LRAIC model for fixed networks in Denmark

Specification document

Danish Business Authority

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0 Introduction

0.1 Background

In 2003, the Danish Business Authority[1] started to regulate a number of TDC's wholesale prices in accordance with the LRAIC pricing methodology. As part of this process, a model was constructed in collaboration with the industry (including TDC).

Since then, the model has been updated on a yearly basis and every three years the DBA considers whether there are suitable grounds for a more extensive update.

In particular, significant updates can be due to:

- Customer base / Traffic trends;
- Upgrades of TDC network (NGN/NGA);
- New services (IPTV…).

This document is part of the fourth extensive update project.

DBA has commissioned TERA Consultants to modify and develop the LRAIC model for fixed networks in Denmark for the period 2012-2014 in order to set prices from January 2015. This project is built along 4 main phases[2]: 1) preparation of a Model Reference Paper (MRP), 2) Revision and development of a LRAIC model, 3) Model circulation and 4) Setting of maximum prices.

As part of the first phase of this project, DBA published in the first half of 2013 a Modern Equivalent Asset (MEA) assessment paper and a MRP paper which serves as a basis for the revision and development of LRAIC models (phase 2 of the project).

Over the last few months, DBA has collected information from the different stakeholders (mainly TDC, Telenor, Telia and Dansk Energi). On the basis of this data, of the existing models, of the MEA and MRP documents published in 2013 and of its expertise, TERA Consultants has revised and developed LRAIC models for fixed networks.

This specification document aims at describing to the industry the structure, parameters and assumptions used during the development of the LRAIC model for fixed networks then used to determine LRAIC based costs for certain wholesale access and interconnection services in Denmark.

Furthermore, this document includes the details of the modifications implemented to the FTTH-P2P fixed LRAIC modelling in 2017 in order to handle the geographical split of costs between regulated and non-regulated areas. As a result of this modification, the model is capable of computing the cost per line for a given area (regulated or non-regulated) as defined by the end-user at building, CO or zip code level.

[1] Previously the National IT and Telecom Agency (NITA)

[2] Excluding kick off of the project which occurred in December 2012 and January 2013.

This modification of the model was made essential by geographical differences in infrastructure roll-out as well as market shares across geographical areas of Denmark. As a result of those differences, the market decisions of markets 3a and 3b relaxed the price control obligation for fibre in certain areas. This way, the total Danish FTTH-P2P network can be split between regulated and non-regulated areas.

0.2 MRP overview

The MRP consists of 81 criteria detailing the approach to be used for the implementation of DBA's LRAIC model. The aim of this section is to summarize the main criteria and outputs of the MRP.

Overall goal

The LRAIC model should be based on forward-looking long-run average incremental costs and ensure that pure LRIC termination costs can also be calculated.

Structure of the model

The structure of the model should consider the following rules:

- Access and core are to be modelled separately. Co-location and results will be included in the core model. The demarcation between core and access is the line card (that is part of the access increment);
- The models will capture the demand for all services contributing to the economies of scope: voice, broadband, TV and leased lines services (based on TDC's leased lines list);
- The modelling is based on the scorched-node approach[3].

Core technology

The core network should be modelled based on a full IP packet switch technology (no SDH). The LRAIC models should not include DWDM equipment in the core network, except for long distances.

Media-gateways will be installed for the interconnection with TDM networks.

Access technologies

Several access networks will be modelled:

- Nationwide copper network;
- Cable-TV network (based on YouSee's footprint);

[3] Real TDC's nodes locations are kept.

- Existing FTTH network (the DONG area);
- Nationwide FTTH network.

The access network model should be based on the following rules:

- The model is based on the "scorched node" approach (as far as data availability allows it);
- For fibre, both PTP and PON should be modelled;
- For the modelling of each access network, all of TDC's local fixed network present demand in terms of active subscriptions is considered (i.e. 100% of the "copper + cable-TV + fibre" demand);
- Drop wires are deployed only for active customers + some inactive customers (to reflect the churn);
- Access network is modelled based on geomarketing data that is processed with shortest path algorithms (modelling is performed at the road section level[4]).

0.3 Structure of this document

This paper details the approach followed when building the LRAIC model. The paper has the following structure:

- **Section 1** - Overview of the model (see §1): Gives a high level view of the model structure
- **Section 2** - Estimating the access demand (see §2): Calculates the access network demand based on active copper, cable-TV and fibre lines
- **Section 3** - Equipping the copper access network (see §3): Dimensions the copper access network
- **Section 4** - Equipping the fibre access network (see §4): Dimensions the fibre access network
- **Section 5** - Equipping the cable-TV access network (see §5): Dimensions the cable-TV access network
- **Section 6** - Capturing core/BTO civil engineering and cables requirements (see §6): Dimensions the core network and the BTO (business customers) network.
- **Section 7** - Equipping the core network (see §7): Dimensions the core network assets to handle the demand from all services
- **Section 8** - Co-location modelling (see §8): Derive the co-location unit costs

[4] A road section is defined as the space between two crossroads. As a consequence, a street can be composed of several road sections.

