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

FIXED CORE MODEL DOCUMENTATION

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Summary

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List of acronyms and definitions

ANCOM	National Authority for Management and Regulation in Communications of Romania
BB	Broadband
BH	Busy Hour
BRAS	Broadband remote access server
BRI	Basic Rate Interface
CAPEX	Capital Expenditure
CWDM	Coarse Wavelength Division Multiplexing
DP	Digital Point
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DWDM	Dense Wavelength Division Multiplexing
Eth	Ethernet
EU	European
FTTC	Fibre To The Cabinet
HD	High Definition
IGW	International Gateway
ILA	Intermediate Line Repeater
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPTV	Internet Protocol Television
ISDN	Integrated Services Digital Network
LL	Leased Lines
Lx	Local Exchanges
Mbps	Megabits per second
MDF	Main Distribution Frame
MGW	Media GateWay
MPLS	Multiprotocol Label Switching
MUX	Multiplexer
NGN	Next Generation Network
OADM	Optical Add-Drop Multiplexer
ODF	Optical Distribution Frame
ONU	Optical Network Unit
OPEX	Operational Expenditure
OTM	Optical Terminal Multiplexer
P	Provider
PCP	Point Concentrator Presence
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge

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POTS	Plain Old Telephone Service
PRI	Primary Rate Interface
PSTN	Public Switch Telephone Network
RCU	Remote Concentrator Unit
RSU	Remote Service Unit
RT	Rom Telecom
Rx	Remote Exchanges
S(H)DSL	Symmetrical (High-speed) Digital Subscriber Line
SD	Standard Definition
SDH	Synchronous Digital Hierarchy
SSW	Soft Switch
TDM	Time-Division Multiplexing
TV	Television
Tx	Transit Exchanges
VoD	Video On Demand
VoIP	Voice Over Internet Protocol
WACC	Weighted Average Cost of Capital
WDM	Wavelength Division Multiplexing

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0   Context and objectives

0.1 Disclaimer

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

0.2 Regulatory context

Taking into account the European Commission Recommendation mentioned under Article 15 of the Directive 2002/21/CE, ANCOM reviewed beginning 2012 the different relevant markets in order to identify operators with a significant market power on fixed markets. Significant market power operators have to provide the following electronic communication services at efficient cost-oriented tariffs, based on cost models.

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

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

- Annuities evolved according to a yearly approach;

- Network dimensioning is based on a modified scorched node approach;

- Two scenarios have been considered:

  1. Specific operator scenario based on Romtelecom's current core network which is a combination of legacy and NGN architectures.

  2. Generic operator scenario based on an efficient NGN target architecture that considers Ethernet and IP-MPLS technologies.

To develop these models, ANCOM held, with the assistance of TERA Consultants, several meetings with the different fixed operators (including Romtelecom and RCS&RDS) in order to:

- Explain extensive data requests that have been circulated to operators regarding costs, services, network deployments, etc. ; and

- Get a deep understanding of their core network.

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

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- ANCOM statistics data base;

- Benchmarks; and

- TERA's expertise.

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

This Service Demand Module model has as a starting point real historic demand levels for the period 2006 – 2010 (or 2011 when available), and includes forecasts for the period 2012 – 2020. The results of the service module are described in section 2.

Other data provided by operators form key inputs of fixed core model that enables to determine service costs.

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

- Description of the different platforms modelled in the fixed core model (see section 1);

- Description of the data used for the traffic and the number of users for each service (see section 2);

- Description of the different engineering rules used by the different equipments (see section 3);

- Description of the asset prices and the OPEX (see section 4);

- Description of the depreciation approach (see section 5);

- Description of the different allocations carried out in the model (see section 7);

- Description of some main results (see section 8).

0.3 Scope of the fixed core model

While the access network goes from the exchange/cabinet to the end user, the core network connects the different exchanges/cabinets of the network together.

Figure 1 – Scope of the fixed core and access network for illustration purposes
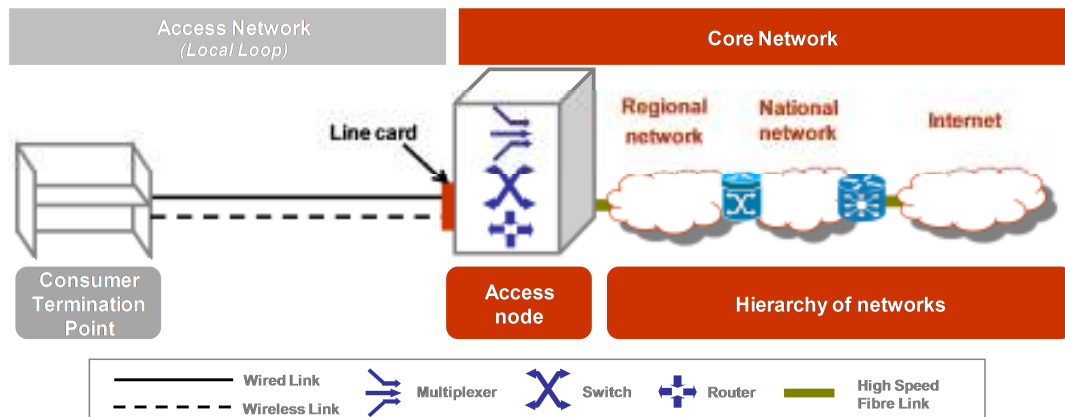
Source: TERA Consultants

The fixed core model is dimensioned from the access node line cards (RSU, DSLAM, RCU, etc) to the end of the network. Some data of the fixed access model developed in 2010 are used as inputs of the fixed core network model, for the core trenches and fibre costs.

0.4 Steps of the fixed core cost model

The development and implementation of the bottom-up models involves typical steps that are detailed in the figure below. They have been followed to build the draft fixed core model.

Figure 2 – Typical steps of the fixed core model

Source: TERA Consultants

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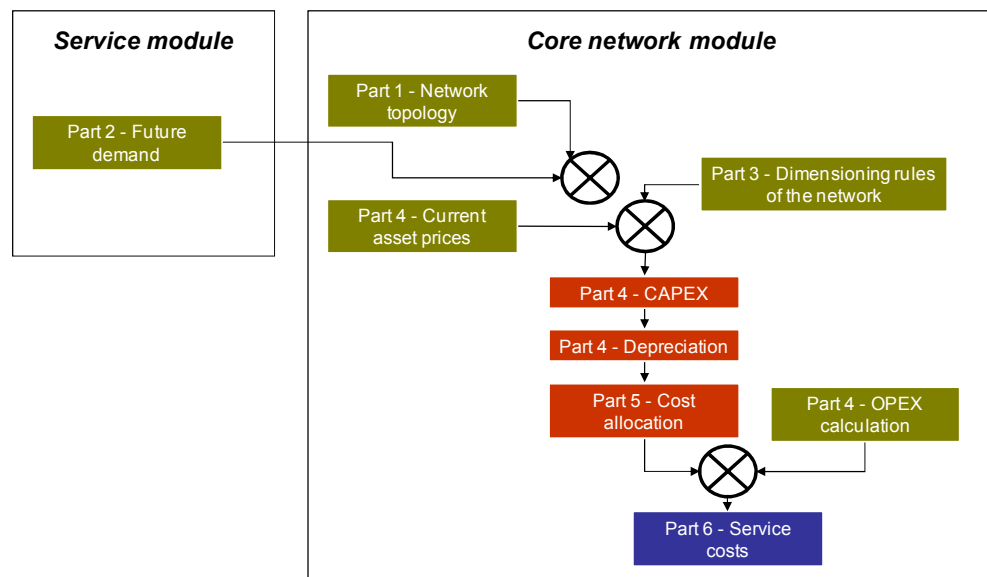
- **Step 1 – Network topology:** the location of nodes along with the required type of equipment (routers, switches, etc) is determined (see section 1);

- **Step 2 – Future demand**: forecasts regarding the evolution of the traffic over the period under consideration are developed (Service module) (see section 2);

- **Step 3 – Dimensioning the network**: this consists of determining the number of assets that are required at each level of the network to fulfil the demand (the traffic). The most important part of this step consists of creating the routing table. Using current dimensioning rules, this enables to determine the number of assets of an optimized network. For each service, the equipment and links that the service uses are determined (see section 2 & 3);

- **Step 4 – Current asset prices**: the step consists of populating the model with the prices of the assets used (see section 4.1);

- **Step 5 – CAPEX calculation**: this step is completed by multiplying the number of assets (step 3) by the price of assets (step 4) (see section 4.1);

- **Step 6 – Depreciation**: the selected depreciation formula is applied to annualized investments cost into annual charges. Decisions have to be made regarding asset lives, asset price trends and WACC (see section 5);

- **Step 7 – OPEX calculation**: OPEX are added to investments' annual charges. It is to be noted that corporate overhead costs are allocated at this stage (see section 4.2);

- **Step 8 – Cost allocation**: costs are allocated to the different services according to the selected allocation key (required capacity) (see section 7);

- **Step 9 – Service costs:** the cost model calculates for each service the corresponding cost per unit (see section 8).

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1 Platforms modelled in the fixed core cost model

1.1 Introduction

Like other European incumbents in Europe, Romtelecom's network is made of several technologies: legacy/TDM and NGN.

As it was stated in the conceptual framework, the European commission recommends the development of NGN model in its 2009 recommendation on the fixed termination rates.

But in order to reflect the current situation and to give a view of how costs are evolving with NGN, it is also useful to model the costs of a legacy network.

Figure 3 – Evolution of the costs of fixed core network (for illustrative purposes)
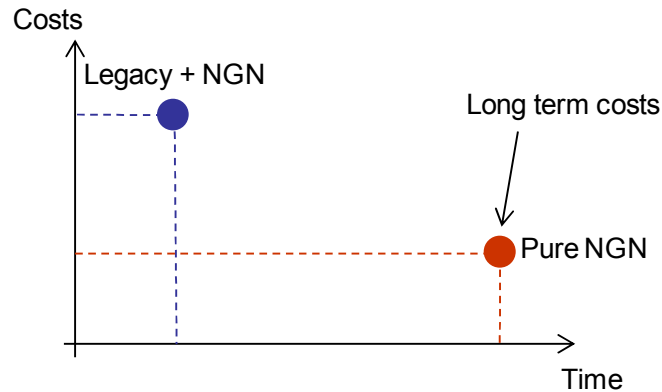
Source: TERA Consultants

Thus, in accordance with the conceptual framework, two scenarios are implemented in the fixed core model:

- One (for a specific operator scenario) based on Romtelecom's current core network which is a combination of legacy and NGN architecture;

- The other one (for a generic operator scenario), based on an efficient NGN target architecture based on Romtelecom NGN architecture.

It is stated in the conceptual framework that the model will apply the modified scorched-node approach for fixed bottom-up models.

- The modified scorched node approach implies taking existing topology as the starting point, followed by the elimination of inefficiencies. (This may involve changing the number or types of network elements that are located at the nodes to simplify and/or decrease the cost of the switching hierarchy).

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However, in practice, the most pragmatic way of implementing the modified scorched node approach is to consider the target architecture of the operators in the considered network;

- According to Romtelecom, the today's PSTN network of Romtelecom is already reflecting the target architecture, so no modification is needed. The transport network's topology depends on the specificity of the geographic and demographic of Romania and cannot be changed easily. Indeed, Romtelecom indicated to ANCOM that changes in the PSTN topology had been cancel out recently: However, with the development of IMS and VoIP, the PSTN technology, even if it is not changing, is less and less reflecting the major technology used for providing voice services.

- The NGN network is new, so no modifications are needed in the architecture. Only sites and equipment presence are considered.

Like other incumbent operators, Romtelecom has developed different infrastructures that are used at each level of the network.

The figure below describes the different technologies that are modelled in each scenario.

Figure 4 – Technology modelled
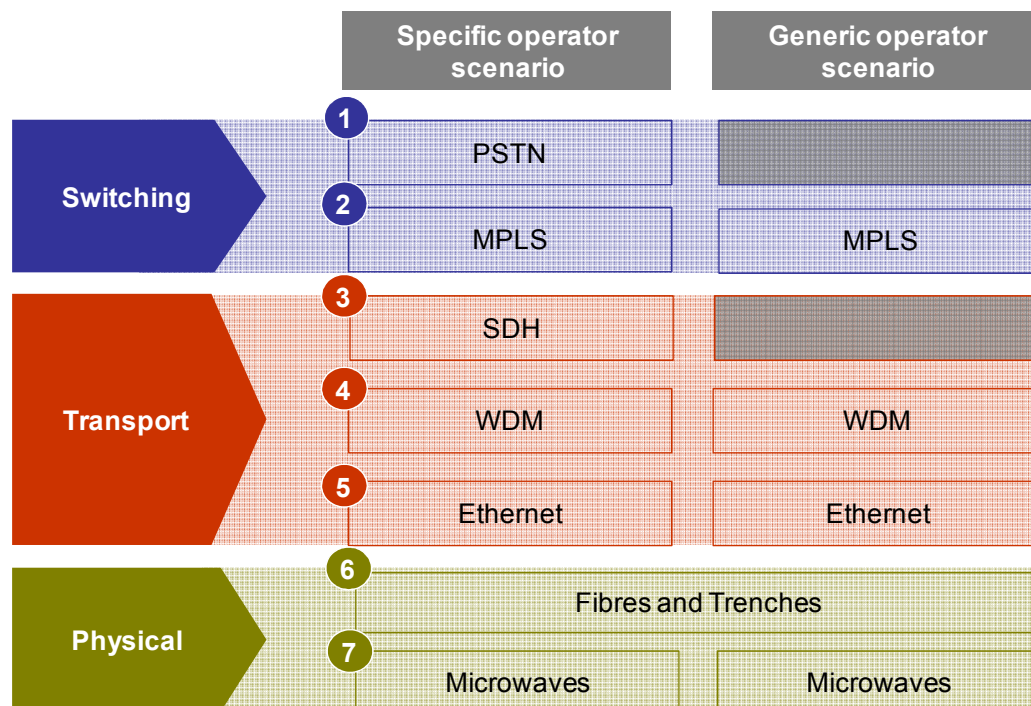
Source: TERA Consultants

The modelled architecture and the way the different core network technologies are used to provide services is illustrated on the Figure 5 below:

Figure 5 - The architecture of the network modelled (Romtelecom architecture)
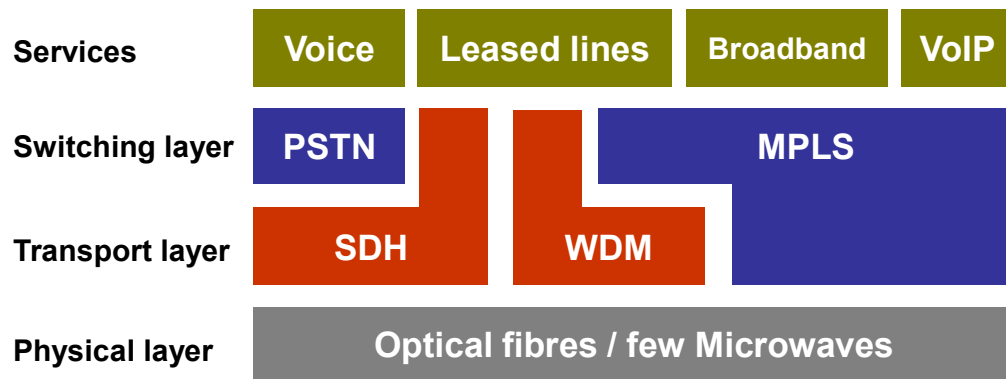
Source: TERA Consultants

Each platform is described hereafter.

