (% on HCC GRC value) | Switching network  (% on HCC GRC value) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) | Total network infrastructure excluding fiber cables and ducts  (% on network OPEX) |

# Service cost calculation

After major costs with the help of the engineering model are established, the service cost calculation stage follows.

**HCC1**

**HCC2**

**HCC3**

**…**

**HCCn**

**NC1 NC2 NC3**

**NCn**

**NCn volumes**



**NCn unit costs**

**Service usage**

**Service costs**



Figure 14: Service cost calculation flow

Figure 14: Service cost calculation flow shows that after network elements are established, HCCs are allocated to NCs (see section 8.1 Homogeneous cost categories allocation to Network Components). Further total Network Components costs are calculated by summing up the appropriate HCCs. Total Network Components costs are divided by service volumes and Network Component unit costs are calculated. And finally, Network Component unit costs are multiplied by service usage factor and service costs are calculated

(see Table 10. HCCs to NC allocation matrix).

## Homogeneous cost categories allocation to Network Components

The essential part of LRAIC methodology is allocation of Homogenous Cost Categories to Network Components. Network Components represent logical elements that are functionally integrated and from the combination of which any services may be established. An example of a Network Component is the logical meaning of MSAN which includes the annual cost of MSAN along with all mark up costs resulting from maintenance, localization and supporting activities (e.g. administration, accounting etc.).HCCs to NC allocation matrix is presented in Table 11.