- **Section 9** - Depreciation, cost allocation and results (see §9): Derive the network costs and service costs from the network dimensioning
- **Section 10** - Model implementation and usage (see §10): Shows how to run and update the model
- **Section 11** Validating the cost models - (see §11): Shows how the models have been challenged

1 Overview of the model

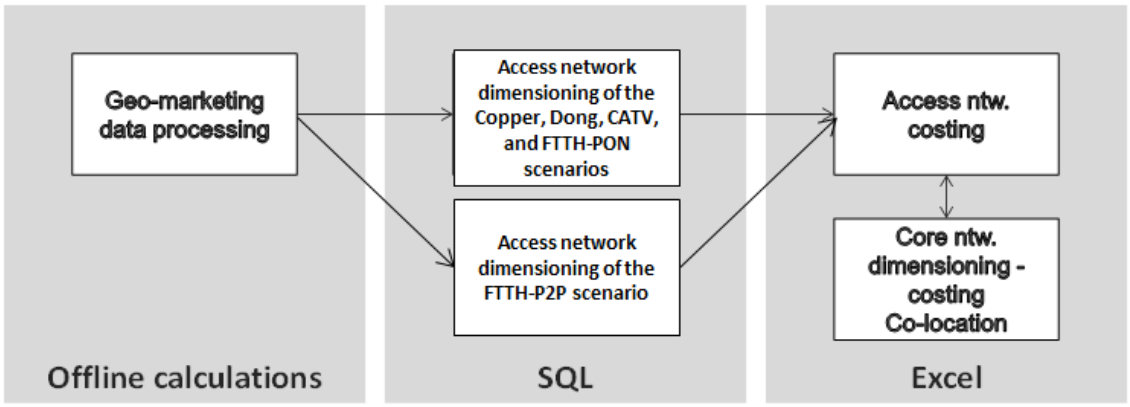
This section describes the basic structure and operation of the model.

1.1 Introduction

The model is a hierarchy of 5 interlinked sections (see Figure 1):

- **Geo marketing data-processing** (offline calculation): aims at determining all cables paths from the end-users to the network nodes (shortest path algorithms). A specific geo-marketing tool is used to perform these off-line calculations.
- **Access network dimensioning of the Copper, Dong, CATV, and FTTH-PON** (SQL): Based on the geo-marketing data analysis, the access network is dimensioned (cables, civil engineering, etc.). Due to large amount of data to be treated, the calculation is performed with in SQL.
- **Access network dimensioning of the FTTH-P2P scenario and splitting into regulated and non-regulated areas** (SQL): Based on the geo-marketing data analysis, the access network is dimensioned (cables, civil engineering, etc.) and each cost item is assigned to the regulated or non-regulated area based on its cost drivers. Due to large amounts of data to be treated, the calculation is performed with SQL.
- **Access network costing** (Microsoft Excel): Once the dimensioning is performed, costs are derived (multiplying the asset count by the unit costs). Depreciation and allocation of trench costs between core and access networks is then performed. The maximum amount of calculations (including investment calculation) is conducted in Microsoft Excel.
- **Core network + Co-location model** (Microsoft Excel): Dimensions and derives the costs of the core network. Derives the costs of co-location.

Figure 1 – Structure and interaction of the model



Source: DBA

The core network consists mainly of active equipment (traffic related costs). The access network consists essentially of passive equipment (non-traffic related costs).

The demarcation between the core and the access network is set at the line card facing the aggregation router.

NB: In practice, the line card dimensioning and costing calculation is located in the core part of the model (along with the rest of the DSLAM) but its dimensioning is based on the number of access lines and is not traffic-related (as in the access network model dimensioning).

1.2 Access network cost model

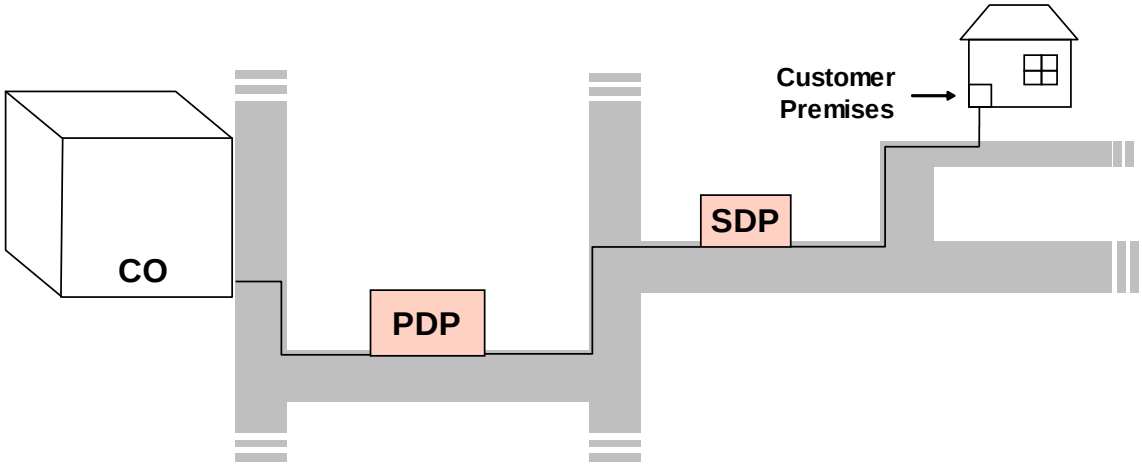
The access network cost model aims at modelling the costs of all cables and trenching associated with customer lines to link all customers from the customer's premises to a concentration point (Central Office) where active equipment are located.

This is performed for different access technologies (see Figure 2):

- Copper;
- Fibre PON/P2P;
- Cable-TV.