1.2 PSTN platform

The PSTN platform is made of four different levels of aggregation as it is described in the figure below:

Figure 6 – PSTN platform simplified diagram (1)

International level:
2 International gateways (IGW)
Located in Brasov and Bucharest

Transit level:
10 Transit exchanges (Tx)
Located in each region and
all connected each other

Local level:
96 Local exchanges (Lx)
Located in each county

Access level:
2 521 Remote exchanges (Rx)
Rx are the access nodes
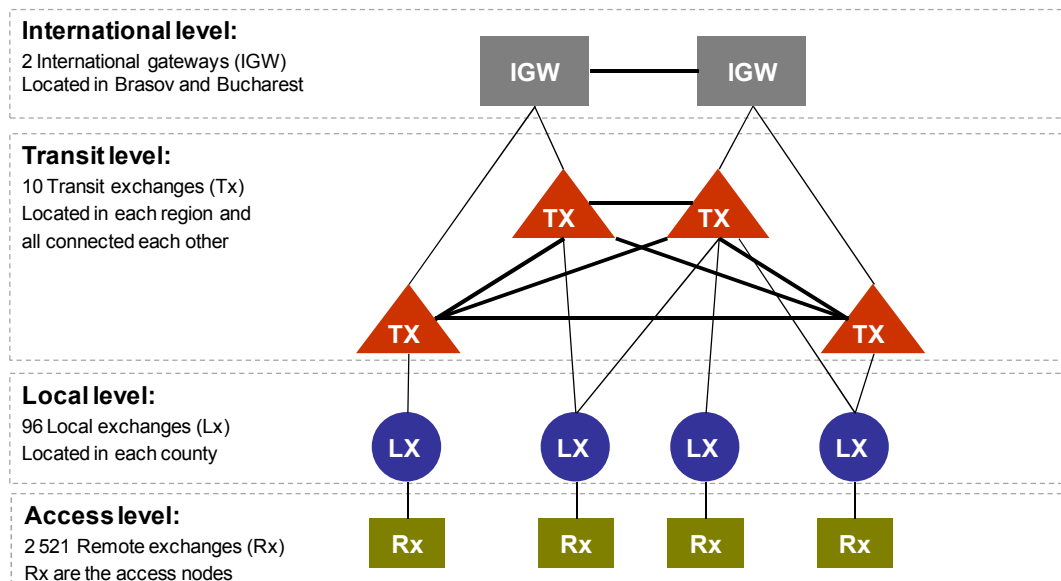
Source: TERA Consultants

- The access level (also called Rx), the first level of switching network, is composed by the remote exchanges. Access nodes are the level where customers are linked to the network (see below for more details).

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- The local exchanges (also called Lx) aggregate the access level traffic and compose the second level of the switching. Customers can also be connected at the local exchanges which have in this case the functionality of access nodes.

- The third aggregated level of the switching platform is composed by transit exchanges (also called Tx) which are all connected each other.

- Two international gateways are used for international calls.

However, in some remote locations, there is a fifth level in addition to the four first levels. The types of equipment at these nodes are equivalent but for calculation purposes it has been necessary to introduce an additional network level.

Figure 7 - PSTN platform simplified diagram (2)

Source: TERA Consultants

1.3 IP-MPLS platform

The IP-MPLS platform is made of five different levels of aggregation as it is described in the figure below:

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Figure 8– IP-MPLS platform simplified diagram
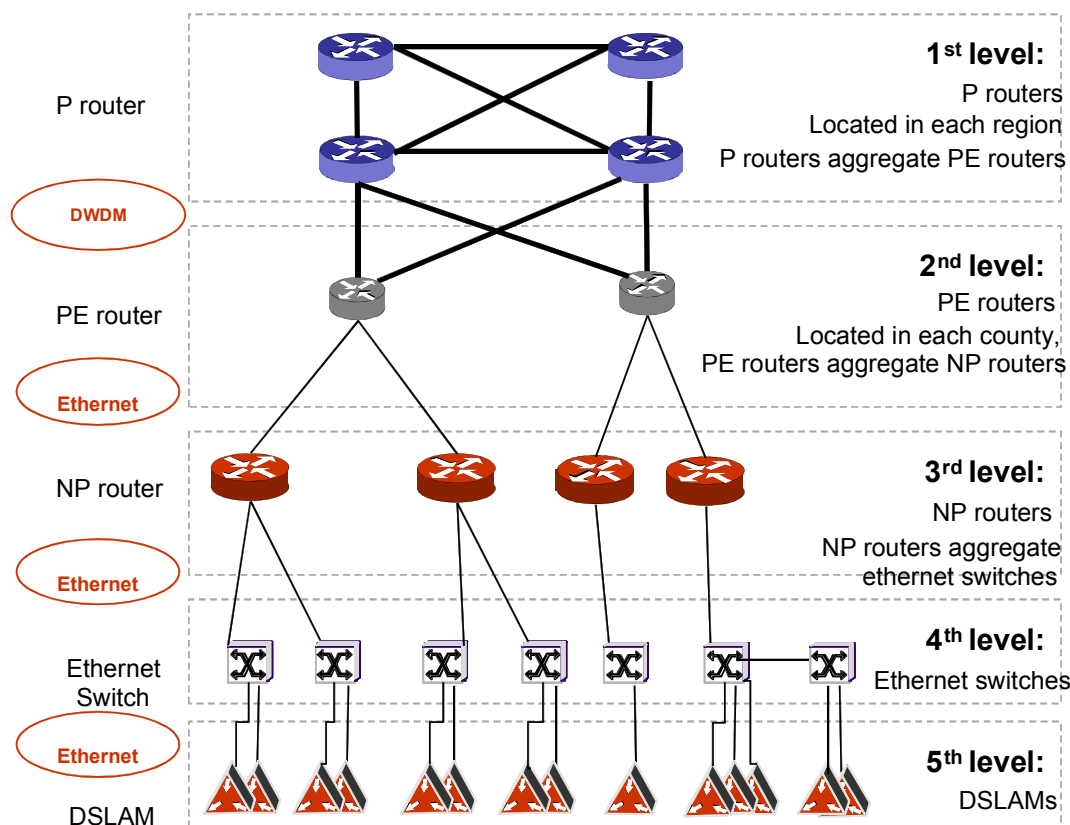
Source: TERA Consultants

The IP-MPLS platform is made of five different levels:

- DSLAMs are access nodes that can handle voice services, TV and broadband services where customers are connected, and where leased lines slower than 2Mbps are connected. Access network copper pairs are directly connected to DSLAMs. DSLAM can be installed in cabinets, containers or exchanges;

- Ethernet switches compose the first level of aggregation. DSLAMs and leased lines above 2Mbps are connected to Ethernet switches;

- Ethernet switches are connected to NP routers which compose the first IP-MPLS equipment;

- Then, NP routers are aggregated to PE nodes;

- P nodes, on which are connected PE nodes, are the most aggregated level in the MPLS network.

Romtelecom specified that few DSLAMs have optical fibre capacity (FTTH), but as very few details have been provided and due to the low number of lines concerned, they have not been included in the model. Also, Romtelecom provided some information

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about OLTs used for FTTH but as these nodes are deployed in a very small number of sites today and no clear plan about FTTH deployment has been provided by Romtelecom, they have not been taken into account. This would in any case mainly impact the access network costs rather than the core network costs.

There are other equipments in the IP-MPLS network such as BRAS, IMS or MGW. A broadband remote access server (BRAS) is a node which ensures the interconnection between the DSLAMs and the network of the Internet Services Providers. The BRAS also manages the quality of service in the network for broadband services. The IMS platform enables to provide VoIP services on the NGN network. The MediaGateWay (MGW) handles calls from NGN network to legacy networks.

Romtelecom stated, during a meeting with ANCOM on the first week of August, that the number of DSLAMs presented is insufficient to cover the whole Romanian population. So, in order to respond to the growing DSL access demand, the number of DSLAMs in the model increases depending on the demand growth. To derive the increase in the number of DSLAMs, the following elements are considered:

- Romtelecom provided the number of kilometres of core fibre cables it intends to deploy for FTTx in 2012 and 2013. Knowing that FTTH does not require new core fibre cables but only access fibre cables, this number has been considered to be fully applicable to FTTC[1] and DSLAMs;
- Each DSLAM requires a given length of fibre cable for backhaul. This length is shorter for already deployed DSLAMs compared to future deployed DSLAMs (which are deployed in less and less dense areas). A parameter of fibre cable length per DSLAM is therefore used[2];
- The two figures enable to derive the number of locations where DSLAM will be deployed in 2012 and 2013.

1.4 SDH platform

The SDH platform is used to transport all the PSTN traffic and SDH leased lines traffic. It is a legacy network. The figure below shows for illustrative purposes the way PSTN and SDH are linked together.

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[1] FTTC (Fibre To The Cabinet) requires optical fibre deployment from the MDF building to the Cabinet

[2] This parameter is used for total fibre length allocation, and to estimate the number of new DSLAMs deployed based on the evolution of the length of the fibre network, provided by RomTelecom

Figure 9 - Interconnection between the PSTN network and the SDH network for illustrative purposes
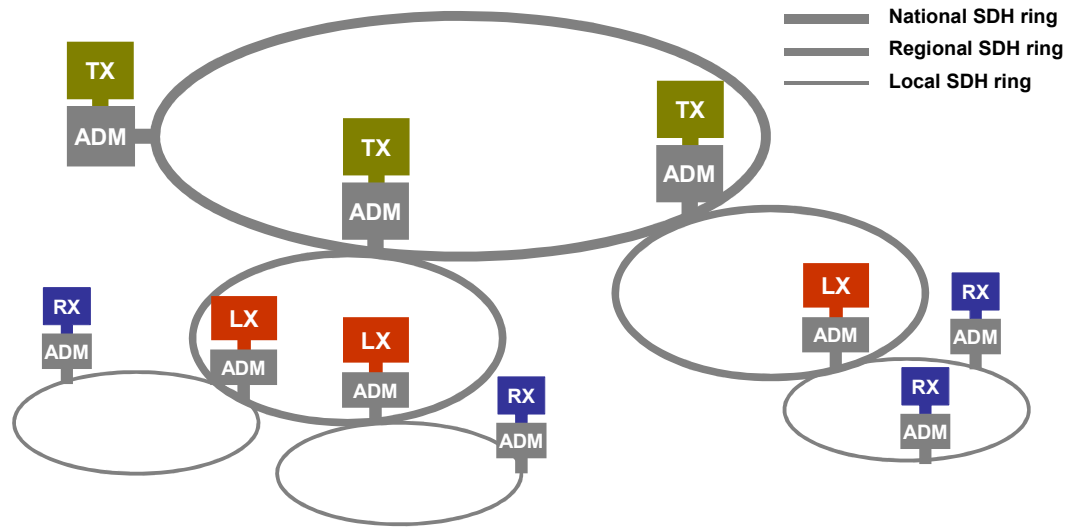
Source: TERA Consultants

The SDH network is divided into three hierarchical levels of rings, which are inter-connected:

- Local (732 rings);
- Regional (48 rings);
- National (14 rings).

These rings, which pave the country and enable to connect the different locations of the country, are considered in the model. No efficiency adjustment is carried out to the number of rings and their geographical scope as it is supposed that Romtelecom's engineers have deep knowledge of the local specificities of Romania.

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1.5 WDM platform

The WDM platform is made of three technologies:

- DWDM;
- CWDM;
- PWDM.

The CWDM network is not considered in the model because there are very few CWDM links compared to DWDM links in Romtelecom's network. Also CWDM is typically used in areas where the fibre core network has not sufficient fibres. In an optimised network and in this precise context, it does not seem relevant to consider such platform in the model.

The DWDM network permits to enhance the capacity of the fibres where it is needed. It is divided into three hierarchical levels of rings, which are inter-connected:

- Local (✂ rings)
- Regional (✂ rings)
- National (✂ rings)

The DWDM network is deployed on ✂ different sites that are present in the map below:

Three types of equipment are deployed to connect the sites in the network: OADM, OTM and ILA equipment (see below).

Figure 10 – OTM and OADM in a chain topology and OADM in a ring topology

If there is more than 60km, an ILA is added.

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Source: TERA Consultants
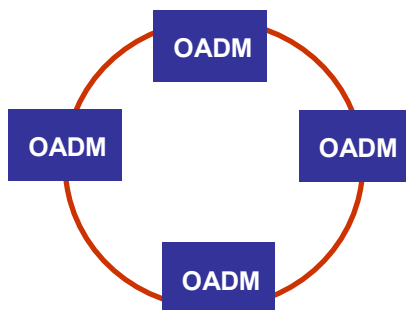
An OADM is installed if it is on a route between other nodes whereas an OTM is used if the node is located at the end of a linear system. ILAs are deployed for long distance, to support the traffic between two distant points.

Romtelecom provided the nature of the equipment for each site. The model chooses the type of equipment according to Romtelecom choices[3].

The traffic that is transiting between the following equipment does not use the DWDM network and these network elements are directly connected to fibres that are deployed between them:

- between DSLAM and switches;
- between switches and NP routers; and
- between NP routers and PE routers..

However, for some links, PWDM is used. Romtelecom provided the number of PWDM links today and for the future years and this is accounted for in the model.

Whereas, the DWDM network is supporting the traffic between PE and P routers, between P routers and to support some specific leased lines as well.

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[3] These choices are considered relevant for both Romtelecom and the generic operator networks.

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1.6 Trenches & Fibres network

The different core network elements are linked to each other mainly thanks to fibres. Romtelecom provided all the details of the fibre network all over the country (number of fibre segments, length of each segment, number of fibres in each segment dedicated to each platform).

The core network counts ✂km of cables and ✂km of fibres, (20 fibres per cable in average) which are divided into four levels:

- The local level;

- The metropolitan level;

- The regional level;

- The national level.

The trenches network is used for both access and core network. Sometimes, core network and access network are using the same trenches.

On those links, the model allocates the cost to both networks on a 50/50 distribution, in line with the approach followed in the 2010 access network developed by ANCOM.

Romtelecom states that the total number of km of trenches dedicated to the core network reaches ✂km in 2010 and grows by 5000km every next year due to new MPLS equipment deployment. According to data provided, in 2011 an additional ✂ km of trenches are shared with the access model.

Thus, in 2011, ✂km of trenches are dedicated to the core network and ✂km are shared with the access network as well.

Figure 11 – Distribution of fibres shared with the access network

	2010	2011
Not shared (dedicated)	✂ km	✂ km
Shared with access	✂ km	✂ km

Source: TERA Consultants

This number is increasing in 2012 and 2013 by 5,000km according to Romtelecom's data.

A route in the fixed core network can be used by different platforms.