Table 11. HCCs to NC allocation matrix

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ref.** | **HCC name** |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | NC1 | NC2 | NC3 | NC4 | NC5 | NC6 | NC7 | NC8 | NC9 | NC10 | NC11 | NC12 | NC13 |
|  |  | Access Node (AN) | Local Node (LN) | Transit Node (TN) | Transmission - AN - LN | Transmission - LN - LN | Transmission - LN - TN | Transmission - TN - TN | IMS | IC Billing and regulatory | MGW / MGC | IE | TN-IE | CPE |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **A. Infrastructure** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | Trench |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 2 | Primary duct - 1 hole |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 3 | Primary duct - 2 holes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 4 | Primary duct - 6 holes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 5 | Primary duct - 12 holes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 6 | Primary duct - 24 holes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 7 | Primary duct - 48 and more holes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 8 | Manholes |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **B. Ground reconstruction** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 9 | Grass reconstruction |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 10 | Sidewalk reconstruction |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 11 | Asphalt pavement reconstruction |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 12 | Concrete pavement reconstruction |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **C. Passages under obstacles** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 13 | Passage under road (up to 15m) |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 14 | Passage under road (above 15m) |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 15 | Passage under railway tracks |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 16 | Passage under rivers and channel |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 17 | Passage under other obstacles |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **D. Additional works** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 18 | Project works |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 19 | Consent of the landowners |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 20 | Geodetic service |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **E. Fiber cable** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 21 | Fiber cable – 12 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 22 | Fiber cable – 24 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 23 | Fiber cable – 48 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 24 | Fiber cable – 72 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 25 | Fiber cable – 96 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 26 | Fiber cable – 144 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **F. Joints for fiber cables** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 27 | Joint for 12 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 28 | Joint for 24 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 29 | Joint for 48 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 30 | Joint for 72 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 31 | Joint for 96 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 32 | Joint for 144 fibers |  |  |  | X |  |  | X |  |  |  |  |  |  |
| 33 | Section measurement |  |  |  | X |  |  | X |  |  |  |  |  |  |
| **G. MSAN** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 34 | Chassis - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 35 | Chassis - Type 2 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 36 | Chassis - Type 3 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 37 | Chassis - Type 4 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 38 | Chassis - Type 5 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 39 | Subscriber cards - Type 1 - ADSL | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 40 | Subscriber cards - Type 2 - SHDSL | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 41 | Subscriber cards - Type 3 - POTS | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 42 | Subscriber cards - Type 4 - ISDN - BRA | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 43 | Trunking card - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 44 | Optical module - GE - Type 1 - LR - (Long Range) | X |  |  |  |  |  |  |  |  |  |  |  |  |
| **H. OLT** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 45 | Chassis - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 46 | Chassis - Type 2 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 47 | Chassis - Type 3 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 48 | Subscriber cards - Type 1 - GPON | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 49 | Optical module - Subscriber cards | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 50 | Trunking card - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 51 | Type 1 - LR - (Long Range) | X |  |  |  |  |  |  |  |  |  |  |  |  |
| **I. Access Ethernet Switch** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 52 | Chassis - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 53 | Subscriber cards - Type 1 - P2P | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 54 | Subscriber cards - Type 2 - P2P | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 55 | Trunking cards - GE - Type 1 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 56 | Trunking cards - GE - Type 2 | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 57 | Optical module - Subscriber cards | X |  |  |  |  |  |  |  |  |  |  |  |  |
| 58 | Optical module - Trunking cards - GE | X |  |  |  |  |  |  |  |  |  |  |  |  |
| **J. Edge Ethernet Switch** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 59 | Chassis - Type 1 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 60 | Chassis - Type 2 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 61 | Chassis - Type 3 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 62 | Switching cards |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 63 | Trunking cards - GE - Type 1 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 64 | Trunking cards - GE - Type 2 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 65 | Trunking cards - 10GE - Type 3 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 66 | Trunking cards - 10GE - Type 4 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 67 | Optical module - GE - Type 1 - SR - (Short Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 68 | Optical module - GE - Type 2 - LR (Long Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 69 | Optical module - 10GE - Type 1 - SR - (Short Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 70 | Optical module - 10GE - Type 2 - LR (Long Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| **K. Aggregation Ethernet Switch** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 71 | Chassis - Type 1 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 72 | Chassis - Type 2 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 73 | Chassis - Type 3 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 74 | Switching cards |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 75 | Trunking cards - GE - Type 1 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 76 | Trunking cards - GE - Type 2 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 77 | Trunking cards - 10GE - Type 3 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 78 | Trunking cards - 10GE - Type 4 |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 79 | Optical module - GE - Type 1 - SR - (Short Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 80 | Optical module - GE - Type 2 - LR (Long Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 81 | Optical module - 10GE - Type 1 - SR - (Short Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| 82 | Optical module - 10GE - Type 2 - LR (Long Range) |  |  |  | X |  |  |  |  |  |  |  |  |  |
| **K. Core Ethernet Switch** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 83 | Chassis - Type 1 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 84 | Chassis - Type 2 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 85 | Chassis - Type 3 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 86 | Switching cards |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 87 | Trunking cards - GE - Type 1 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 88 | Trunking cards - GE - Type 2 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 89 | Trunking cards - 10GE - Type 3 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 90 | Trunking cards - 10GE - Type 4 |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 91 | Optical module - GE - Type 1 - SR - (Short Range) |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 92 | Optical module - GE - Type 2 - LR (Long Range) |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 93 | Optical module - 10GE - Type 1 - SR - (Short Range) |  |  |  |  |  | X |  |  |  |  |  |  |  |
| 94 | Optical module - 10GE - Type 2 - LR (Long Range) |  |  |  |  |  | X |  |  |  |  |  |  |  |
| **L. Transit Node - IP router** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 95 | Chassis - Type 1 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 96 | Chassis - Type 2 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 97 | Switching cards - Chassis - Type 1 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 98 | Switching cards - Chassis - Type 2 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 99 | Trunking cards - 10GE - Chassis - Type 1 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 100 | Trunking cards - 10GE - Chassis - Type 2 |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 101 | Optical module - 10GE - Type 1 - SR - (Short Range) |  |  | X |  |  |  |  |  |  |  |  |  |  |
| 102 | Optical module - 10GE - Type 2 - LR (Long Range) |  |  | X |  |  |  |  |  |  |  |  |  |  |
| **M. MGW** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 103 | Chassis - Type 1 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 104 | Voice processing card |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 105 | Trunking cards - GE - Type 1 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 106 | Trunking card - Type 1 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 107 | Trunking card - Type 2 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 108 | Trunking card - Type 3 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 109 | Trunking card - Type 4 |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 110 | Optical module - GE - Type 1 - SR - (Short Range) |  |  |  |  |  |  |  |  |  | X |  |  |  |
| **N. MGC** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 111 | Main unit - MGC |  |  |  |  |  |  |  |  |  | X |  |  |  |
| 112 | Expansion unit - MGC |  |  |  |  |  |  |  |  |  | X |  |  |  |
| **O. IMS** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 113 | IMS - Cabinet |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 114 | IMS core - Service frame |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 115 | IMS core - Service card - Type 1 - A-SBG |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 116 | IMS core - Service card - Type 2 - telephony AS |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 117 | IMS core - Service card - Type 3 - CSCF & MRCF |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 118 | IMS core - Service card - Type 4 - BGCF |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 119 | IMS core - Service card - Type 5 - DNS server |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 120 | IMS core - Service card - Type 6 - Service Delivery AS |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 121 | HSS - Service card - Type 1 - Control card |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 122 | HSS - Service card - Type 2 - Database card |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 123 | IMS - Licenses - Type 1 |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 124 | IMS - Licenses - Type 2 |  |  |  |  |  |  |  | X |  |  |  |  |  |
| 125 | HSS - Licenses |  |  |  |  |  |  |  | X |  |  |  |  |  |
| **R. Billing IC System** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 126 | Main unit |  |  |  |  |  |  |  |  | X |  |  |  |  |
| 127 | Expansion unit |  |  |  |  |  |  |  |  | X |  |  |  |  |
| **S. Regulatory costs** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 128 | Regulatory costs |  |  |  |  |  |  |  |  | X |  |  |  |  |
| **T. Optical CPE equipment** | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 129 | Optical CPE equipment |  |  |  |  |  |  |  |  |  |  |  |  | X |