In the case of the fibre P2P network, the model can be used to compute the access network cost of all cables and trenching linking the all customers to the Central Office of any specific region defined at the building level, CO or zip code level.

Figure 2 – Architecture of access networks modelled



Source: DBA

The access network includes:

- The final drop wire to the customer's premise;
- The trenching (in some cases ducted) between the final connection point and the remote or host DSLAM/OLT/CMTS;
- Cable and optical fibre in this part of the network; and
- Other assets such as manholes, poles and overhead cables (if used).

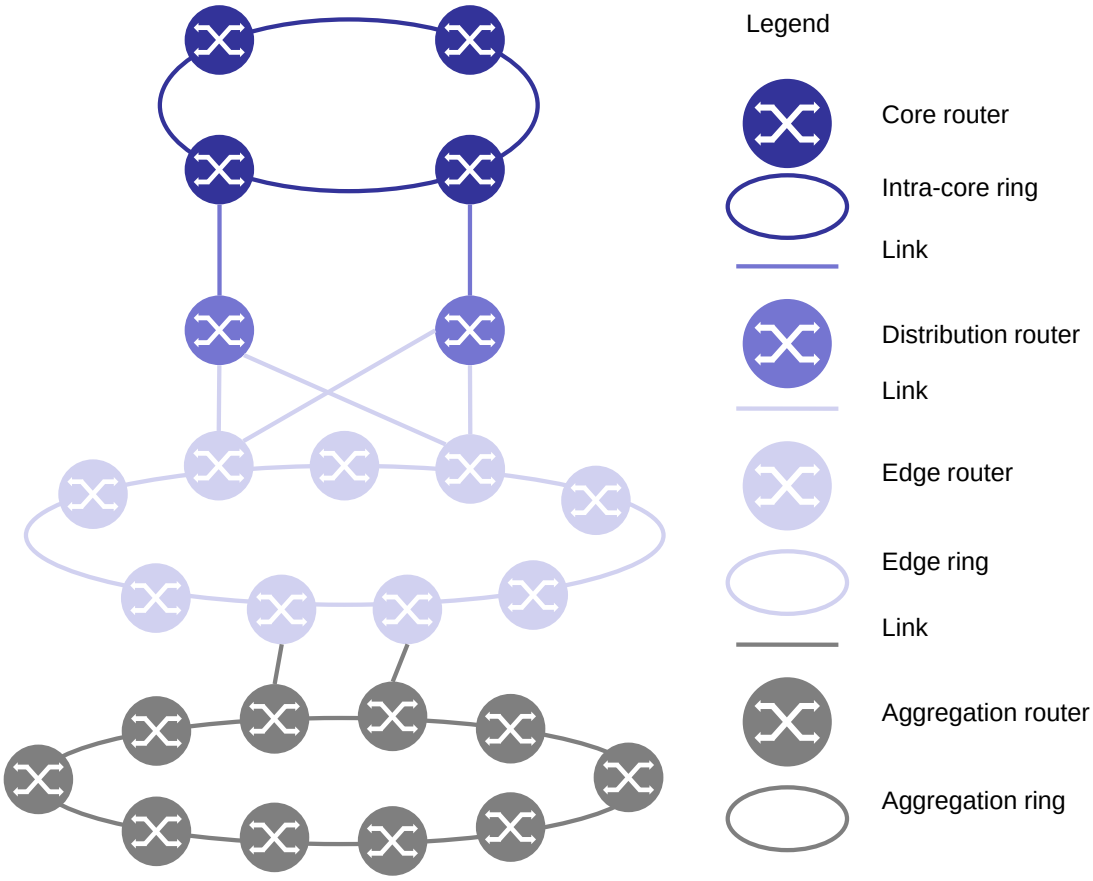
1.3 Core network cost model

The core network cost model aims at modelling the cost of the core network for the mix of access network technologies within Denmark (i.e. a unique per core Mbps cost is calculated, whatever the access network technology).

Assets within the core network typically include (see Figure 3):

- DLSAMs, OLTs or CMTS except line cards;
- Backbone/core routers;
- Transmission links between the exchanges;
- Optical fibre and trenching between all levels of core node locations.

Figure 3 – Architecture of core network modelled



Source: DBA

In the case of FTTC, the DSLAMs are located at the street cabinet, but for practical reasons they will be modelled in the core network.

2 Estimating the access demand

The geo-marketing data is a key input for the LRAIC access network cost model. Several preliminary steps are required to estimate the access demand using geomarketing data:

- Collect the reference files (see §2.1);
- Work on the road network database (see §2.2);
- Work on the address database (see §2.3);

2.1 Reference files

Geocible, the DBA's expert on Geographic Information System, has aggregated the network topology data submitted by TDC with the cartography of Denmark.

The table hereafter lists the files which have been considered as reference files to define the access network demand (see Figure 4).

Figure 4 – Input tables for the geo-marketing analysis

Ntw.	File type	Description	Source
All	GIS	Describes : • the national road network • the buildings of the country • the addresses of the country	KMS
All	CSV	Provides additional data regarding the addresses of the country	AWS http://file.aws.dk/csv.html
Copper	Access	Provides an extract of TDC information system. The database provides all copper addresses passed.	cobber_trail.mdb *Provided by TDC the 26/08/2013*
Fibre	Access	Provides the address of buildings connected to each DN.	TDC https://wholesale.tdc.dk/wholesale/produkter/aftaler/Sider/whitelists.aspx
CA-TV	CSV	Provides kvh-x (national address identifier) and coordinates of cable-TV addresses passed.	YouSee *YouSee_Homes_passed_2013_06.csv*

Source: DBA

An important work has been carried out by TERA and Geocible to ensure data consistency between the different data sources.