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Figure 12 – Sharing of a route between different platforms
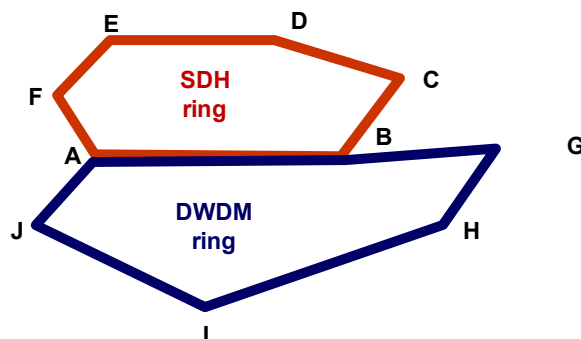
Source: TERA Consultants

In that case, the cost of the route is distributed on a 50/50 basis between the SDH and the DWDM. However, some routes can be shared with three platforms for example, then its costs will be distributed on a 1/3 basis between the different platforms (see section 6.2.1).

In the generic operator scenario, as the SDH network is not used anymore, a part of trenches dedicated only to the SDH network (those which support PSTN but where MPLS has not yet been deployed) is considered as migrated to the NGN network to recover some non-covered areas, and the whole length allocated to the NGN is taken into account. Part of the SDH network which is removed corresponds to part that will not be used anymore for MPLS (because for example MPLS needs less redundancy).

It is also assumed that the generic operator shares its trenches with the other alternative networks present on each geotype. This number is illustrated in the Table 1 below. It is assumed that 70% of the trench length is shared when there are two operators and that the costs are shared equally between both operators.

Table 1 - Number of operators sharing trenches

Geotype	Number of operators (including the generic operator)	% of costs allocated to the generic operator
Metropolitan	4	29%
Local (1 operator)	1	100%
Local (2 operators)	2	65%
Regional	3	46%
National	4	29%

Source: TERA Consultants

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1.7 Microwaves

Romtelecom operates two types of microwave links:

- TDM (PDH) links that are used to connect remote units with local switches, especially in difficult to access small towns or rural areas;

- Hybrid (PDH & Ethernet) links that are used to connect DSLAMs.

Romtelecom provided a list of ✂links with the localization of both extremities. The model assumes the following distribution of the links types among the ✂links (based on number of DSLAMs connected through fibre and provided by Romtelecom).

Figure 13 – Distribution of microwave links

Wireless used for DSLAMs	42%
Wireless used for SDH links	58%
Percentage of SDH Wireless reused for NGN in full NGN	50%

Source: TERA Consultants

In the full NGN scenario, a parameter which can be adjusted is set to migrate a part of SDH wireless links into MPLS links.

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2   Traffic and number of users

This part of the document describes the different services that are modelled on each platform (PSTN and NGN):

- The first part specifies for each service which platforms are used;

- The second part describes the different steps followed in order to model services on the PSTN platform;

- The third part describes the steps followed to model the different services on the NGN platform;

- The last part describes how leased lines are modelled on the different platform. This service is described separately because it is very specific compared to the others.

2.1 List of services

Several services are modelled in the fixed core model.

The following table explains which platform each service is using in both scenarios that are modelled.

Table 2 – Platforms used for the different types of services

	"Legacy + NGN"		"Full NGN"	
	Switching	*Transport*	*Switching*	*Transport*
PSTN Voice	PSTN	SDH		
ISDN Voice	PSTN	SDH		
IP Voice	IP-MPLS	Eth/WDM	IP-MPLS	Eth/WDM
Broadband Retail	IP-MPLS	Eth/WDM	IP-MPLS	Eth/WDM
Broadband Bitstream	IP-MPLS	Eth/WDM	IP-MPLS	Eth/WDM
IPTV	IP-MPLS	Eth/WDM	IP-MPLS	Eth/WDM
Retail LL	MUX/IP-MPLS	SDH/Eth/WDM	IP-MPLS	Eth/WDM
Wholesale LL	MUX/IP-MPLS	SDH/Eth/WDM	IP-MPLS	Eth/WDM

Source: TERA Consultants

As a consequence, for leased lines, in the full NGN scenario, a migration from legacy technologies to NGN is assumed. Also, PSTN is replaced by VoIP.

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2.2 PSTN[4]

Like all the platforms for the dimensioning of the fixed core network, the PSTN core network requires two types of data:

- The number of customers which enables to dimension the number of ports needed at access nodes, where the customers are physically linked to the network (see section 2.2.1);

- The usage of the service (PSTN traffic) which enables to dimension the other nodes in the network (see section 2.2.2 and 2.2.3).

The traffic which dimensions the equipment in the core network is the PSTN voice traffic that is transiting on it at the busiest hour of the year.

The approach used to calculate the PSTN traffic handled by each node at the busiest hour follows two steps:

- The first step is to estimate the number of activated lines during the busiest hour of the year (see section 2.2.2);

- Then, it is necessary to determine the technical traffic at each PSTN node: this technical traffic is calculated by multiplying the number of active lines by the routing factors of the different equipments (see section 2.2.3)

2.2.1 Number of PSTN customers

The service module calculates the evolution of the number of PSTN and VoIP lines in the market.

Between 2006 and 2011, PSTN lines decreased regularly with an average loss of approximately 175,000 lines per year. This loss was a direct migration from Romtelecom PSTN service to competitors because until 2011 Romtelecom VoIP services where provided at a lower extent and the total number of PSTN + VoIP lines was merely stable over years.

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[4] ISDN services are also covered in this section

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Figure 14 – Evolution of the number of PSTN and VoIP lines of the market
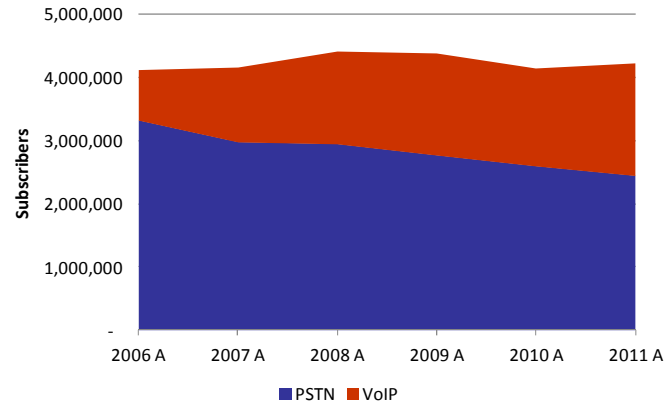
Source: ANCOM

The following number of PSTN lines presented in the figure is allocated to Romtelecom.

Figure 15 – Evolution of the number of PSTN lines in Romania
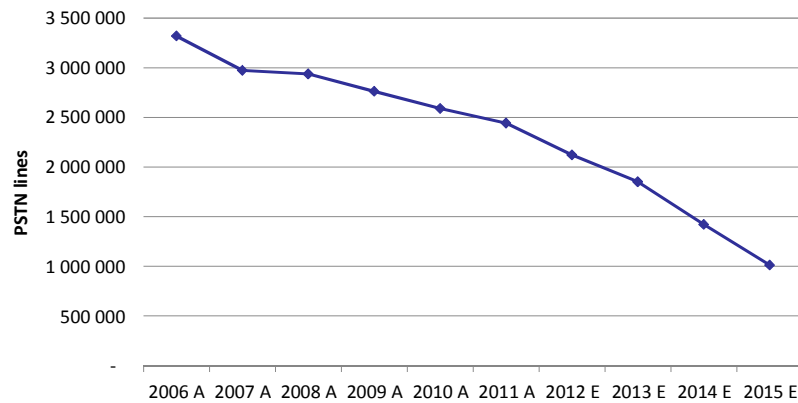
Source: TERA Consultants analysis

As Romtelecom started providing VoIP services recently, the forecast of the VoIP lines of Romtelecom is based on the evolution of the ratio of VoIP lines over broadband lines of one incumbent in another country where the evolution of VoIP is more advanced and can serve as a basis for forecasts.

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Figure 16 – Evolution of the number of VoIP lines of Romtelecom
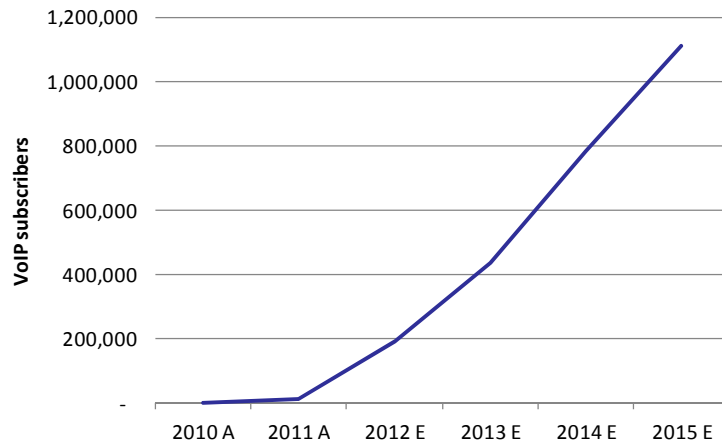
Source: TERA Consultants analysis

Figure 17 – Evolution of the number of VoIP lines of competitors in Romania
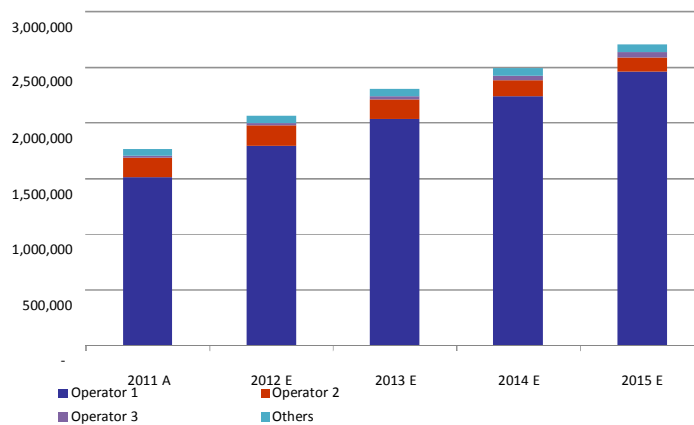
Source: ANCOM and TERA Consultants analysis

In order to calculate the number of ISDN customers and given that ISDN is more related to large and medium businesses, it has been considered that the evolution of the number of ISDN lines is based on the number of medium and large firms in Romania.

The service module assumes the number of medium and large firms is slightly increasing by 3% per year[5].

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[5] Source: Eurostat

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Figure 18 – Evolution of the number of ISDN lines in Romania
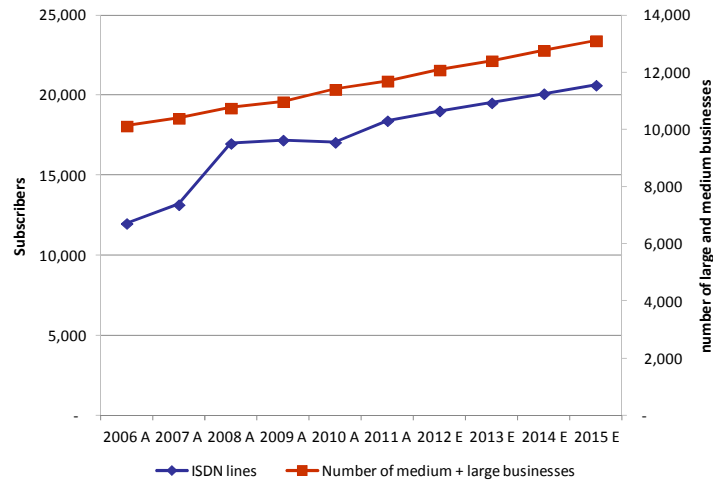
Source: TERA Consultants analysis based on Eurostat data base

2.2.2 PSTN Traffic

As detailed in the conceptual framework, the final output of the service demand module for fixed network corresponds to the total domestic traffic of the relevant operator.

The model uses historic data provided by Romtelecom regarding the number of lines in order to determine the domestic traffic of the relevant operator.

The figure below represents the traffic per line. This evolution is based on the trend of past data.

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Figure 19 – Evolution of the traffic per line
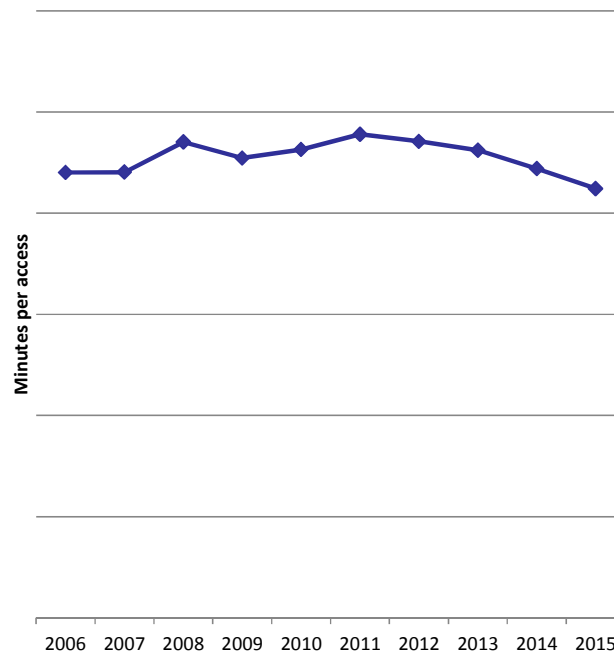
Source: TERA Consultants analysis

In order to calculate the PSTN and VoIP traffic, the total number of minutes per household is spread between PSTN and VoIP lines according to the voice IP migration trend detailed above. (The model assumes that by end of 2015, the VoIP number of minutes will reach more than 50% of the total number of minutes related to voice services).

Figure 20 – Evolution of the voice traffic between PSTN and VoIP

Source: TERA Consultants analysis

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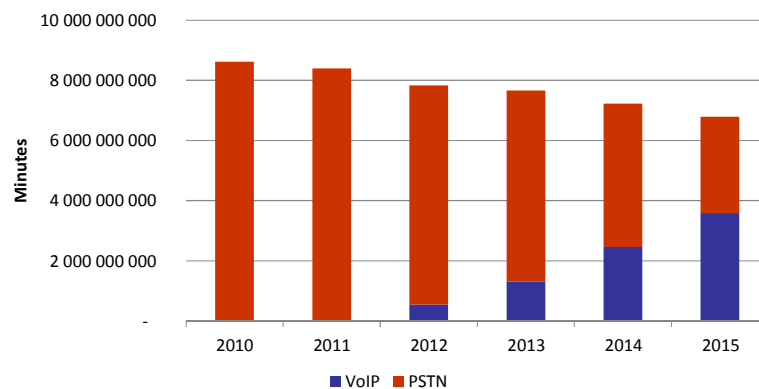
Then, the forecasted total number of minutes for PSTN lines is spread over all the different services based on the actual split of traffic provided by Romtelecom:

- Voice traffic originated on net;

- Voice terminated on net[6];

- Voice traffic originated at relevant interconnection layers;

- Voice traffic originated in other national or international networks, terminated in the network at relevant interconnection layers;

- International transit;

- Etc…

2.2.3   PSTN Routing Factors and Busy Hour

The dimensioning PSTN traffic at each level of the network and at each node is then calculated on the basis of the routing factors and the busy hour traffic at the different PSTN nodes.

2.2.3.1   Routing Factors

The routing factors indicate how many times each PSTN equipment is activated for each type of calls. For example, for a national call origination, the Rx level will be used 1,03 times in average, the Lx one time in average and the Tx 1,98 times in average.