## Network Component average unit cost

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

|  |  |
| --- | --- |
|  | (86) |

Where:

*TNCC* – Total Network Component costs, LTL;

*Volume* – Annual traffic[[5]](#footnote-5) utilizing the appropriate Network Component. Below, Table 12 explains how the appropriate volume is calculated.

As described in section 2 *LRAIC methodology*, model will have a functionality of calculating costs of any service included in the economic model according to Pure LRAIC, LRAIC+ and LRAIC++ principles. Based on these methods, different calculation algorithms of TNCC costs are applied (more information provided in section2 *LRAIC methodology*):

* Pure LRAIC method – includes only incremental costs related to network components used in the provision of the particular service
* LRAIC+ method – includes only incremental 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 service incremental as well. The group of service could be total voice services, total data services and access services
* LRAIC++ method – includes costs described in LRAIC+ method description plus common and joint cost. The common and joint cost related to each group of service (total voice services, total data services and access services) are calculated separately for each Network Component using an equal-proportional mark-up (EPMU) mechanism based on the level of incremental cost incurred by each group of service (total voice services, total data services and access services).

It also has to be noted, that according the Recommendation provided in the legal background, voice termination services should be calculated using Pure LRAIC approach.

Table 12. Traffic utilizing Network Components

| **Network Component** | **Unit** | **Traffic included** |
| --- | --- | --- |
| Access Node (AN) | Weighted service volumes in minutes | Voice traffic  Data traffic |
| Transit Node (TN) | Weighted service volumes in minutes | Voice traffic  Data traffic |
| Transmission - AN – TN | Weighted service volumes in minutes | Voice traffic  Data traffic |
| Transmission - TN – TN | Weighted service volumes in minutes | Voice traffic  Data traffic |
| IMS | Weighted service volumes in minutes | Voice traffic |
| IC Billing | Weighted service volumes in minutes | Voice traffic |
| MGW / MGC | Weighted service volumes in minutes | Voice traffic |
| International Exchange – International MGW[[6]](#footnote-6) | Weighted service volumes in minutes | Voice traffic |
| Transmission - TN – IE\* | Weighted service volumes in minutes | Voice traffic |

## Service cost

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

Service matrix with service usage factors is provided in Table 13. Service matrix.

The capacity based services unit cost will be calculated based on average utilization of IC ports, which will be provided by the Operator to be modeled. Based on the average utilization of IC ports, the monthly volume of the wholesale voice services (termination, origination and transit) provided over one IC port will be calculated. The cost of the capacity based services will be calculated by multiplying the unit cost of each type of the wholesale voice service by the proper monthly volume of the service provided over one IC port.