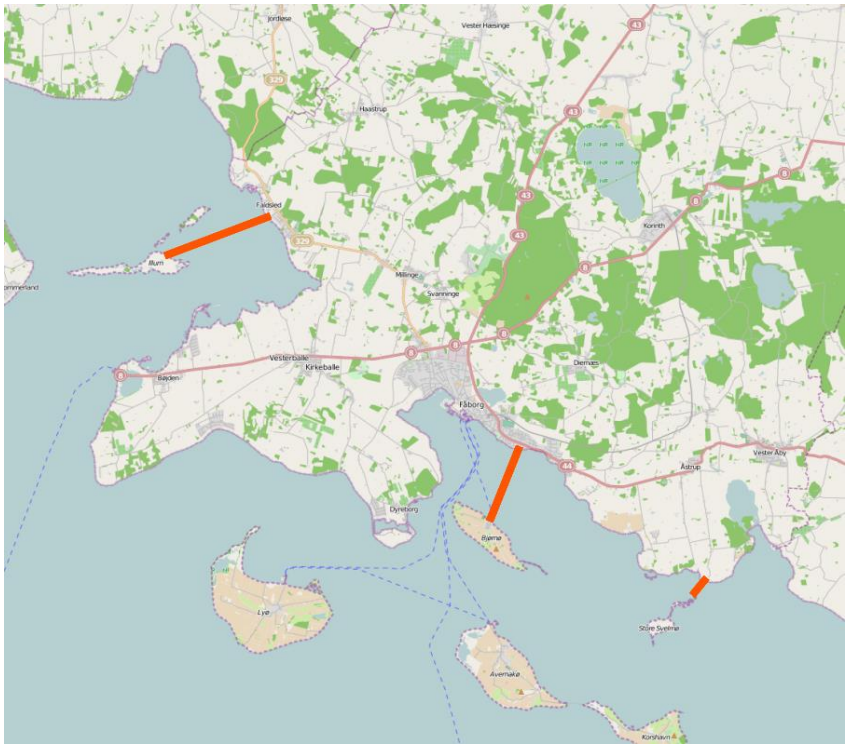
2.2 Preliminary work on the road network database

The KMS database provides details on the entire Danish road network. In order to ensure the connectivity of the road network, several amendments have been required. These include:

- Remove road sections that are not connected to the network and where no buildings are located (e.g. stadiums, quarries…);
- Add "virtual"[5] road sections to connect inhabited islands with no PDP to the rest of the network (see Figure 5 and Figure 6).

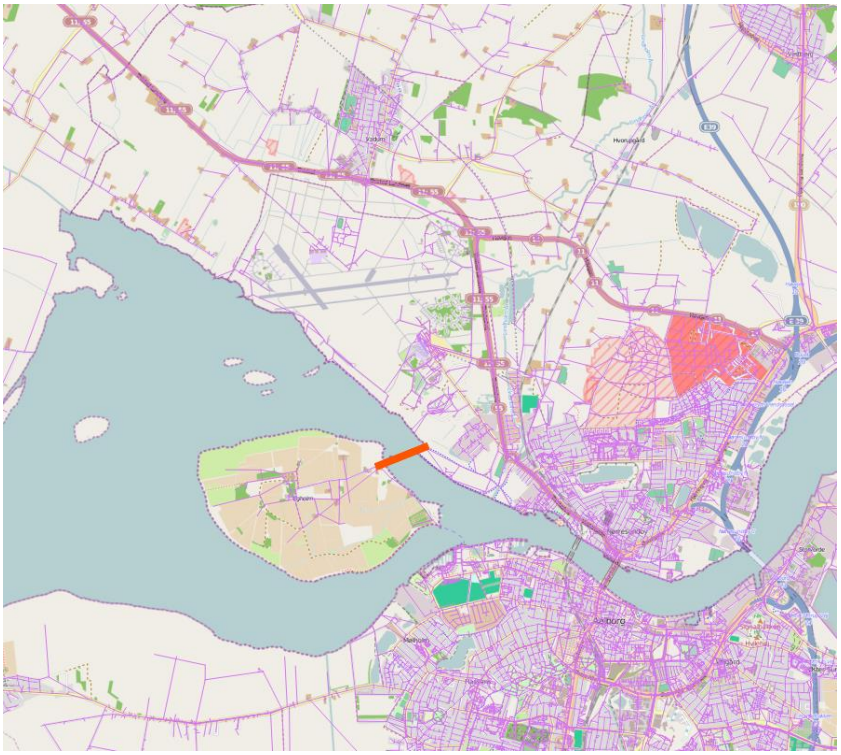
[5] During the network modelling, no trenches / cables will be installed on these sections. If there is a bridge, then the network will follow the bridge. If there is no bridge, then a radio connection will be used for the link

Figure 5 – Example of islands with no Central Office (virtual road section required)



Source: DBA

Figure 6 – Example of island with no Central Office, with the KMS road network in purple