Figure 21 – Example of the routing of national call origination
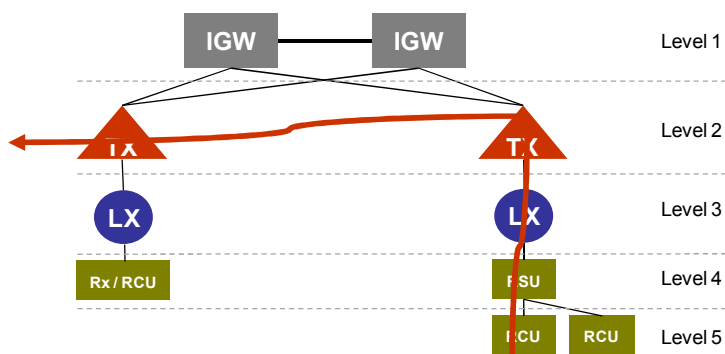
Source: TERA Consultants

As it is described in the figure above, some Rx levels are made of two parts: the RCU and the RSU. Due to the fact that, in some areas, those two parts are present, the routing factor for the Rx level for the national call origination is above one.

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[6] Actually voice traffic originated and terminated on-net have the same routing factors, therefore the calculated cost is identical for both services.

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Then, the Rx is linked to the Lx level and one Lx will be active for that call. Finally, given the fact that Tx are linked together (see section 1.2), the national call origination will most of the time use several Tx. The routing factors for the Tx is an average.

Routing factors have been provided by Romtelecom and checked by TERA Consultants. They are different for each type of calls because the destination of the call is different, so it will use different types of equipment.

2.2.3.2 Busy Hour Traffic

In order to dimension the core equipment with the traffic that is transiting at the busiest hour, Romtelecom provided some information which enables to approximate the Busy Hour Traffic per access node.

In fact, Romtelecom provided the busy hour of each Lx for the year 2011. The model allocates the busy hour of the associated Lx to each line linked to it. Then, this busy hour is as well allocated to the level above the Lx: the Rx level.

Figure 22 – Calculation of the busy hour Erlang per line at the LX level

Equipment location code	LX00001	LX00002	LX00003
Total Erlang at LX	1 000	1 500	400
Total lines connected	40 000	30 000	7 000
Erlang per line at LX	0,0	0,0	0,1

Source: TERA Consultants

This table is used to calculate the busy hour traffic at the remote unit and the associated capacity (by multiplying those factors by the routing factors). Indeed, the traffic which is taken into account for each equipment is the Busy Hour Traffic per Remote Unit balanced by the associated routing factor of the equipment.

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2.3 NGN

The NGN platform is modelled in both specific and generic scenario. The generic scenario is based on the generic operator market shares that have been already discussed in the conceptual framework.

Figure 23 – Market share of the generic operator

	Market share of generic operator (%)
National backbone	25%
Regional backbone	33%
Local/Metro network where RCS&RDS is	50%
Local/Metro network where RCS&RDS is not	100%

Source: ANCOM, conceptual framework

In order to take into account those market shares in the model, a factor will be apply to adjust the volume of traffic of Romtelecom so that it fits to the market share detailed above.

Contrary to the PSTN structure, which supports only PSTN voice service, the NGN platform is used for several services as it is described in the section 2.1:

- Broadband;
- VoIP;
- IPTV;
- Leased lines.

The factor for each service is calculated by dividing the market share of the generic operator by the market share of Romtelecom detailed below:

Figure 24 – Market share of Romtelecom for the different services

2011	Market share terminating traffic **(%)	Market share in originating traffic (%)	Broadband traffic market share (%)	Leased Lines market share * (%)
RomTelecom	65%	66%	32%	64%

*: Due to limited data regarding the traffic of leased lines for each operator, it has been considered that the model takes into account the market share in terms of lines.

**: The share of transit, CPS and wholesale line rental traffic is very limited as a proportion of the total traffic and the impact therefore very limited. It has been therefore considered the market share of the total traffic of each operator

Source: ANCOM

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The following parts will describe the different steps followed to model each service (except the leased lines that are specific and described in a specific part).

2.3.1   Broadband service

The same approach as the one described to dimension the PSTN platform can be applied to dimension the broadband service.

The dimensioning of the broadband service requires two types of data:

- The number of customers which enables, once spread per exchange/cabinet/container, to dimension the number of ports needed at access nodes (DSLAM), where the customers are physically linked to the network;

- The broadband traffic at the busiest hour, which enables to dimension the other nodes in the network.

2.3.1.1   Number of Broadband customers

In order to calculate the number of broadband lines in Romania, the model uses the past evolution of the broadband penetration in relevant European countries (Austria, Hungary, Ireland, Italy, Portugal and Spain).

- The rationale behind this is that Romania will follow the same trend as these countries but with a few years delay (other EU countries follow a different trend);

- Broadband penetration shall reach by end 2015, 23% of the inhabitants in Romania (delay of four years).

Figure 25 – Evolution of the fixed broadband penetration of the market in relevant EU countries
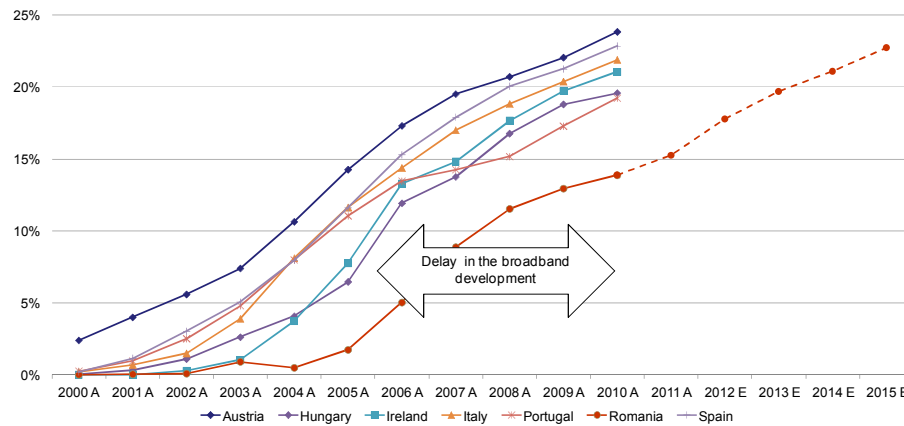
Source: TERA Consultants analysis based on EU Commission's data

For market shares, forecasts are based on past observed trends.

Figure 26 – Evolution of the fixed broadband market in Romania
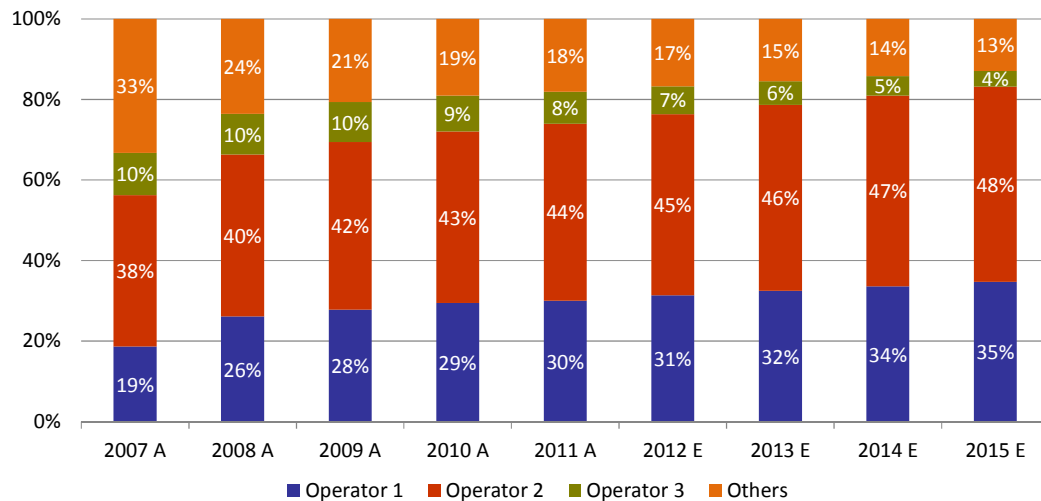
Source: TERA Consultants analysis based on EU Commission's data

2.3.1.2 *Broadband traffic at busy hour*

The broadband traffic that is used for the required capacity approach and that dimensions the core network is the broadband traffic at the busiest hour. The broadband traffic at busy hour depends on the broadband busy hour average capacity per line of the year, which is calculated by dividing the total broadband traffic by the number of broadband customers.

Based on Cisco evolution forecasts, the model assumes the broadband traffic will be multiplied by five between 2010 and 2015.

Figure 27 – Evolution of the fixed broadband traffic in Romania
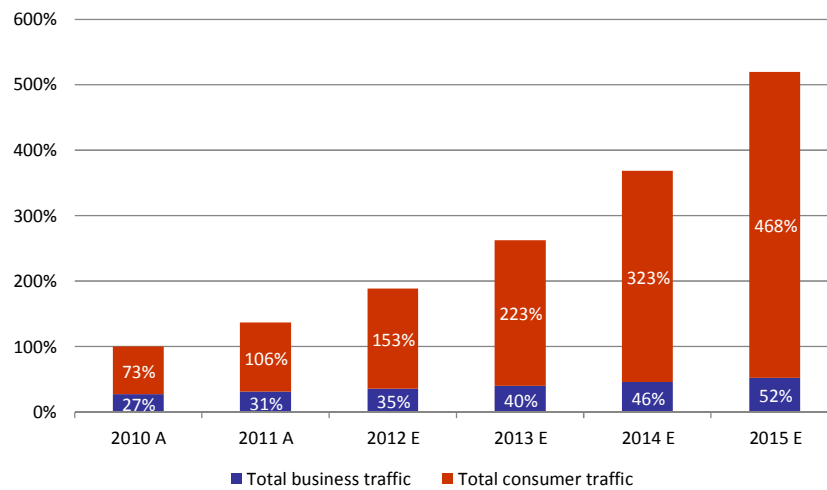
Romtelecom provided the broadband busy hour average capacity per line for the year 2011. Indeed, in proportion of the variation of the number of customers for each year, compared to 2011, the service module calculates the following table.

Figure 28 – Evolution of the busy hour average capacity per line

	2011	2012	2013	2014	2015
Broadband busy hour average capacity per line (Mbps)	0,18	0,24	0,34	0,47	0,67

Then, the model calculates the busy hour broadband traffic by multiplying the number of broadband customers by the busy hour average capacity per line.

NB: The VoD service is already included in the broadband service.

2.3.1.3 Broadband routing factors

Once the model has calculated the broadband busy hour traffic, it has to be balanced by the routing factors in order to determine the traffic that dimensions the different equipments at each level of the network.

For the specific operator scenario, the following routing factors are applied in order to calculate the broadband traffic at each level:

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Table 3 – Broadband routing factors for the specific scenario (1)

	Broadband
National level[7]	2.00
Regional level[8]	2.00
Local level[9]	2.00
DSLAM	1.00

Source: TERA Consultants

These routing factors simulate the fact that any equipment in the MPLS network is supposed to be connected to two aggregators for redundancy purpose. This allows for the network to continue running even if a router fails. The model's routing topology considers only one parent equipment per node; the routing factor allows then to simulate the doubled connection capacity.

Figure 29– Broadband routing factors for the specific scenario (2)
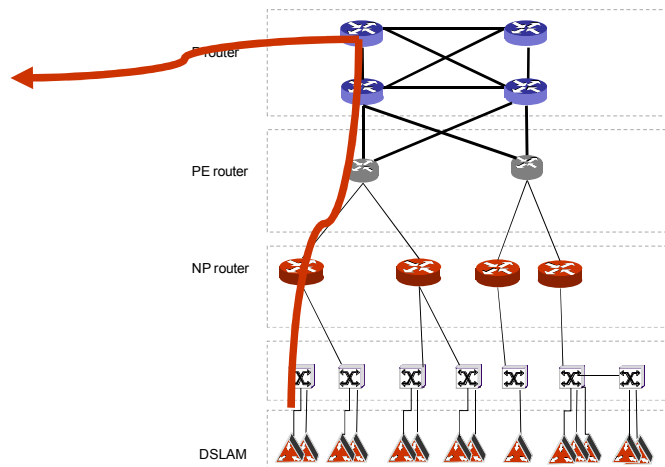
Source: TERA Consultants

For the generic operator scenario, with the methodology described previously (see section 2.3), the following routing factors are applied in order to calculate the broadband traffic at each level:

---

[7] National level: P router

[8] Regional level: PE router

[9] The equipments which compose the local level are: switches and NP router

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Figure 30 – Broadband routing factors for the generic scenario

2011	Broadband
National level	25% / ✂% = ✂
Regional level	33% / ✂% = ✂
Local level (with RCS&RDS)	50% / ✂% = ✂
Local level (without RCS&RDS)	100% / ✂% = ✂

Source: TERA Consultants

2.3.2   VoIP

2.3.2.1   Number of VoIP customers

The evolution of the number of VoIP customers has been described in the section 2.2.1.

2.3.2.2   VoIP traffic at busy hour

The VoIP traffic that dimensions the core network is the VoIP traffic at the busiest hour. The VoIP traffic at busy hour depends on the VoIP busiest hour Erlang per line of the year, which is calculated by dividing the VoIP traffic at peak hour by the number of VoIP customers.

The VoIP busy hour Erlang per line is different in the specific operator scenario and in the generic operator scenario, because the number of subscriptions decreases in the "full NGN" scenario (some customers in the "VoIP + PSTN" scenario have both a VoIP and a PSTN line) but the traffic remains stable.

These values are similar to the calculated values for PSTN.

It is assumed that a VoIP call requires 100kbps.

2.3.2.3   VoIP routing factors

In the specific operator scenario, the following routing factors are applied in order to calculate the VoIP traffic at each level. Those routing factors are representing the routing factors for one VoIP customer (whether is it a termination or an origination call regarding the customer).

Those routing factors remain the same in the case of an off-net call but should be taken twice into account in the case of an on-net (without the media gateway and IMS) call because it implies that two VoIP customers of the operator are users.

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Table 4 – VoIP routing factors for the specific scenario

	VoIP
National level	2.00
Regional level	2.00
Local level	2.00
DSLAM	1.00
Media Gateway	1.00 for off-net and the ratio (VoIP lines/Total RT lines) for on-net as a local call from VoIP network can go either on VoIP network either on PSTN line.
IMS	1.00 for off-net and the ratio (0.5*VoIP lines + 1*PSTN lines)/Total RT lines for on-net 0.5 VoIP lines/RT lines factor is considering that for an on-net call, two branches of a VoIP call use only 1 time the IMS. 1xPSTN lines/RT lines factor is considering that for an on-net call from VoIP to PSTN, the VoIP branch uses 1 time the IMS.