Table 13. Service matrix

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Access Node (AN) | Transit Node (TN) | Transmission - AN – TN | Transmission - TN - TN | IMS | IC Billing | MGW / MGC | International Exchange[[7]](#footnote-7) (IE) | Transmission\* - TN - IE | CPE |
| Call origination | *WA(f,5,1; f,6,1)* | *WA(f,5,2; f,6,2)* | *WA(f,53; f,6,3)* | *WA(f,54; f,6,4)* | 1 | 1 | *WA(f,5,5*+ *f,5,5)* | *0* | *0* | *1* |
| Call termination | *WA(f7,1; f,8,1)* | *WA(f7,2; f,8,2)* | *WA(f,7,3; f,8,3)* | *WA(f,7,4; f,8,4)* | 1 | 1 | *WA(f,7,5*+ *f,8,5)* | *0* | *0* | *1* |
| Call transit 1 | *f,9,1* | *f,9,2* | *f,9,3* | *f,9,4* | 1 | 1 | *f,9,5* | *f,9,6* | *f,9,7* | *0* |
| Call transit 3 | *f,11,1* | *f,11,2* | *f,11,3* | *f,11,4* | 1 | 1 | *f,11,5* | *f,11,6* | *f,11,7* | *0* |
| Call transit 1/3 | *WA(f9,1; f,10,1; f,11,1)* | *WA(f9,2; f,10,2; f,112)* | *WA(f9,3; f,10,3; f,11,3)* | *WA(f9,4; f,10,4; f,11,4)* | 1 | 1 | *WA(f,9,5*; *f,10,5*; *f,11,59)* | *0* | *0* | *0* |
| Call transit 4 | *f,12,1* | *f,12,2* | *f,12,3* | *f,12,4* | 1 | 1 | *f,12,5* | *f,12,6* | *f,12,7* | *0* |
| Call transit 5 | *f,13,1* | *f,13,3* | *f,13,4* | *f,13,8* | 1 | 1 | *f,13,5* | *f,13,6* | *f,13,7* | *0* |
| Call transit 4/5 | *WA(f12,1; f,13,1)* | *WA(f12,2; f,13,2)* | *WA(f12,3; f,13,3)* | *WA(f12,4; f,13,4)* | 1 | 1 | *WA(f,12,5; f,13,59)* | *WA(f12,6; f,13,6)* | *WA(f12,7; f,13,7)* | *0* |
| Call transit 6 | *f,14,1* | *f,14,2* | *f,14,3* | *f,14,4* | 1 | 1 | *f,14,5*+ *f,14,5* | *f,14,6* | *f,14,7* | *0* |

fR – Appropriate routing factor (Network element routing factors are provided in Table 5. Routing factors);

*fx,y* – x – Number of row in Table 5. Routing factors; y – number of column in Table 5. Routing factors.

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

|  |  |
| --- | --- |
|  | (87) |

Where:

n – From 1 to 7 number of Network Component;

 – Average service usage factor, provided in the service matrix. See Table 13. Service matrix.

UCi – Unit Network Component cost, LTL.