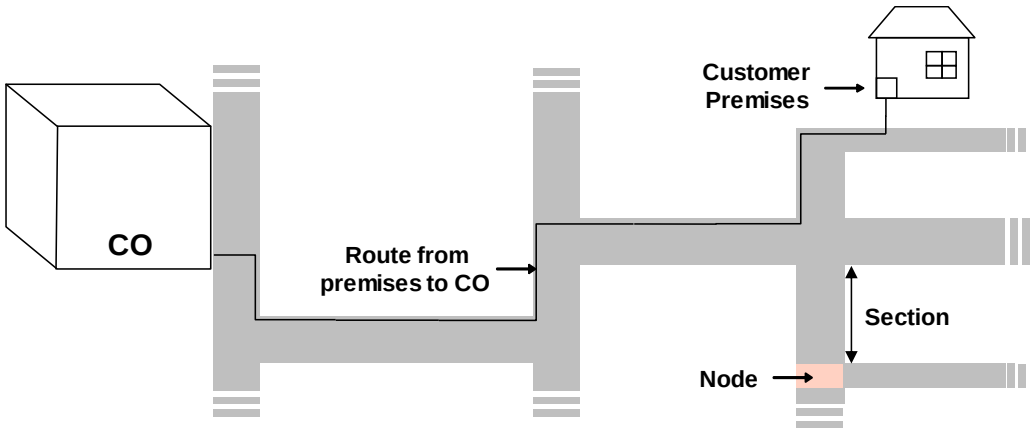


Source: DBA

During the modelling, all premises are aggregated to reach the Central Office by following the road network.

The road network is described by the KMS database and consists of road sections and nodes at the end of each road section (see Figure 7). A road section is a segment of road which is not intersected by any other road.

Figure 7 - Road sections



Source: DBA

2.3 Preliminary work on the addresses database

As explained in the MRP, the access networks in the LRAIC model is dimensioned by passing all premises of the area they cover. As an efficient operator does not deploy a drop wire until the end-user becomes active, final drops will only be installed for active customers in the LRAIC model (plus a mark-up for end-users churning after a drop wire has been deployed). Inside buildings with several accommodations, drop wires from the building basement to all accommodations are installed even if some accommodations do not host any active customer.

However, costs should be recovered over the subset of connected locations assumed to have an active subscription.

As a consequence, the number of active lines in Denmark is required.

The access networks demand are based on the total number of active lines in Denmark. This corresponds to the aggregation of the demand from the different access technologies (Copper, cable-TV, Fibre).

In order to define the demand to be used as the starting point for the access network modelling, an address database detailing all the active lines within Denmark has to be built.

Addresses have been identified in a unique way based on the combination of the following four parameters:

- Zip code;

- Street name;
- House number;
- House letter.

A specificity of Denmark is that all premises have a unique national identifier, the "kvhx" code. Depending on its length, it provides more details on locations. The combination described above can be identified as unique using 11 characters.

Due to the history, the databases provided are not consistent, and some retreatments have been required in order to isolate a clean set of addresses which can be merged.

TDC's copper customers' address database[6] has been used as a starting point.

As TDC's network is the most widespread and fine meshed, TDC's database has been used as a starting point.

In order to have a database that can easily be used, several amendments have been made to the submitted database:

- House number has been extracted from the street name for a number of addresses;
- City zipcode has been extracted from the street name for a number of addresses;
- House letters have been extracted from house number for a number of addresses;
- Some street names have been corrected;
- Some missing data have been recovered using the kvhx code and the other databases (mainly KMS).

This database **has then been complemented with FTTH addresses** as described on TDC wholesale's website[7]. This database lists all fibre lines with a split between:

- Lines with a final drop over 30m[8];
- Lines with a final drop under 30m[9].

Addresses from the cable-TV customers[10] have also been added after they have been turned into the same format. The database provided contained only kvhx codes and coordinates of customers.

[6] Provided by TDC

[7] https://wholesale.tdc.dk/wholesale/produkter/aftaler/Sider/whitelists.aspx

[8] When such a line is proposed in a wholesale offer, the final drop is sold as a one-off fee.

[9] When such a line is proposed in a wholesale offer, the final drop can be included in the monthly rental.

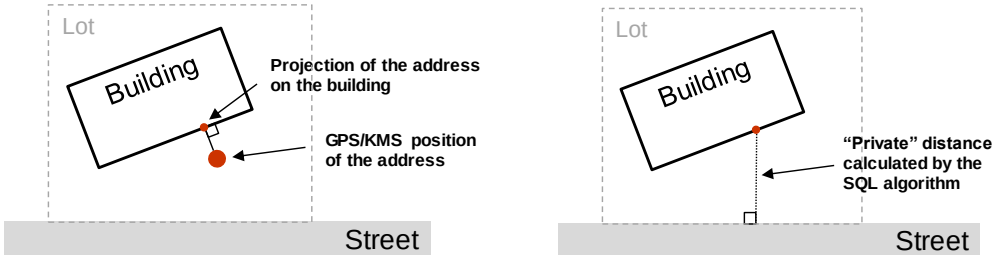
At this stage, the addresses database includes the demand corresponding to all access technologies: copper, cable-TV and fibre.

For all addresses in the database, corresponding XY geographic coordinates are required in order to merge it with the road network data. This is performed using the following methodology:

- Link the unique combination described above to KMS addresses;
- Use the "kvhx" ID used in both KMS and customer databases;
- Link the unique address combination to AMS database[11] addresses;
- Use XY coordinates already included in the customer databases;
- Use google geocoding (Google maps, Google Earth…);
- Use the average XY geographic coordinates of closest two addresses.