Source: TERA Consultants

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Figure 31 – VoIP routing factors for the specific scenario (off-net call)
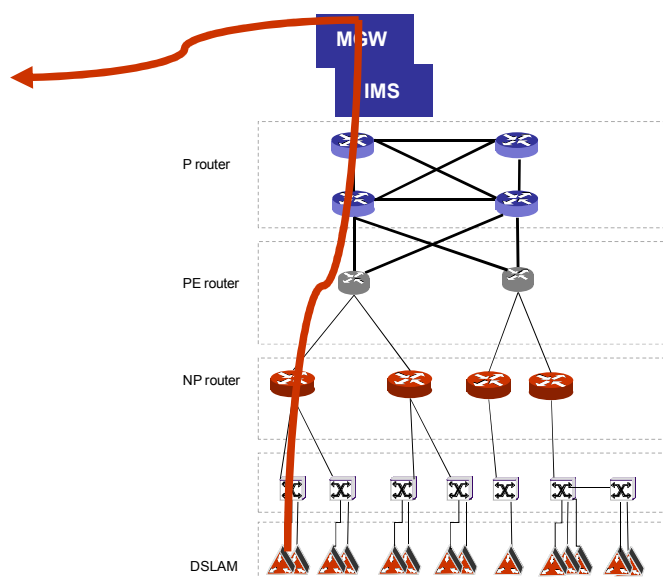
Source: TERA Consultants

Figure 32 - VoIP routing factors for the specific scenario (on-net call)
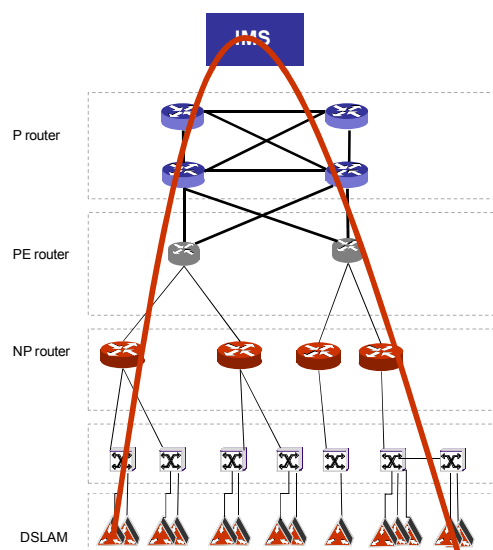
Source: TERA Consultants

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In the generic operator scenario, with the methodology described previously (see section 2.3), the following routing factors are applied to calculate the VoIP traffic at each level.

As described in the section 2.3, there are calculated by dividing the market share of the generic operator by the market share of Romtelecom at each network level[10].

Figure 33 – VoIP routing factors for the generic scenario

2011	Voice
National level	25% / ✄% = ✄
Regional level	33% / ✄% = ✄
Local level (with RCS&RDS)	50% / ✄% = ✄
Local level (without RCS&RDS)	100% / ✄% = ✄

Source: TERA Consultants

It is also important to note that in the context of migration from PSTN to VoIP, the voice on-net calls are of three types:

- The on-net calls between 2 PSTN users. In this case, routing factors are the same as the routing factors described above;
- The on-net calls between 2 VoIP users. In this case, routing factors are the same as the routing factors described above;
- The on-net calls between a VoIP user and a PSTN user. In this case, the MGW is used and the routing factors are:
  - On the PSTN, the routing factors of a national call termination;
  - On the NGN, the routing factors of a call termination.

These specificities are taken into account in the specific operator model. The latter type of on-net calls is assessed based on the proportion of VoIP customers vs PSTN customers.

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[10] At the local level, where there is RCS&RDS, the voice market share of Romtelecom reaches ✄%, considering that Romtelecom has a market share of ✄% for only ✄% of the total households.

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2.3.3 IPTV

2.3.3.1 Number of IPTV customers

Contrary to other broadband-based services, the traffic related to IPTV service is not depending on the number of IPTV customers. It is a multicast service.

2.3.3.2 IPTV traffic

Romtelecom provided all the IPTV parameters needed to calculate the traffic that transits at P level. Some assumptions based on TERA Consultants' expertise to evaluate the traffic at each upper level.

Figure 34 - IPTV Traffic Parameters

Number of SD channels	122
Bitrate per SD channel	3
Number of HD channels	13
Bitrate of HD channels	6
Number of Picture in Picture chan	42
Bitrate of Picture in Picture chann	0,3
Total traffic at P (Mbps)	456,6

Source: Romtelecom

There are in line with parameters observed in other countries.

2.3.3.3 IPTV routing factors

For the specific operator scenario, the IPTV routing factors are calculated with the following method. The model estimates the total traffic at the P router on the basis of data provided by Romtelecom. Then, the model establishes the traffic at each DSLAM on the basis of the proportion of traffic going up to DSLAMs.

The same methodology is used at each level and permit to calculate the IPTV routing factors.

Table 5 – IPTV routing factors for the specific scenario

	IPTV
DSLAM	0,2
Switch	0,6
Routers	1,0
P-P IPTV	1,0

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Source: TERA Consultants

In fact, those routing factors reflect the fact that all the channels are not sent to each piece of equipment at each level, except for the P and the IP routers levels. Then, concerning the switches and the DSLAMs levels, only a proportion of the channels depending on the channels requested by customers are sent to the equipment. Indeed, those routing factors are reflecting the statistical use of the channels.

For the generic operator scenario, the routing factors are identical to the routing factors for the specific scenario. Even if the number of customers does not remain the same, the use of the IPTV where there is some customers will remain statistically the same.

2.3.4   Traffic transiting on the different levels

At each level, the NGN traffic is the sum of the VoIP, IPTV and broadband traffic. It is assumed that all services have a same busy hour (conservative approach).

2.3.4.1   Traffic at DSLAMs

The number of NGN customers (same methodology for broadband and VoIP) is distributed across the different areas in two steps:

- First the total number of NGN customers is spread per locality based on the population of each locality; Then these customers are spread among each sites of this locality based on the number of DSLAMs present at each site in the 2011 inventory. Thus, based on the number of VoIP and broadband customers on each site, it is possible to determine the associated traffic at each DSLAM.

2.3.4.2   Traffic at switches

DSLAMs are linked to Ethernet switches. Some of the DSLAMs do not have any parent nodes due to some missing information in Romtelecom database. The traffic outgoing from those DSLAMs is allocated on an average basis to all switches of their judet.

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Figure 35 – Distribution of the DSLAMs traffic
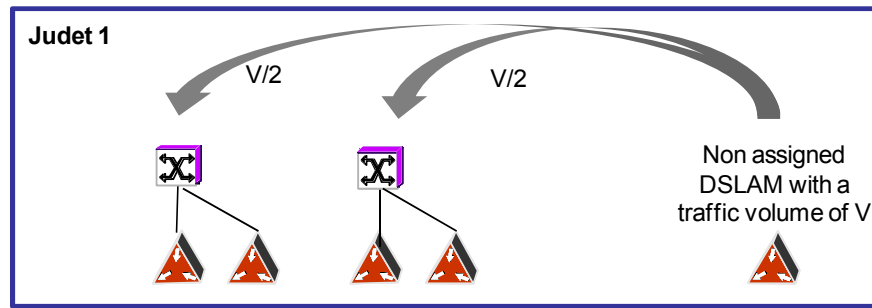
Source: TERA Consultants

2.3.4.3 Traffic at the different routers

The model calculates the number of DSLAMs in a judet, and so the number of Ethernet switches.

As no parent information concerning the relation between switches and router has been provided, the total traffic aggregated by switch in a judet is equally distributed to NP routers of the judet.

The same approach is used for the traffic between NP and PE routers. As the hierarchy between PE and P routers have been provided by Romtelecom, the traffic at each P is calculated directly as the sum of the traffic coming from the relevant PEs.

Figure 36 – Traffic from NP routers going to PE routers
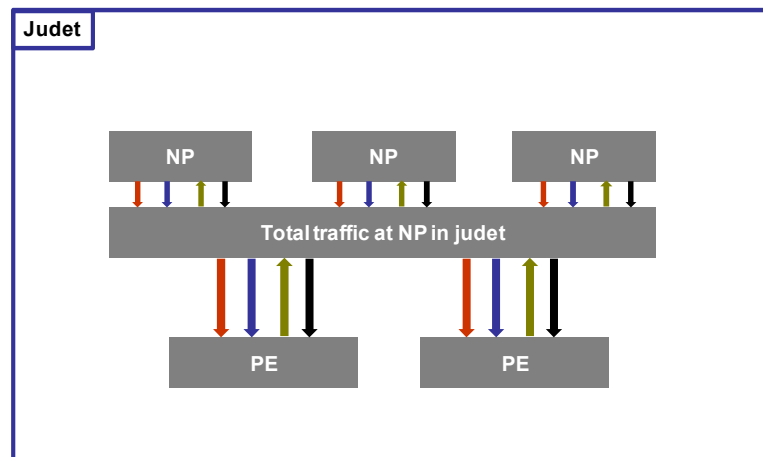
Source: TERA Consultants

2.4 Leased lines

Leased lines are treated separately due to their specificities. Indeed, there are different types of leased lines, depending on the technology used (SDH, NGN, WDM),

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depending on the location of the two ends of leased lines (local, regional, national or others), depending on the speed. And these types can change over the years.

2.4.1 Distribution per length category

Leased lines are divided into several categories:

- International leased lines

- Other leased lines

    o Local;

    o Regional;

    o National.

In the model, international leased lines are included in the national leased lines category (an international leased line crosses all levels of rings, the calculation takes in account that only one end is required).

Figure 37 – Illustration of the different types of leased lines
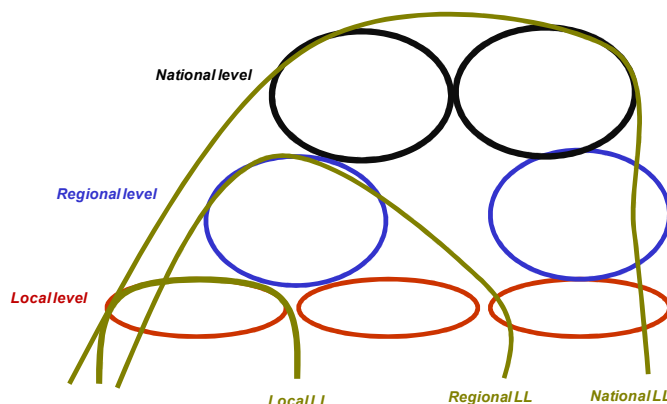
Source: TERA Consultants

In the figure above, the red circles represent the different equipments which are present at the local level. The blue circles represent the different equipments which are present at the regional level and the dark ones, at the national level.

The different categories of leased lines are represented by the green lines. A local leased line uses only the equipments that are present at the local level. The regional leased line use equipments that are present at the local and the regional level. And the national one use all the equipments in the different level.

The following table represents the average ring usage of a leased line based on data provided by Romtelecom, all leased lines are considered to go through the local level:

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Table 6 – Leased lines ring usage

Type	%
Local	100
Regional	✂
National	✂

Source: TERA Consultants

This distribution is not supposed to change over the year.

2.4.2 Distribution per speed and technology

Leased lines can be produced on different types of technology:

- SDH;

- DWDM;

- IP-MPLS.

In addition, leased lines are split into two types: leased lines lower than 2 Mbps and leased lines faster than 2 Mbps.

The following figures represent the evolution of the distribution per platform. There are based on information provided by Romtelecom for the year 2011. Then, the model uses some assumptions for the following years, taking into account data in the service module.

2.4.3 Distribution per location

Then, it is necessary to allocate the different leased line categories to the different locations in order to establish the demand per location. The exact location of leased line ends is not available and therefore some assumptions are necessary:

- The SDH leased lines are classified by decreasing traffic output in each judet. Then, SDH leased lines with the highest traffic are allocated to locations with the highest traffic generated by PSTN voice services.

- Concerning MPLS leased lines, the same approach is used by considering the number of DSL lines to allocate the leased lines below 2 Mbps and the volume of internet traffic at the switch to allocate the leased lines above 2 Mbps.

- Then, for the WDM leased lines, the same approach is used by considering the WDM leased lines and the total traffic in each locality.

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In absence of actual information, this approach takes the reasonable assumption that the geographic concentration of leased lines traffic follows the concentration of voice and internet traffic.

2.4.4   Routing of the SDH leased lines

SDH leased lines are only considered in the "Legacy + NGN" scenario.

The model assumes that:

- Local leased lines use local SDH rings;

- Regional leased lines use local and regional SDH rings;

- National leased lines use local, regional and national SDH rings.

2.4.5   Routing of the MPLS leased lines

The following figure shows which type of equipment are used for each type of MPLS leased lines:

- Local leased lines use the network elements from the DSLAM to the NP routers;

- Regional leased lines use the network elements from the DSLAM to the PE routers;

- National leased lines use the network elements from the DSLAM to the P routers.

Table 7 – Routing of the MPLS leased lines per category (1)

Source: TERA Consultants

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Figure 38 Routing of the MPLS leased lines per category (2)
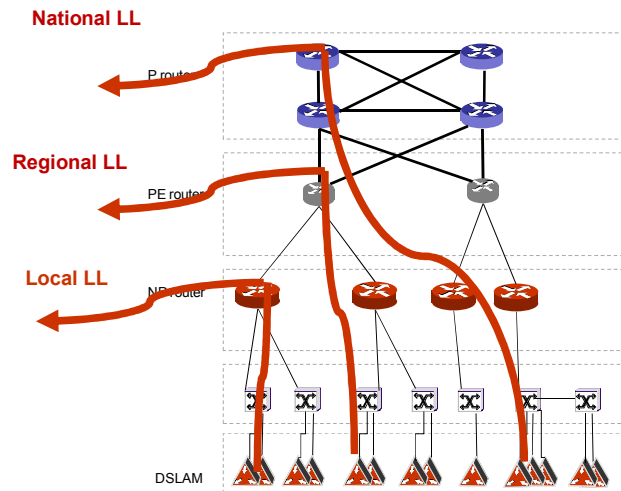
Source: TERA Consultants

2.4.6 Routing of the WDM leased lines

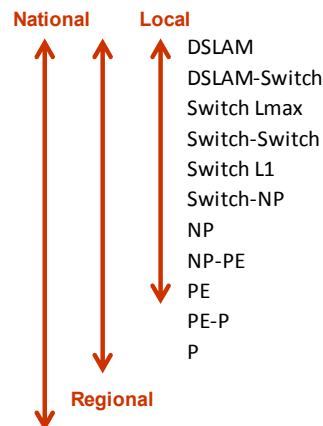The same approach as the one used for the SDH leased lines is used for the WDM leased lines:

- Local leased lines use local WDM rings;

- Regional leased lines use local and regional WDM rings;

- National leased lines use local, regional and national WDM rings.

In addition, the regional and national MPLS leased lines are going through the WDM platform because there are using PE-P and P-P links which are covered by the WDM technology.

2.4.7 Scenario of the generic operator ("Full NGN" scenario)

In the generic operator scenario, non NGN leased lines (SDH leased lines) are removed from the SDH platform and considered as NGN leased lines on the basis of the distribution between WDM and MPLS leased lines.

Then, routing factors are calculated with the approach described at the beginning of the section 2.3

So, the following routing factors are applied in the generic model in order to have the leased lines traffic at each level:

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Figure 39 – Leased line routing factors (generic scenario)[11]

2011	Leased line
National level	25% / ✂% = ✂
Regional level	33% / ✂% = ✂
Local level (with RCS&RDS)	50% / ✂% = ✂
Local level (without RCS&RDS)	100% / ✂% = ✂

Source: TERA Consultants

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[11] At the local level, where there is RCS&RDS, the leased line market share of Romtelecom reaches ✂, considering that leased lines have been subscribed mainly in urban area and that Romtelecom has a market share of 100% for only 8% of the urban footprint

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3   Engineering rules

Once the model has calculated the traffic distribution by service, location and technology in each node, the optimised number and size of equipments has to be modelled under a modified scorched node approach. The optimised cost is then calculated.