WA – weighted average of routing factor, weighted with volume of service

# Annex 1. Second sub-model: cost calculation of Auxiliary services for network interconnection

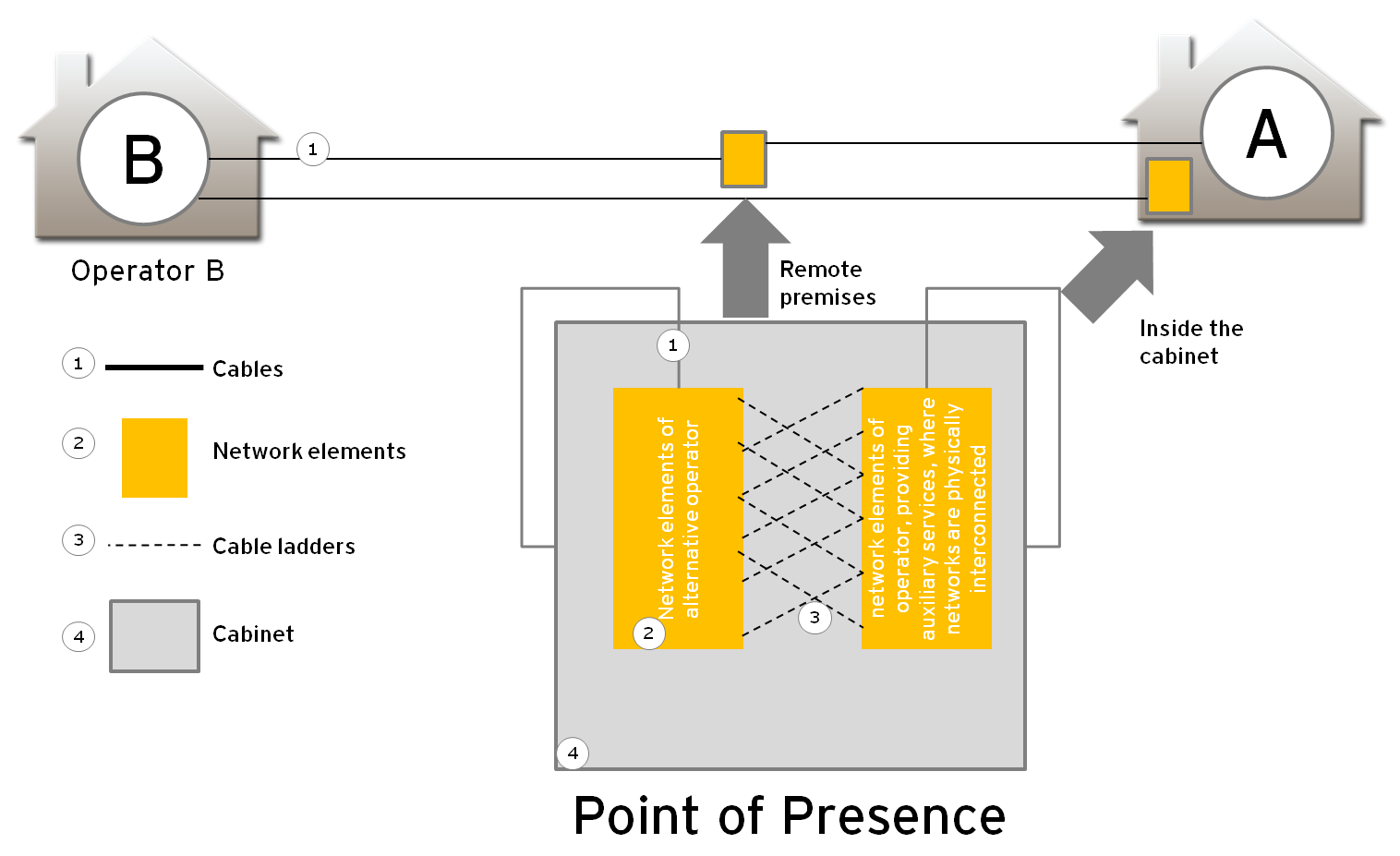
In this annex, principles of the second sub-model are provided. There are lots of alternatives for network interconnection. Sometimes networks are interconnected at the premises of one operator near switches or alternative network elements, but for security and network management reasons networks may be interconnected at some remote premises (Point of Presence, PoP). In current regulatory practice of call termination services, RRT has imposed that network elements required for network interconnection have to be implemented by interconnecting operators themselves and no charge shall be applied for these elements. RRT has also imposed that interconnecting link shall be installed by party able to implement such link in cheapest way and costs related with link that connects networks shall be equally split. Network elements from switches of a particular operator to PoP might be implemented and maintained by that operator. Access to these network elements might be forbidden for security reasons or particular charges might me applied for access to premises and network elements that could be used for other interconnecting party to install a link from PoP to switches. Access to network elements from PoP to switches might also be used for installation of a interconnecting link not only for call termination services, but also for origination and transit services. The objective of this model is twofold:

1) to calculate long run average incremental costs of network elements for installation of a interconnecting link in the PoP where networks can be interconnected for provision of call termination, initiation and transit services;

2) to calculate long run average incremental costs of intermediate network elements of interconnection link from PoP to switch (exchange) used in construction of interconnection link for provisions of call termination, initiation and transit services;

In general access to these network elements could be called Auxiliary services. The general scheme of Auxiliary service for network interconnection is provided below.

Figure 15. General scheme of auxiliary services.



In Table 14. Service definitions., definitions of the second sub-model services are provided.

Table 14. Service definitions.

|  |  |  |
| --- | --- | --- |
| **Service name** | **Service definition** | **Measure** |
| Access to auxiliary services for network interconnection | 1) Provision of network elements in order to install an interconnection link in Point of Presence between network elements (from one operator to the other operator);  2) Provision of network element or elements as intermediate parts of network interconnection link. | Costs of access to passive and (or) active infrastructure for installation (construction) of a link for network interconnection. |

Depending on the type of agreement between the alternative operator and the provider of auxiliary services, four types of services will be modeled:

1. Lease of physical space in premises of the provider of auxiliary services (general scheme of a services is provided below and notations should be understood as in Figure 15);

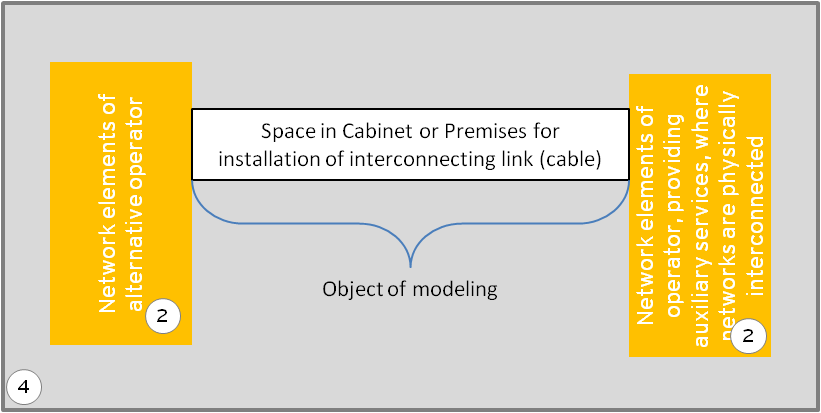


Figure 16. General scheme of auxiliary services for the first service.