Once the XY geographic coordinates are determined of each address, they are projected on the building database of the country. A check has been done to verify whether there is a building in the same cadastre (matrikel) as the address. When there is no building in the same cadastre, or the building is more than 50m from the original address, the XY coordinates have been kept as provided. Then the new coordinates are projected on the closest road section to evaluate the length between the building and the section to estimate the drop wire length (see Figure 8).

Figure 8 – Projection of addresses on a building and on the road section



Source: DBA

Each address of the country now includes a building projection and a road section associated to it.

Once a clean address database has been established, it is possible to estimate the number of premises per address.

[10]Provided by TDC

[11] Open source alternative geomarketing database

Each line of the databases provided by the operator is related to one premises. In order to extract the information, on top of the address, two pieces of information have to be isolated for each premise: the floor and the door.

Two approaches have been followed:

- Extracting the characters after the 11th character of the kvhx code;
- Extracting the lasts characters of the address.

Once it has been extracted, a database of premises can be created, on which each line is tagged if the premises is passed or not for each network (copper, cable-TV or Dong), and for each line whether the line is active or not for the copper and cable-TV networks.

2.4 Estimating the number of active line in each scenario

The total number of active copper lines is determined by summing all the following lines categories: PSTN, ISDN, broadband only (retail or bitstream), raw copper, and copper leased lines. PSTN, broadband only, raw copper and copper leased lines are considered to use one active line. It is considered that ISDN customers are using 2 active lines in the copper network and that they would substitute this access with 1 active line in all others scenarios.

In line with the MRP, the model includes a nationwide copper network (i.e. a network covering all premises passed by TDC's copper network, TDC's cable-TV network and TDC's FTTH network) with full demand (i.e. combined demand for TDC's copper network, cable-TV network and FTTH network).

In order to estimate the overlap of premises being passed by several networks, and the overlap of active customers on several technologies, the following data have been extracted from the address database:

Figure 9 – Coverage statistics per network

	Total model	Copper coverage	Cable-TV coverage	Dong coverage
Active copper	1,545,463	1,545,463	580,008	73,852
Active cable-TV	1,115,755	945,053	1,115,755	30,469
Active Dong	10,808	9,529	6,893	10,808
Total active	2,234,897	2,073,724	1,276,335	96,353
Total passed	3,400,268	3,154,737	1,464,261	112,334
Overlap copper-cable-TV in the zone	**84%**	83%	75%	82%
Adjusting factor for the technology (Total active / Active - 1)		34%	**14%**	791%

Penetration in the covered area	66%	66%	87%	**86%**
Penetration of the technology in the covered area	79%	49%	76%	10%

Source: DBA

The access model is running using 3 different coverage areas:

- A national coverage
- The cable-TV coverage
- The Dong coverage

The access network modelled aims at handling the aggregated demand of all existing access platforms (Copper, Fibre and CATV). In Denmark, active subscribers can have a unique connection of one given technology (copper only, fibre only or CATV only customers) or a combination of the different available access technologies (Copper&CATV, Copper&Fibre, Fibre&CATV or Copper&CATV&Fibre). Some active customers also have multiple copper connections (e.g. one for broadband and one to connect a fax). The number of active customers having multiple CATV or multiple fibre connections is very limited. As a consequence, a preliminary step of the access network modelling is to derive the demand for the BU model network from this real life demand.

In particular, 2 questions would need to be addressed:

1. would an active customer having multiple copper accesses have multiple accesses with the network modelled?

2. would an active customer having a combination of different access technologies have multiple accesses with the network modelled?

As regards the first question on multiple copper connections, multiple copper accesses (i.e. a customer having two active copper lines in the same building) should be modelled by multiple accesses in the BU model for copper.

As regards the second question on combination of several access technologies, DBA considers that an active customer having multiple accesses based on different access technologies in the real life would more likely have a unique active line in the context of a unique access platform.

Therefore, DBA believes the following principles are appropriate:

1. All active lines corresponding to the modelled technological scenario are included.
2. Active lines not corresponding to the modelled technological scenario are only included if the specific end-user does not have one (or more) active lines corresponding to the modelled technological scenario.

On this basis the demand is calculated as follows:

- The number of active lines for the copper national coverage should be equal to active copper lines + the number of active CATV and/or fibre customers without an active copper line.
- The demand for national fibre will be calculated as the number of active fibre customers + the number of active copper customers + the number of CATV customers without an active copper line.
- The number of active lines for the cable-TV coverage should be equal to (active cable-TV lines) x ('Adjusting factor')
- The number of active lines for the fibre coverage should be equal to Total passed FTTH lines x Fixed telecom penetration

Regarding the number of active fibre customers, no information on the overlap with the other networks has been provided. The quality of the fibre network allows to provide any service provided by the copper or CATV network at the same level of quality, furthermore the total number of active customers for the fibre network is quite limited (less than 0.5% of the total modelled lines), therefore the impact of an overlap would be very limited. It has therefore been considered that fibre customers are not using any other technology at the same time, and the number of active fibre customers is added to the other active customers without adjustment (the adjustment factor has been set to one). In order to simplify the calculation of the active customer database, TDC is required to provide in the annual update the number of CATV customers using no other technology.

As the number of active lines evolves each year, in order to capture a full demand in the area, it has been necessary to define some extrapolation rules.

In order to simplify the calculation of the active customer database, TDC is required to provide in the annual update the number of CATV customers using no other technology.