This part describes all the engineering rules that are used to dimension the different platforms.

3.1 PSTN

In order to determine the number of PSTN equipments required, as explained in section 2.2, two types of data are used:

- The traffic at each PSTN node;

- The number of customers at each access node.

Such information enables to calculate the capacity of the different equipment required including the ports, service cards and network cards.

Depending on the maximum number of customers that need to be managed at each PSTN node, the model chooses the most appropriate main equipment.

The table below represents the different possibilities for each type of nodes.

Table 8 – Dimensioning rules for PSTN equipments (1)

Maximum number of customers managed	RCU	RSU	Rx	Lx	Tx	IGW
Equipment type	1	1	1	1	1	1
Very small	32	32	32	5 000	-	-
Small	320	320	320	20 000	-	-
Medium	1 600	1 600	1 600	40 000	-	-
Large	100 000	100 000	100 000	500 000	-	-

Source: TERA Consultants

For example, if there are 3 000 customers linked to a RCU, the model chooses the large equipment.

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Then, line cards have to be dimensioned. There are two types of cards: service cards (for PSTN, BRI and PRI customers) and interconnection cards (for SDH connection).

Depending on the number of customers' type on each node, the following engineering rules enable to calculate the number of service cards needed.

Table 9 – Dimensioning rules for PSTN equipments (2)

Maximum number of ports per card	RCU	RSU	Rx	Lx	Tx	IGW
Service cards						
PSTN residential line card	32	32	32	32	-	-
ISDN PRI line card	8	8	8	8	-	-
ISDN BRI line card	8	8	8	8	-	-

Source: TERA Consultants

For example, if there are 70 PSTN customers on a RCU node, the model puts three PSTN residential line cards.

And depending on the SDH traffic on each node, the model chooses the type of card needed for transmission.

Table 10 – Dimensioning rules for PSTN equipments (3)

Maximum number of ports per card	RCU	RSU	Rx	Lx	Tx	IGW
SDH interconnection cards						
E1 line card	32	32	32	32	32	32
STM1 line card	4	4	4	4	4	4
STM4 line card	2	2	2	2	2	2
STM16 line card	1	1	1	1	1	1

Source: TERA Consultants

All those dimensioning rules are deducted from the dimensions that were used in the model developed in 2005. They have indeed not changed.

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3.2 NGN

The NGN network includes the Ethernet aggregation network and the IP/MPLS network. The associated dimensioning rules are linked to:

- The traffic at each NGN node;

- The number of customers at each access node;

- The capacity of the different equipment used, including:

    o Number of service ports;

    o Number of cards required;

    o Number of DSLAMs required;

    o Switches;

    o NP routers;

    o PE routers;

    o P routers;

    o BRAS;

    o Media Gateways;

    o IMS (the model assumes SSW are included in the IMS platform).

The first level of the NGN network is made of DSLAMs. There are several types of DSLAMs and the DSLAMs selected are the main ones deployed by Romtelecom:

- DSLAM providing SHDSL connections;
- DSLAM providing only DSL connections.

Data about the dimensioning rules have been provided by Romtelecom and some assumptions have been made based on the number of equipment present in the network, their capabilities and their price.

Some different cards can be put in the different types of DSLAM. The table below summarizes the number of ports that each card can support.

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Table 11 – Dimensioning rules for DSLAMs (1)

Maximum number of ports supported	DSLAM with SHDSL	DSLAM with only DSL
Service cards		
POTS cards	30	-
DSL cards	48	24
ISDN PRI cards	16	-
ISDN BRI cards	8	-
SHDSL cards	24	-

Source: TERA Consultants from Romtelecom's data

For example, if there is a need of 20 PRI ports and 15 POTS ports, the model deploys to the location 2 ISDN PRI cards and one POTS card.

Then, this table below gives the number of cards that can be installed in each DSLAM.

Table 12 – Dimensioning rules for DSLAMs (2)

Maximum number of cards supported by one equipment	DSLAM with SHDSL	DSLAM with only DSL
Main equipment	36	1

Source: TERA Consultants from Romtelecom's data

For example, if there are 42 cards in a location where the DSLAM with SHDSL has been chosen, the model calculates two DSLAMs.

Concerning the upper level of the NGN network, they are composed of switches and different routers. The approach detailed above is the same concerning the dimensioning rules of those equipments. Due to lack of information, the capacities of the different equipment are based on TERA's expertise.

Those equipments are dimensioned with the traffic they need to handle. The table below summarizes the different cards which can be installed in the switches and the routers in order to respond to the demand traffic.

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Table 13 – Dimensioning rules for switches and routers (1)

Maximum number of ports supported	Switch	NP	PE	P
Cards				
1 Gbps	24	16	2	2
2,5 Gbps	-	4	2	4
10 Gbps	1	2	1	1

Source: TERA Consultants from Romtelecom's data

Then, this table below gives the maximum number of cards per equipment type.

Table 14 – Dimensioning rules for switches and routers (2)

Maximum number of cards supported by one equipment	Switch	NP	PE	P
Main equipment	10	10	10	20

Source: TERA Consultants

For example, if in the location of a switch, there is a need of more than 10 cards the model will choose the right number of switches.

The BRAS represents a fixed cost for the core network. There is therefore no dimensioning issue for this type of equipment.

IMS are nodes in charge of processing the signalling traffic generated by all calls using the network and media gateways are used to connect Romtelecom's IP network to other operators (fixed or mobile, national or international).

Regarding the media gateways, RCS&RDS provided some dimensioning rules. The media gateway is made of a fixed and a variable, traffic dependent part. The variable part depends on the number of Erlang divided by $\asymp$. (One variable part permits to support $\asymp$ Erlang).

Regarding the IMS platform, Romtelecom states the actual IMS platform is made of five IMS nodes and permits to support 150 000 VoIP customers.

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3.3 SDH

On each site, the SDH equipment is chosen depending on the maximum capacity link needed. In order to model an operational network, only one brand had been chosen for which most speeds are available for its equipment.

Depending on the maximum capacity of SDH traffic links on the site, the model chooses a frame and then the different cards that are installed in. As Romtelecom did not provide STM64 equipment, it was necessary to create a "fictive" equipment based on TERA Consultants' expertise and other data provided by Romtelecom.

Data about the cards dimensioning rules have been provided by Romtelecom and some assumptions have been made based on the number of equipment present in the network, their capabilities and their price. One card has been chosen for each capacity.

Table 15 – Dimensioning rules for SDH equipment (1)

Maximum capacity	E1	STM1	STM4	STM16	STM64
Name of the equipment	1650 SM	1650 SM	1650 SM	1650 SM	- [12]

Source: TERA Consultants

Table 16 – Dimensioning rules for SDH equipment (2)

Speed card	E1	STM1	STM4	STM16	STM64
Maximum number of ports	21	4	2	2	2

Source: TERA Consultants

For example, it means that if the location supports 5 STM1 links and 5 E1 links, the model allocates 2 STM1 cards and 1 E1 card.

The model considers as well that all leased lines below 2Mbps are handled by the SDH technology using MUX. This enables to estimate the number of ports required at each site. The number of cards required is then determined on the basis of the traffic and the capacity of the different cards provided by Romtelecom.

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[12] In absence of information from Romtelecom, an assumption has been made regarding the price of this equipment based on benchmark information.

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Figure 40 – Dimensioning rules for SDH – MUX equipment

Card Type	Capacity per port	Number of ports
2B1Q	64 Kb/s	6
27LC	64 - 128 Kb/s	6
28LC	64 - 1 Mb/s	6
V.35	64 - 1920 Kb/s	6
E1	2Mb/s	1
DE1	2x 2Mb/s	2

Source: TERA Consultants

3.4 DWDM

There are four brands of equipment considered in the DWDM network. For each of these brands, three equipment types and few types of cards are available.

The three types of equipment for the DWDM that have been described in the section 1.5 are ILA, OADM, OTM.

Table 17 – Dimensioning rules for DWDM equipment

Equipment type	ILA	OADM	OTM
Max number of cards	8	20	20

Source: TERA Consultants

Romtelecom provided different cards with different capacity. The table below summarizes the different cards with the maximum number of ports associated.

Table 18 – Dimensioning rules for DWDM equipment

Card type	1Gbps	2.5Gbps	10Gbps
Max number of ports	1	2	1
-	2	4	2
-	4	-	-

Source: TERA Consultants

The availability of these cards depends on the brand of the considered node. The choice of the brand is done site by site based on Romtelecom's choice and the number and types of cards is then determined depending on the capacity of available cards and the traffic on the card.

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3.5 Microwaves

Whatever is the use of the microwaves links (for SDH or MPLS network), the cost of the link is identical, according to information provided by Romtelecom.

The microwaves equipment does not have particular dimensioning rules, because the number of links is supposed fixed, and the capacity sufficient for the coming years.

3.6 Building and other equipment

The model also dimensions the building requirements in terms of:

- Power;
- Air conditioning;
- Power equipment (batteries, rectifiers generators) and
- Floor space.

3.6.1 Power consumption

The model determines the total power consumption and cooling requirement on the basis of the consumption of each of its equipment. They have been provided by Romtelecom.

Based on the power consumption of each telecom equipment, the model estimates, based on a mark-up, the additional power consumption related to other equipment (especially air conditioning). This mark-up is set to the value of 0% because it balances the fact that the power consumption provided for each network equipment corresponds to the maximum possible power consumption.

3.6.2 Floor space

The model determines the number of rack/shelf requirements on the basis of information provided by Romtelecom and TERA's expertise. It permits to estimate the floor space required.

Romtelecom provided a floor space for each network equipment and a space per shelf for each type of network equipment. The model assumes the number of rack per shelf presented below:

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Figure 41 – Floor space calculation (1)

	Racks per shelf	Space per shelf
PSTN	5	3
SDH	5	2
MPLS	5	2
DWDM	5	2

Source: TERA Consultants

Figure 42 – Floor space calculation (2)
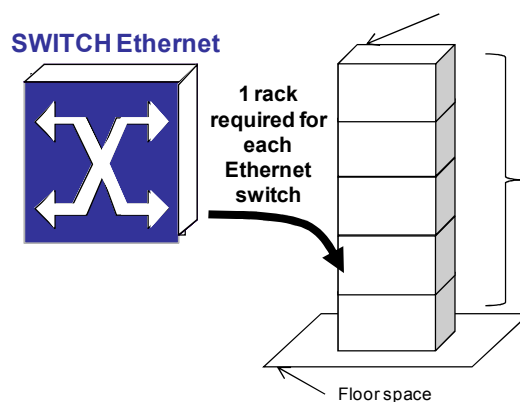
Source: TERA Consultants

The model considers that costs incurred by the lightening system, cleaning, fire alarm and security system are included in the unit cost of floor space.

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4   Unit costs and OPEX

The previous steps enable to determine the number of assets necessary for the network in the two scenarios. As explained in section 0.3, the next step consists in multiplying these numbers by the unit prices.

In order to take into account the specificities of the country, it is preferable to use as a basis the latest unit prices and operating costs provided by Romtelecom and/or by other operators responding to the data request. The unit cost information has been crosschecked with benchmarks based on Tera's expertise with the industry.

However, the following treatments have been made.

4.1   Asset unit prices

Different types of situations occurred for unit costs:

- Regarding the PSTN platform, Romtelecom did not provide any cost equipment because it does not buy anymore PSTN equipments. So, the model includes the cost of the equipment used in the model developed in 2005, balanced by the price trend until the current year.

- Regarding the switches and routers, Romtelecom provided data from its top-down model for the year 2011. In order to be consistent with this data, the model sets unit costs for cards and switches so that the total cost at each layer of "switch + associated cards" and "routers + associated cards" is equal to the total cost provided by Romtelecom.

The figure below explains the principle which is followed:

Figure 43 – Principle to calculate detailed costs of switches and routers
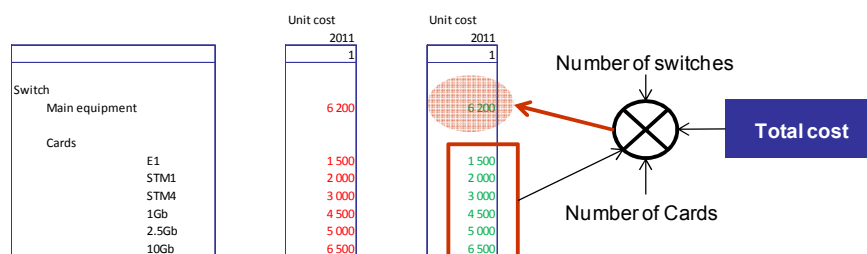
Source: TERA Consultants

In fact, Romtelecom provided the total cost of the switches, the number of switches and the number of cards. So, the model calculates a unit cost per card based as well on TERA's expertise. The same methodology is used for all the different routers.

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Regarding the MGW, Romtelecom provided data but on an aggregated basis, without split between fixed and variable parts. RCS&RDS provided unit costs as well as dimensioning rules for a fixed and traffic dependant variable part.

- Regarding the IMS, Romtelecom provided data related to the unit cost of two IMS platforms.

- Regarding the WDM equipment cost, Romtelecom provided unit costs for variable and fixed elements for 4 different brands. These prices have been used in the model.

- Regarding the SDH, Romtelecom provided several unit costs for the main equipment. The model considers the cheapest equipment for each capacity category for a consistent manufacturer. Regarding cards, Romtelecom provided extensive data. Again, the model considers the cheapest one for each capacity, corresponding to the main equipment manufacturer.

- Regarding the microwaves equipment costs, Romtelecom provided an annualized cost per site for the most recent equipment. This amount is used for each site where there is some microwaves links.

- Regarding the fibre costs, Romtelecom provided the cost of a cable made of 8 fibres, so this enables to calculate the unit cost per fibre. However, in average in the fixed core network, Romtelecom deploys larger cables (close to 48 fibres) with a much lower cost per fibre. As a consequence, based on TERA Consultants' expertise, the unit cost per fibre has been divided by 3. It is then possible to estimate total costs related to fibres on the basis of the data detailed in the description of the fibre network (Romtelecom provided a file which details the different portions of cables and the associated number of fibres). This cost has been multiplied by 2 to include joints.

Regarding the trenches costs, the analysis of 2010 fixed access model provides data for 2010. Trench costs are presumed constant in real terms

4.2 Building and other equipment

4.2.1 Floor space

Buildings costs are calculated based on unit costs provided in the 2010 access model updated with public information on rents.[13]

The total floor space cost is the sum of the "pure" floor space cost, and additional costs for fire alarm, fire extinguishment, security system and other costs of adapting the technical space.

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[13] http://realestate.romtelecom.ro/en/

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4.2.2 Air conditioning and power equipment

In addition to telecom equipment, air conditioning and power supply equipments have to be installed. Power required by telecom equipment installed seems to be a relevant cost driver for those categories.