1. Lease of space in cable ladders/trays in the premises of the provider of auxiliary services (general scheme of a services is provided below and notations should be understood as in Figure 15);

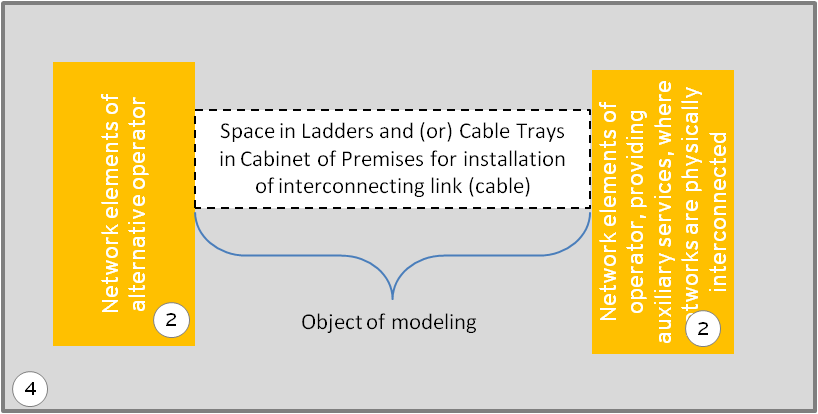


Figure 17. General scheme of auxiliary services for the second service.

1. Provision of passive network elements from PoP to switch (exchange) for installation of interconnection link (intermediate parts of interconnection link used for network interconnection). Below is provided a general scheme of this service and notations should be understood as in Figure 15.

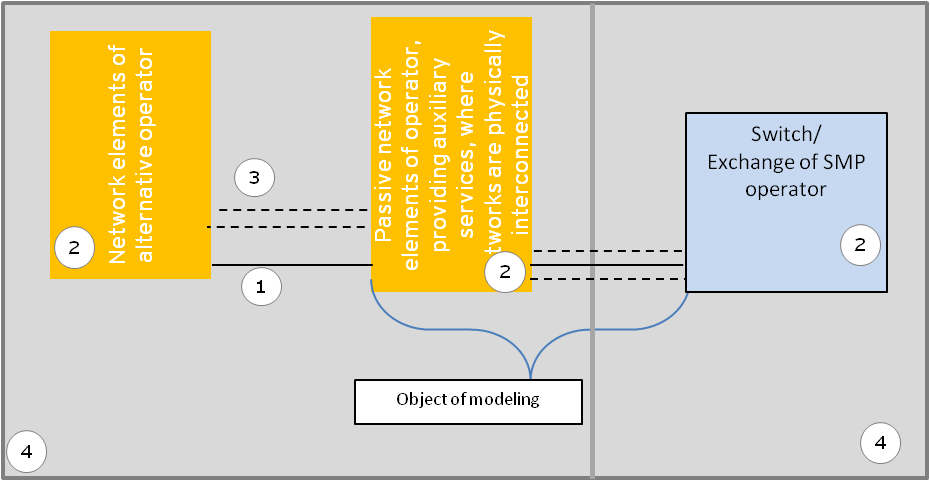


Figure 18. General scheme of the third service.

1. Provision of passive and active network elements from PoP to switch (exchange) for installation of interconnection link (intermediate parts of interconnection link used for network interconnection). Below is provided a general scheme of this service and notations should be understood as in Figure 15.