3 Equipping the copper network

This section aims at describing the copper network dimensioning process. At the end of the dimensioning process, the asset count for the copper network is determined.

3.1 Reference files

The table hereafter lists the files which have been considered as reference files to equip the copper network (see Figure 10).

Figure 10 – Input tables for the copper network

Ntw.	File type	Description	Source
Copper	Excel	File listing all the MDFs, the PDPs and the SDPs (with more than 10 pairs)	TDC *lraic_kobber.xlsx*
Copper	Shapefile	Location of all the Central Offices (copper ntw)	TDC *centraler_point.shp*
Copper	Shapefile	Boundaries of the copper network (Central Offices' coverage areas)	TDC *Ctfl_DK_region.shp*

Source: DBA

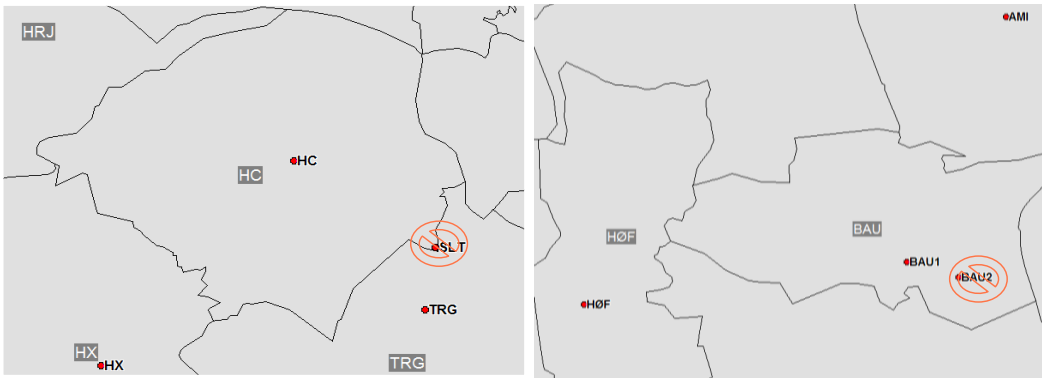
3.2 Preliminary work on copper network inputs

TDC has provided 1,182 shapes corresponding to the coverage areas of COs in the file "Ctfl_DK_regions.shp" (called regions hereafter) and a list of 1,187 centraler-points (Central Office).

The study of the Central Office list and the shapefiles representing their boundaries showed that 5 areas had 2 Central Offices. In these regions, one Central Office has been removed in order to keep one Central Office per area (see Figure 11). The following Central Offices have been removed:

- HC region: HC kept, SLT removed;
- BAU region: BAU1 kept, BAU2 removed;
- FANØ region: FANØ2 kept FANØ1 removed;
- VM: VM2 kept, VM1 removed;
- HDB: HDB1 kept, HDB2 removed.

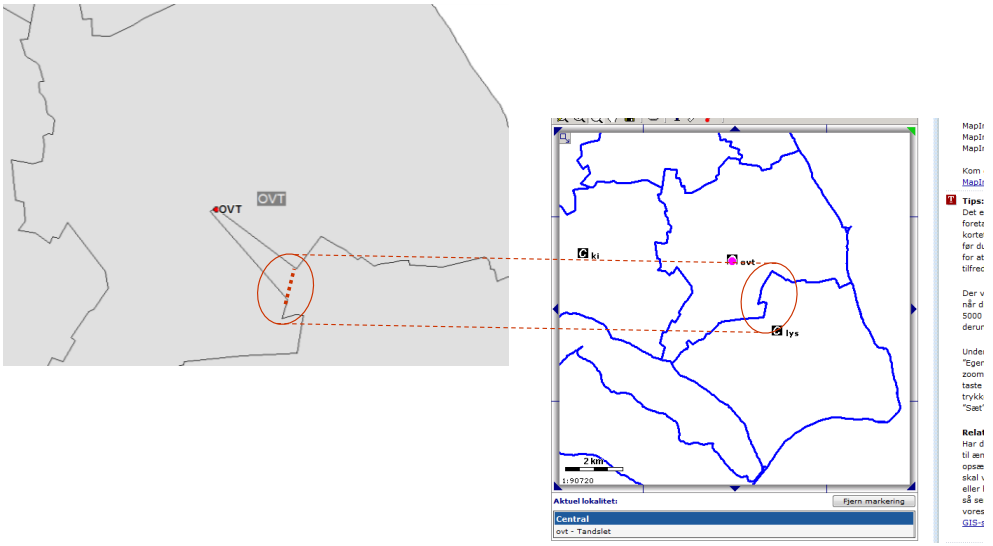
Figure 11 – Example of Central Office removed



Source: DBA

One Central Office was located in an incorrect area, probably due to lack of precision of the boundaries as represented in the Shapefile provided to DBA. The boundary has been redesigned in order to have the Central Office in the right area (see Figure 12).