Figure 44 – Power equipment unit costs

	Total space cost 2011	Unit price 2010	Price trend	Unit price 2011	Useful life	Annualized unit price 2011
Air conditioning system per BTU/h (Ron/(BTU/h))	0,46	2	0%	2,34	12	0,34
Battery back-up system per W installed (Ron/W)	0,14	1	0%	0,88	12	0,13

Source: TERA Consultants

Unit costs for both air conditioning system and power equipment have been taken from the 2010 access model. Costs have been annualized in order to get annual prices.

4.3 OPEX

4.3.1 OPEX calculation

The core network other OPEX elements are calculated using as a starting point actual operating expenditure recorded in Romtelecom's accounts for the core network.

Depending on the category, OPEX is taken into account differently in the model.

1. The electricity is recalculated based on the calculated telecom equipment inventory;

2. Materials, other third parties, maintenance and repairs-third parties, disposal of assets and other costs total value are based on Romtelecom information for 2011, forecasted based on the inflation rate. This category is referenced as "other OPEX";

3. Floorspace is calculated based on floorspace required by telecom equipment calculated inventory;

4. Salaries category is split into three sub-categories:

    a. VoIP interconnection

    b. PSTN interconnection

    c. Other staff

They are supposed to evolve with inflation and number of staff projections provided by Romtelecom. In the "full NGN" scenario, the level of staff costs is

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expected to decrease by 60% due to the lower number of platforms to monitor[14].

4.3.2   OPEX allocation

Electricity and floorspace are allocated to technologies based on telecom equipment requirement.

The "other OPEX" category is allocated to the different services on a pro rata basis of the different investment CAPEX amount.

Some modifications on the CAPEX investment are necessary to do this allocation.

1. The microwaves equipment and equipment related to energy are not taken into account because the calculated amount is an annualized cost.

2. The amount of the fibres and trenches that is taken into account for this calculation is half of the fibres and trenches CAPEX investment, otherwise the amount allocated to fibres and trenches is too important.

Romtelecom provided a split of Staff employees, the total staff salaries amount is then distributed following the distribution (Spreadsheet "Staff")

The total amount calculated for each of these categories is then spread among related technologies based on their CAPEX distribution (Spreadsheet "Staff"):

These results mean that for example 44% of total staff is allocated to the SDH network, and 32% is allocated to MPLS network.

4.4 Other costs

4.4.1   Common and indirect costs

Romtelecom provided common costs allocated to the core network, these common costs are added on top of the final calculated cost for LRAIC calculation, but not for Pure LRIC calculation. It represents around 5.7% of the total annual cost.

Indirect costs are all costs allocated to the core network, but not detailed in the cost elements modelled and described in the previous parts of this document. They are made of CAPEX and include IT costs, transport costs, etc. and have been estimated based on Romtelecom's top-down information which lists the Gross Replacement costs of each of their assets. These costs have also been allocated on top of the total calculated cost for LRAIC calculation but not for the Pure LRIC calculation. It represents about 4.5% of the final cost.

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[14] Several studies show a decrease of core network OPEX with NGN (average of minus 60%): 77% decrease of IP and DWDM costs according to Cisco , 60% decrease according to italtel, one Cisco study showed a 67% reduction in transit network opex for the TI transit network over three years

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4.4.2 Interconnection and bad debt costs

Romtelecom provided some interconnection specific costs. These costs are allocated to all calls using interconnection. In case of Pure LRIC calculation these costs are counted as an incremental cost of the incoming voice service.

Considering that some of the specific interconnection costs are already recovered through the provision of ancillary interconnection services provided at a POI, for avoidance of double counting costs, only a specific part of the total costs provided by Romtelecom has been taken into account for the call termination.

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5   Depreciation

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

The most appropriate methods for depreciation of investments are:

- Tilted Annuity
- Adjusted Tilted Annuity

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

Currently, in the model, annuities are calculated based on the tilted annuity method, by assuming in the formula that the first annual cost recovery is happening one year (in average) after the investment is made.

The formula used is:

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

Where,

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

The adjusted tilted annuity/economic depreciation is not applied at this stage but may be implemented when the setting of regulated prices will be discussed.

Economic asset lives are used in the bottom-up cost model. Asset lives have been provided by Romtelecom for most of the assets of the fixed core network. Otherwise, data are based on benchmark and TERA's expertise.

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Figure 45 – PSTN assets life

PSTN Costs

	Useful life
Capex	
RC equipment costs	12
RC uplink cards	12
RC residential voice cards	12
RC ISDN PRI cards	12
RC ISDN BRI cards	12
RS equipment costs	12
RS uplink cards	12
RS residential voice cards	12
RS ISDN PRI cards	12
RS ISDN BRI cards	12
RX equipment costs	12
RX uplink cards	12
RX residential voice cards	12
RX ISDN PRI cards	12
RX ISDN BRI cards	12
LX equipment costs	12
TX equipment costs	12
IGW	12

Source: TERA Consultants

Figure 46 – MPLS assets life

MPLS Costs

	Useful life
Capex	
DSLAM main equipment costs	12
DSLAM POTS cards costs	12
DSLAM DSL cards costs	12
DSLAM ISDN PRI cards costs	12
DSLAM ISDN BRI cards costs	12
DSLAM SHSDL cards costs	12
Switchs main equipment costs	12
Switchs cards costs	12
Router NP main equipment costs	12
Router NP cards costs	12
Router PE main equipment costs	12
Router PE cards costs	12
Router P main equipment costs	12
Router P cards costs	12
BRAS equipment costs	12
SoftSwitch costs	12
Media Gateway costs	12
International Gateway (data) cost	12

Source: TERA Consultants

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Figure 47 – Fibre, DWDM and SDH assets life

Fibre costs

	Useful life
Fibre investment	20

DWDM costs

	Useful life
Capex	
DWDM main equipment costs	12
DWDM cards costs	12

SDH Costs

	Useful life
Capex	
SDH main equipment costs	12
SDH cards costs	12
SDH mux costs	12

Source: TERA Consultants

Price trends are used in order to take into account changes in prices. Romtelecom did not provide any information related to price trends. The model therefore based its assumptions on an international benchmark of price trends.

Figure 48 – Price trends benchmark

	XA	DK	SE	XB	FR
Frame	-5%	-5%	-2%	-5%	-9%
Cards	-5%	-5%	-3%	-5%	-5%
Software	-5%	-5%	-4%	-5%	

DK: Denmark, SE: Sweden, FR: France, XA and XB are countries for which data is not public

Source: TERA Consultants

These price trends are expressed in nominal terms and in Euros. The model is itself expressed in Euros.

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6   Pure LRIC method

The Pure LRIC approach consists in modeling the network considering two scenarios:

- A scenario considering the network as it is modeled with the integrality of the demand
- A scenario considering the network required to support the demand but not taking in account the incoming traffic

In both cases the total cost of the network is considered. The avoided cost resulting in (hypothetically) removing the incoming traffic of a service is then recovered only through the incoming traffic.

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

The amount of common costs is considered as fixed and is not taken in account in the differential calculation of the "pure LRIC".

The model allows the user in the 'Pure LRIC Costs' spreadsheet to calculate the Pure LRIC cost of three "services":

- PSTN pure LRIC

- VoIP pure LRIC

- Voice (PSTN + VoIP) pure LRIC

These costs can be calculated using a macro in the spreadsheet "Pure LRIC Costs". A button is available to calculate the cost of each service, and another one is available to calculate the three categories at the same time.

As the Pure LRIC calculation requires the model to run with two different parameters, the calculation can take few minutes to be performed. It is to be noted that the user should not click on the excel window while the calculation is running otherwise it may stop the calculation and display incorrect results.

As it requires a lot of time to be performed, the sensibility calculation hides the excel window while it is calculating. The window will be shown again once the calculation is done.

Please note that the Full NGN parameter has to be set manually before launching the calculation.

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7   Cost allocation (LRAIC+ method)

7.1 Principles

As it was decided in the conceptual framework, "*ANCOM intends to implement the required capacity (also called 'capacity based') allocation method in the bottom-up models for common costs, as this approach allocates such network costs in accordance with the capacity required by each service and thus conforms to the principle of cost-causation*".

Indeed, in fixed core networks, many costs are shared between several services. Also many assets are shared between several platforms. As a consequence, to determine service costs (and corresponding regulated prices), it is necessary to allocate costs between services.

Figure 49 – Cost allocation diagram (for illustrative purposes only)
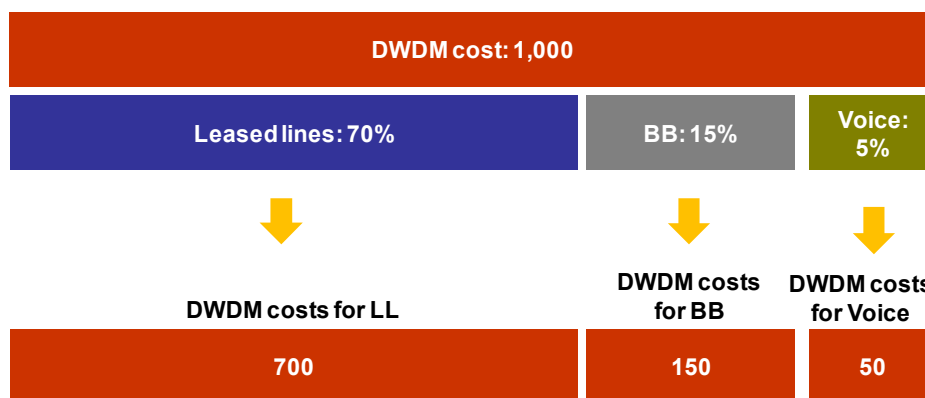
Source: TERA Consultants

For example, the total DWDM costs have to be allocated to different platforms at different levels because DWDM is used by each of them:

- MPLS
    - Local;
    - Regional;
    - National;
- Leased lines DWDM
    - Local;
    - Regional;
    - National.

The allocation processes used in the model are detailed below.

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7.2 Intermediary allocation

7.2.1 Fibres and trenches allocation

Romtelecom provided the inventory of the fibres segment in the network and the number of fibres used for each platform. This enables to calculate the total number of fibres used per each platform listed below:

- SDH
    - Local level;
    - Regional level;
    - National level;
- MPLS
    - DSLAM – Switch links;
    - Switch – switch links;
    - Switch – NP routers links;
    - NP – PE routers links;
- WDM
    - Local level;
    - Regional level;
    - National level.

The inventory provided as well the number of fibres that are installed but not used. For example, it is possible that cables with 8 fibres have been installed and only 6 are used, so there are 2 fibres not used. Those not-used fibres are allocated to the different levels detailed in proportion of the number of fibres used at each level.

The model calculated the cost of a fibre, so can calculate the fibres cost for each level.

The kilometres of trenches are allocated in proportion of the km of cables at each level. The same levels that the ones detailed above are considered for trench allocation.

7.2.2 Microwaves costs allocation

As it was explained before, microwaves are used for two technologies:

- SDH
- MPLS

Microwaves costs are allocated among both networks with the same distribution that the one presented in the section 1.7 of this document.

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7.2.3   MDF costs allocation

The MDF costs are allocated to the following platform in proportion of the number of tie-cables used by each platform:

- PSTN
- SDH leased lines < 2 Mbps
- SDH leased lines > 2 Mbps
- MPLS
- DWDM

However, as long as MDF are already taken into account in the access model, in order to avoid double counting, the unit cost of MDFs has been set to 0.

7.2.4   ODF costs allocation

The ODF costs are allocated to the following platform in proportion of the number of fibres used by each platform:

- PSTN
- SDH leased lines < 2 Mbps
- SDH leased lines > 2 Mbps
- MPLS
- DWDM

7.2.5   DWDM costs allocation

The DWDM costs are allocated to the following platforms:

- MPLS
  - Local;
  - Regional;
  - National;
- Leased lines DWDM
  - Local;
  - Regional;
  - National.

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The DWDM total cost is made of several costs:

- DWDM equipment costs and DWDM fibre costs (see section 6.2.1) that are allocated in proportion of the traffic at the busiest hour for each platform;

- DWDM MDF, ODF and Fibre optics tie cables costs (see sections 6.2.3 and 6.2.4) that are allocated in proportion of the number of ports for each platform;

7.2.6   SDH allocation

The SDH costs are allocated to the following platforms:

- PSTN
  - Local;
  - Regional;
  - National;

- Leased Lines < 2 Mbps
  - Local;
  - Regional;
  - National;

- Leased lines > 2 Mbps
  - Local;
  - Regional;
  - National.

The SDH total cost is made of several costs:

- SDH equipment costs that are allocated in proportion of the traffic at the busiest hour for each platform;

- Part of the microwaves costs allocated to the SDH (see section 6.2.1) on the pro-rata of the traffic at the busiest hour for each platform;

- MUX equipment costs that are allocated to the different level of leased lines < 2 Mbps in proportion of the number of leased lines at each level

- SDH Fibre optics and Copper tie cables that are allocated in proportion of the number of ports for each platform.

- Part of the MDF and ODF allocated to the SDH (see section 6.2.3 and 6.2.4) in proportion of the number of ports for each platform.

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- Part of the fibres cost allocated to the SDH (see section 6.2.1) in proportion of the traffic at the busiest hour for each platform.

7.3 Final allocation

This part of the document is the last step in order to cost the different services provided. It consists in allocating the different costs to the different services that are concerned by the different technology.

7.3.1 PSTN

The different costs calculated in the model are allocated to the different PSTN services.

Two allocations are made for the PSTN costs as it is described in the figure below:

- One allocation per service;

- One allocation per level.

Figure 50 – Allocation levels for the PSTN costs

Per service
    Residential voice
    ISDN PRI voice
    ISDN BRI voice
    Voice interconnection

Per level
    Local
    Regional
    National

Source: TERA Consultants

Regarding the allocation per service, the following costs are allocated on the levels presented in the figure above:

- Rc, Rs and Rx main equipment costs are allocated in proportion of the number of channels used by each services (residential voice, ISDN PRI voice, ISDN BRI voice);

- Rc, Rs and Rx residential voice cards, ISDN PRI voice cards, ISDN BRI voice cards are respectively allocated to the residential voice service, ISDN PRI voice service and ISDN BRI voice service;

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- Lx and Tx main equipment costs are allocated in proportion of the traffic at the busiest hour generated by each service (residential voice, ISDN PRI voice, ISDN BRI voice);

- Lx and Tx residential voice cards, ISDN PRI voice cards, ISDN BRI voice cards are respectively allocation to the residential voice service, ISDN PRI voice service and ISDN BRI voice service;

- The international gateway equipment costs and international gateway OPEX costs are allocated to international voice;

- PSTN OPEX, tie cable and MDF costs are allocated to the different services (residential voice, ISDN PRI voice, ISDN BRI voice) in proportion of the number of customers;

- SDH local, regional and national costs (see section 6.2.6) are allocated to the different service (residential voice, ISDN PRI voice, ISDN BRI voice) in proportion to the PSTN traffic at the busiest hour generated by the different service.

Regarding the allocation per level,

- The local level represents the cost of a local call;

- The regional level represents the incremental cost of a regional call in comparison to a local call;

- The national level represents the incremental cost of a national call in comparison to a regional call.