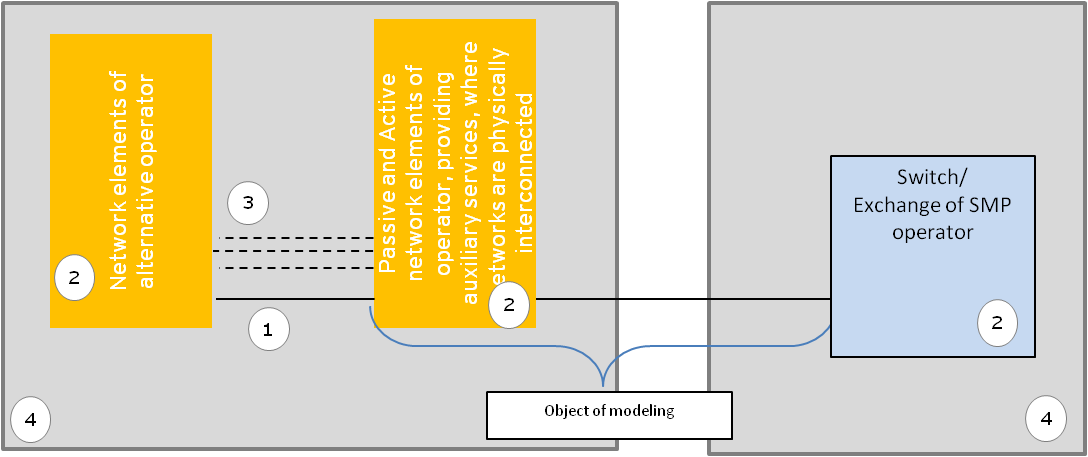


Figure 19. General scheme of the fourth service.

***It is assumed that for fist – third (inclusive) services all network elements are presented in premises of SMP operator. For fourth service it is assumed that PoP might be implemented either in the premises of SMP operator or in the premises of third party.***

***Modeling of First service:***

In modeling first service, periodical costs related to the rent of the technical infrastructure of the provider of auxiliary services will be calculated according to following formula:

|  |  |
| --- | --- |
|  | (88) |

Where:

Si – total space required for the installation of ladders and other equipment in the premises of the provider of auxiliary service, square meters;

*αk* – average rate of rent of property for one square meter, currency.

***Modeling of Second – Forth services:***

**One-off costs of services**

One-off costs are related to the second, third and fourth services. In these scenarios the amount of hours (A hr) required by technical staff to install and set auxiliary services is calculated. Installation process, depending on the scenario modeled, consists of cable arrangement and installation with cable ledges, mounting cabinet to the fixed location, cable wiring and installation of equipment into the cabinet.

One-off costs () are calculated according to the following formula:

|  |  |
| --- | --- |
|  | (89) |

Where:

*toff* - Total time (A hr) required for one-off activities, man-hours;

*αMH* – Average activity man-hour costs (of required qualification), currency.

**Periodical costs of services**

In the modeling of Second – Fourth services, periodical costs of services include both costs related to network equipment and costs related to periodical specific activities.

While calculating the equipment related costs, following equipment is required:

1. Space in cabinet or other premises;
2. Optional: security equipment (sensor and cable);
3. Certain length of cable ladders/trays;
4. Certain length of fiber cable (additional component for third and fourth services) (not applicable for second service);
5. Certain network elements present in the cabinet for POI service to take place (additional component for third and fourth scenario) (not applicable for second service). For Third service it is assumed that Optical Distribution Frame is required to connect the networks and for the fourth service, it is assumed that Aggregation Ethernet Switch is required to make interconnection for other operators possible.

The cost of this service should represent incurred capital cost (CAPEX) together with mark-ups of:

1. Operational costs (OPEX) on network cost;

2. Network management system (CAPEX);

3. Administration and support (OPEX and CAPEX).

Periodical equipment related annual costs are calculated according to the same principles and using the same mark-ups as described for transmission in section *2.7 Mark – ups*.

# Annex 2. Economic depreciation method: analysis and results

Depreciation can be defined as the systematic allocation of the depreciable amount of an asset over its useful life. The depreciable amount is the initial cost of an asset less its residual value estimated at the date of acquisition. Thus depreciation reflects the recovery of invested capital over the asset’s economic life. It can also be defined as a measure of reduction in the economic life of an asset from the usage, passage of time and technological or market changes.

There are two main approaches to depreciation, which are commonly used in bottom-up models: straight-line and annuity (standard or tilted).

Under the straight-line method of depreciation, an asset’s cost is allocated in equal portions over its useful life, taking into account the changes of prices over the whole period of depreciation as well as cost of capital:

Where:

– Current Depreciation

– Holding Gain

– Cost of Capital

– Gross Replacement Cost

– useful life of an element

– Net Book Value

– Gross Book Value

– price change index

– Weighted Average Cost of Capital

The first part of the equation reflects the assumption that an asset’s economic benefits are consumed in equal proportions over its useful life, while the latter is proportional to price changes and cost of capital.