Regarding the allocation per level, the following costs are allocated on the levels presented in the figure above:

- Rc, Rs and Rx costs are allocated to the local level;

- Lx costs are allocated to the local and regional levels (because local calls sometimes use the Lx, see routing factors);

- Tx costs are allocated to the local, regional and national levels (because local and regional calls sometimes use the Tx, see routing factors);

- International Gateways costs are allocated to the international calls;

- PSTN opex costs are allocated to the local, regional, national and interconnection levels in proportion of the total distribution of the traffic;

- Tie cable and MDF costs are allocated to the local level;

- SDH local costs are allocated to the local level;

- SDH regional costs are allocated to the local and regional levels;

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- SDH national costs are allocated to the local, regional and national levels.

Figure 51 – Example of an allocation (based on dummy figures)

	Common costs and indirect costs markup (EUR)	Total annual costs (EUR)	SDH main equipme	SDH cards costs	Wavelinks	SDH mux costs
PSTN local	10 669 115	30 362 602	3 211 687	211 536	343 370	-
PSTN regional	4 959 694	14 114 500	1 862 908	8 055	-	-
PSTN national	10 333 304	29 406 937	1 168 474	1 007	-	-
Total leased lines SDH	183 420 022	521 984 170	-	-	-	-
Leased lines <2Mbps	11 493 764	32 709 423	-	-	-	-
Local	5 252 311	14 947 239	2 135 330	82 602	228 294	810 453
Regional	2 537 338	7 220 860	693 692	29 570	74 165	241 619
National	3 704 116	10 541 323	263 898	18 392	28 214	148 357
Leased lines >=2Mbps	171 926 258	489 274 748	-	-	-	-
Local	76 595 237	217 977 845	33 489 823	581 290	3 580 487	-
Regional	38 137 395	108 532 952	10 879 644	208 089	1 163 172	-
National	57 193 626	162 763 951	4 138 898	129 431	442 501	-
Total	378 333 809	1 076 677 764	9 335 991	1 269 971	5 860 203	1 200 430

Source: TERA Consultants

7.3.2 MPLS

The same approach that the one presented in the section before is applied to allocate the different MPLS costs to the different services presented in the figure below:

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Figure 52 – Allocation levels for the MPLS costs

POTS voice
VoIP voice
Voice interconnection
IPTV
DSL
ISDN PRI
ISDN BRI
SHDSL leased line
    Local
    Regional
    National
Leased line >= 2Mbps
    Local
    Regional
    National

The POTS voice, ISDN BRI and ISDN PRI are not used in the allocation in reality because they are not handled by the NGN network

Source: TERA Consultants

The following costs are taking into account with the associated allocation rules:

- DSLAM main equipment costs are allocated to the different services in proportion of the traffic generated by each service;

- DSLAM card costs are allocated the VoIP voice, IPTV and DSL services in proportion of the DSL traffic respectively generated by the different traffic;

- Switch main equipment costs are allocated to the different services in proportion to the traffic generated by each one;

- Switch card costs are allocated to the different services in proportion of the number of connections;

- NP, PE and P routers costs are allocated to the different services in proportion to the traffic at the busiest hour due to each service;

- BRAS costs are allocated on an equal basis to IPTV and DSL services;

- MGW costs are allocated to the voice interconnection service;

- IMS costs are allocated to the VoIP service

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- DWDM local, regional and national costs calculated before (section 6.2.5) are allocated to the different services in proportion of the traffic at the busiest hour due to each service;

- Tie cables Fibre optics and Copper, MDF and ODF costs calculated before (see Section 6.2.3 and 6.2.4) are allocated to the different services in proportion to the number of customers of each service;

- Wave links costs and fibre costs are allocated to the different services in proportion of the traffic at the busiest hour due to each service.

Figure 53 - Example of the allocation (based on dummy figures)

	Common costs and indirect costs markup (EUR)	Total annual costs (EUR)	DSLAM main equipment costs
POTS voice	-	-	-
VoIP voice	486 437	2 809 986	1 015
Voice international intercor	5 529	31 938	-
IPTV	4 972 379	28 723 795	180 917
DSL	9 371 504	54 136 086	168 374
ISDN PRI	-	-	-
ISDN BRI	-	-	-
SHDSL leased line	34 518	199 401	1 010
Local	30 724	177 482	1 010
Regional	2 806	16 211	-
National	988	5 708	-
Leased line >= 2Mbps	56 144	324 324	-
Local	38 434	222 019	-
Regional	15 467	89 350	-
National	2 243	12 954	-
Total	**125 180**	**723 126**	**351 316**

Source: TERA Consultants

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8 Main results

The bottom-up cost model uses several assumptions that have been described earlier. However, it is necessary to make sure that those assumptions are realistic and do not generate unrealistic results.

To make sure that these assumptions are realistic, several tests have been carried out:

- Calibration of the model thanks to Romtelecom's top-down information. Romtelecom's provided the Gross Replacement Cost for the assets listed in its top-down model. This has been compared to the CAPEX calculated in the model
- Sensitivity analyses were performed;

- Order of magnitude of the results have been compared with other countries.

The two first analyses are described hereafter.

8.1 Calibration of the model

In addition to detailed cost data provided by Romtelecom, the model has to be calibrated and compared to actual costs incurred by Romtelecom. In order to perform this calibration, several sources have been considered, the main one being:

- Detailed financial output of Romtelecom which provides the Gross Replacement Cost of all fixed network assets for the year 2011;
- The fixed access network cost model developed by ANCOM in 2010;
- The fixed core network cost model developed by ANCOM in 2005;
- Additional data provided by Romtelecom in response to the data request sent for this project;
- TERA's expertise on fixed core network cost models.

This section will detail calibrations and checks done for each technological category. All checks have been carried out for 2011 in EURO.

8.1.1 Fibres and connections

The total cost of fibres cannot be reconciled with Romtelecom's financial data or with data from the 2005 fixed core network cost model.

In 2005, the model was considering only SDH as a transport technology, since then some new lines have been added, and the DWDM and MPLS networks have been deployed. In 2005 the model was considering ✂km of trenches, while the current model has more than ✂km.

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The difference between the core model and Romtelecom's financial output[15] may be coming from the fact that most of trenches have already been fully depreciated in Romtelecom's accounts.

8.1.2   DWDM

The following figure represents the total investments in EURO required in order to rebuild the network for the year 2011:

The DWDM being a new technology implemented recently, it was not present in the previous core model in 2005.

Romtelecom in addition to unit costs and financial outputs[16] has provided a total material and installation cost on a per site basis.

The total DWDM cost calculated by the network is higher than the two other figures, i.e. what has really been spent by Romtelecom. After comparing the investment required in each of the four brands deployed by Romtelecom in the model and in reality, the main discrepancy between the model and data provided by Romtelecom relates to one

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[15] The financial output total fibre cost has been calculated mainly from the following categories (97% of costs):

•   Telecom Assets-Transport-Support-Ducting-HDPE-

•   Telecom Assets-Access-Support-Ducting-PVC-

•   Telecom Assets-Access-Support-Chambers-Manholes-

•   Telecom Assets-Access-Support-Ducting-Concrete-

•   Telecom Assets-Transport-Support-Ducting-PVC-

•   Telecom Assets-Transport-Support-Ducting-Concrete-

•   Telecom Assets-Access-Support-Poles-Wooden-

•   Telecom Assets-Access-Support-Ducting-HDPE-

•   Telecom Assets-Transport-Cabling-Fiber-Buried-

•   Telecom Assets-Transport-Cabling-Fiber-Ducted-

•   Telecom Assets-Transport-Cabling-Fiber-Aerial

[16] The total DWDM investment has been deduced from the following financial output categories:

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-DWDM hardware

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-DWDM spare parts

•   Telecom Assets-Transport-Management Systems-Transmissions Other equipment-DWDM-hardware

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-

•   Telecom Assets-Transport-Management Systems-Transmissions Other equipment-DWDM-software

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-CWDM hardware

•   Telecom   Assets-Transport-Transmisions-Other   equipment-WDM   Equipment-CWDM   optical interfaces

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-DWDM software

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-CWDM spare parts

•   Telecom Assets-Transport-Transmisions-Other equipment-WDM Equipment-CWDM software

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brand "✂" for which the calculated cost is 2.9 times the provided total cost. This may be due to the fact that for that brand Romtelecom provided only one kind of service card (one 10Gbps port), which is twice more expensive than the average and does not allow the calibration. The calculation done on generic dimensioning rules may have led to an overestimated interconnection capacity at P and PE than what has been implemented by Romtelecom. In addition, some equipment may not need to use the DWDM and might use direct connections instead.

The dimensioning of a DWDM node is modelled as follows:

- A number of required service ports is calculated for each level:
  - Leased line are connected on regional rings;
  - PE routers are connected on local rings if available, on regional rings otherwise;
  - P routers are connected to national rings;
  - Local rings are connected to all regional rings that they cross;
  - Regional rings are connected to all national rings that they cross;
  - National rings are connected to all national rings that they cross;
- A number of required service ports is calculated for each site (ports used to connect leased lines and MPLS equipment);
- The inventory of main equipment is taken from the inventory of 2011 and considered as constant;
- Security and redundancy are considered to be carried out by the ring architecture;
- NB: No detailed inventory of cards and required specific parts has been provided in order to cross-check engineering rules used by the model to dimension required equipment.

8.1.3 SDH

SDH costs have been checked from two sources:

- the total amount calculated in the 2005 model; and
- the total gross replacement cost as registered in the account for 2011[17].

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[17] The financial output SDH total cost has been calculated considering mainly the following categories (92%):

- Telecom Assets-Transport-Transmisions-Local SDH equipment-ADM - main equipment-
- Telecom Assets-Transport-Transmisions-Regional SDH equipment-ADM - main equipment-
- Telecom Assets-Transport-Transmisions-Local PDH equipment-Multiplexer-
- Telecom Assets-Transport-Transmisions-Local SDH equipment-ADM - tributary cards-
- Telecom Assets-Transport-Transmisions-Regional SDH equipment-ADM - tributary cards-
- Telecom Assets-Transport-Transmisions-National SDH equipment-ADM - main equipment-
- Telecom Assets-Transport-Transmisions-Other equipment-TDM Equipment-
- Telecom Assets-Transport-Transmisions-Digital radio equipment-Outdoor equipment-

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When comparing the amount calculated by the model and Romtelecom's financial outputs, the dimensioning points that might have an important impact on the final total cost are the following:

- The security implemented is the ring protection: two ports are required on each equipment of a ring as explained by Romtelecom, but in practice this may differ and more protection levels could be implemented.

- A site crossed by many rings requires in the model only one main equipment and as many ports as it requires to provide rings services (2 ports for 1 ring, 4 ports for 2 rings, etc.). A second equipment is required only if the number of service cards required exceeds the maximum number of cards the equipment can handle. The equipment capacity is determined by the ring handling the highest traffic (the faster service port used). However, in reality, Romtelecom may have deployed two nodes instead on only one.

It has to be noted that the SDH network may have been upgraded since 2005, due to data requirement and maybe some few additional nodes have been deployed, which explains the difference.

8.1.4   MPLS

MPLS costs have been checked from two sources: data provided by Romtelecom split by type of nodes, and the gross replacement cost (GRC) of assets as listed in Romtelecom accounts.

The difference for DSLAMs between Romtelecom's accounting outputs and the calculated cost can be explained by the fact that only two models of DSLAMs are considered in the model, a new Huawei model, that is cheaper than the average DSLAMs used in practice and an Alcatel used only if another service than DSL has to be provided on the site. One consequence is that the Huawei model does not support additional cards on top of its 24 ports, so the number of DSLAM required on a site may increase significantly.

- Switches, NP, PE, P and BRAS costs have been calibrated using data provided by Romtelecom total cost and therefore, for the year 2011, costs match properly.

- The IMS difference may come from the fact that the current IMS platform installed is over-dimensioned regarding the demand because demand is taking

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- Telecom Assets-Transport-Transmisions-Digital radio equipment-Indoor equipment-
- Telecom Assets-Access-Transmission equipment-PDH equipment-Multiplexer-
- Telecom Assets-Transport-Management Systems-Transmissions SDH-Software - SDH Local (NEM)-
- Telecom Assets-Transport-Transmisions-National SDH equipment-ADM - tributary cards- .

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up. The model considering an efficient operator, additional costs will only be added when required.

- The management system costs considered are the costs provided by Romtelecom as an answer to the data request.

8.1.5 PSTN

The cost of the PSTN network has been checked with data from the gross replacement cost and the core model carried out by ANCOM in 2005.

The cost of PSTN extracted from the 2005 model (for year 2007, then adjusted using the telecom price trend until 2011) is higher than the cost calculated for 2011. It can be explained by the fact that requirements for 2007 were much higher than requirement for 2011 due to the decrease of the PSTN voice demand. The most impacted equipment are LX and TX for which the dimensioning is more related to the traffic, whereas the cost of RX equipment is more related to the number of localities served.

8.2 Sensitivity analysis

Different sensitivity analyses have been performed to challenge the model results. The main one is the comparison of costs between the generic operator scenario and the specific operator scenario and this comparison is described in this section.

An analysis of investments required for both Romtelecom network and generic operator network has been performed. It is to be noted that for the generic operator scenario, some routing factors have been applied on the traffic as explained earlier, which can lead to dimensioning differences.

The generic scenario results in null costs for SDH and PSTN technologies, but as all considered clients of these technologies are migrated to the NGN, it may result on additional costs on MPLS and DWDM technologies.

8.2.1.1 *Trenches, fibres and connections costs*

Trenches, fibres and connections costs have been extracted as an output of the model for both scenarios of the full Romtelecom network and the generic operator.

- In the full NGN scenario, a part of the SDH fibre network is transferred to both MPLS and WDM networks, and the part of trenches previously shared between SDH and other technologies is then transferred entirely to other technologies. As a result the total cost allocated to both MPLS and DWDM goes from 400,000,000€ in Romtelecom scenario to 2,200,000,000€ in the generic operator scenario.

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- ODFs are used to connect optical fibres. As in the full NGN scenario, some SDH equipment has been removed, ODF total cost is reduced.
- The number of tie cables differs all PSTN households not having a VoIP solution are migrating to get a new broadband line. Therefore most of SDH tie cables are attributed to MPLS.

8.2.1.2   DWDM costs

DWDM costs have been extracted as an output of the model for both scenarios of the full Romtelecom network and the generic operator.

DWDM costs vary very little, due to the fact that the traffic calculated at P and PE levels is lower than Romtelecom's traffic. That is a consequence of routing factors applied for the generic operator.

8.2.1.3   MPLS costs

MPLS costs have been extracted as an output of the model for both scenarios of the full Romtelecom network and the generic operator.

- DSLAMs providing only DSL access are highly impacted, as their number of ports is very limited. The migration from PSTN customers to VoIP (Broadband) solution generates many new lines to connect.
- The number of switches main equipment varies slightly as they are able to support a consequent number of cards, however the number of cards gets higher mainly because of new DSLAMs to connect and leased lines migrated from SDH to MPLS.
- The number of NP routers changes following the same pattern: a higher number of switches implies more connection ports, therefore more cards.
- The investment for PE and P equipment remains stable, whereas the investment for cards is a little bit lower. This can be explained by the reduction of the traffic at core level.
- Media gateway and IMS costs are both directly related to the number of customers.

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