Standard annuity calculates recurring capital payments for a given number of periods as a sum of total economic depreciation and capital costs:

It is also possible to reflect economic value of an asset using the tilted annuity method. The aim of tilted annuity is to:

* Smooth the unit costs by calculating equal charge of capital cost and depreciation over the whole period of cost recovery;
* Adjust the level of cost recovery to the changes of Modern Equivalent Asset prices in year of calculation.

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

The major advantage of tilted annuity over standard annuity is that it takes into account the adjustment of prices of MEA in all years of calculation. In comparison to standard annuity, this method results in higher capital payments if the price of an asset decreases and lower capital payments if the price of an assets grows. Almost exclusively, in telecommunication industry, the prices of assets have decreasing trend.

It is also possible to reflect the economic value of an asset using economic depreciation methodology. The aim of calculation of economic depreciation is to:

* reflect an ongoing character of investments and “smooth” costs for the whole period of cost recovery;
* smooth the unit costs in regard to changing infrastructure utilization over the whole period of cost recovery;
* adjust the level of cost recovery to the changes of Modern Equivalent Asset prices in all periods of cost recovery separately

in such manner that the sum of the present value of all incurred capital investments is equal to the sum of the present value of all recovered costs.

The major benefit of the calculation of economic depreciation is that it takes into consideration changing infrastructure utilization and mitigates its impact by spreading it over the whole period of cost recovery. This could be important if the utilization of the network changes considerably from year to year due to network roll-out that is not effectively utilized by the increase of the traffic demand in short term. In such case, the justified cost of lower utilization would be back loaded and recovered in equal charge over whole period of cost recovery.

Moreover, development of an economic depreciation model requires much more input data and assumptions (that have to be provided by the operators) than other depreciation methods. This is due to the fact that economic depreciation calculation is based on the whole period of cost recovery (30 or more years) and each year of calculation requires an assumption on the profile of price changes and service volume.

Another drawback of economic depreciation is that it requires a consideration of the entire lifespan of the network and, due to the increasing with time discount factor applied to each cost, the calculation will place considerable emphasis on historic events. If a hypothetical operator made less efficient business decisions in early years, those decisions may have larger impact on the calculated depreciation in the following years.

Because of the practical as well as theoretical difficulties with the calculation of economic depreciation more simple approaches are preferred. Tilted annuity approach generates a depreciation profile similar to that of economic depreciation assuming lack of considerable changes in the utilization of the network from year to year and requires much less input data from operators and estimates to be made.

Charts 1 and 2 present an exemplary comparison of profiles of economic depreciation and tilted annuity depreciation.

|  |  |
| --- | --- |
| Chart 1: Economic depreciation and tilted annuity depreciation under the assumption of constant volume of services and decreasing prices of MEA. | Chart 2: Economic depreciation and tilted annuity depreciation under the assumption of increasing volume of services and decreasing prices of MEA. |

The table below presents the main assumptions used to present comparison of profiles of economic depreciation and tilted annuity depreciation.

| **Parameter** | **Chart 1** | **Chart 2** |
| --- | --- | --- |
| Period of analysis | 30 years | 30 years |
| Asset lifetime | 10 years | 10 years |
| Price change | -1% | -1% |
| Services volume change | 0% | 1% |
| WACC | 12% | 12% |

The situation presented on Chart 2 is based on the assumption that the increasing volume of services will cause additional investments in some period of time, after which level of infrastructure utilization is lower than the most efficient. The “smoothing” of “volatile” level of utilization is included in the economic depreciation, while the tilted annuity method does not take it into consideration.

Considering all the above, BU LRAIC model will include straight-line and annuity (standard or tilted) methods where the tilted annuity approach generates a depreciation profile which is most similar to that of economic depreciation.

1. In 2005 RRT has initiated construction of LRAIC model for calculation of costs of call termination, call origination and call transit services provided via fixed network. In 2005 a BU-LRAIC model was implemented by RRT. In 2006 TD-LRAIC results were provided by regulated operator. In early 2008 a HY-LRAIC model was finalized and the regulation of prices currently is based on cost modeling results of HY-LRAIC model. [↑](#footnote-ref-1)
2. Costs of network management system (NMS) are calculated as a mark-up. [↑](#footnote-ref-2)
3. These elements are optional [↑](#footnote-ref-3)
4. These elements are optional [↑](#footnote-ref-4)
5. Only successful calls are included in this parameter. [↑](#footnote-ref-5)
6. These elements are optional [↑](#footnote-ref-6)
7. These elements are optional [↑](#footnote-ref-7)