Figure 12 – Move of OVT/LYS boundary

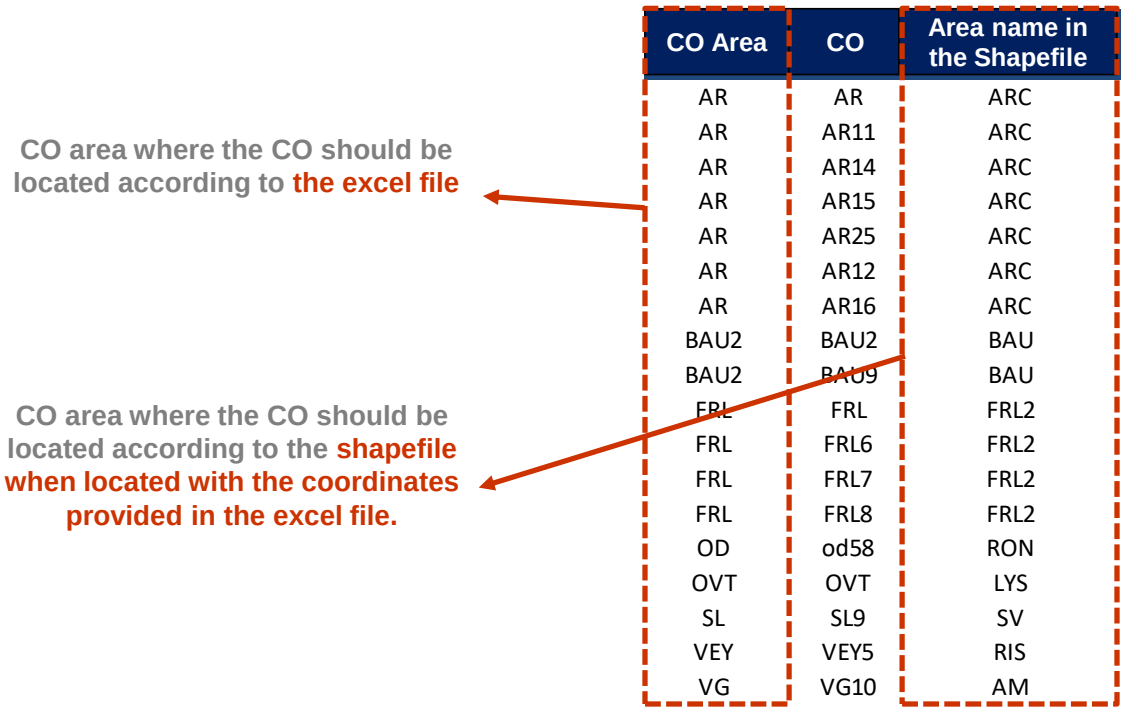


NB: The Central Office "OVT" is located in the LYS region instead of being in the OVT area

Source: DBA

In the "lraic_kobber.xlsx" file, TDC has provided the XY geographic coordinates of the Central Offices, PDPs and SDPs as well as with the name of the Central Office area in which these nodes should be located. All the Central Offices have been located on the maps provided by TDC, however, some inconsistence was identified as the location of 18 Central Offices stated in the Shapefile did not match the Central Office area listed in the Microsoft Excel file.

Figure 13 – List of Central Office with inconsistencies between CO_AREA and theShapefile



CO Area	CO	Area name in the Shapefile
AR	AR	ARC
AR	AR11	ARC
AR	AR14	ARC
AR	AR15	ARC
AR	AR25	ARC
AR	AR12	ARC
AR	AR16	ARC
BAU2	BAU2	BAU
BAU2	BAU9	BAU
FRL	FRL	FRL2
FRL	FRL6	FRL2
FRL	FRL7	FRL2
FRL	FRL8	FRL2
OD	od58	RON
OVT	OVT	LYS
SL	SL9	SV
VEY	VEY5	RIS
VG	VG10	AM

Source: DBA

The table has been cleaned in order to eliminate these inconsistencies[12].

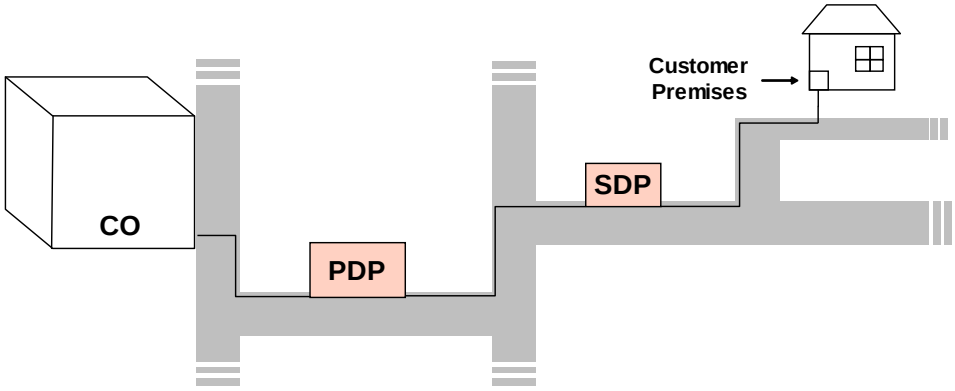
It is to be noted that when several nodes are located on the same road section (e.g. several PDPs), only one is kept, and the other are modelled bottom-up as SDPs if required.

3.3 Copper graph

The architecture of the modelled TDC copper network (see Figure 14) includes 3 levels of nodes: Central Offices (MDFs), PDPs and SDPs (from the core to the end-user, PDPs and SDPs).

[12] In case of an inconsistency that cannot be solved, an MDF should be considered as part of the shapefile area that correspond to its XY (same approach for PDPs)

Figure 14 – Copper network architecture



Source: DBA

The study of TDC's inputs has underlined that SDPs are located very close to the end-user (most of the time in the end-user's own road section). As a consequence, SDPs have not been considered in the treatment of the geo-marketing data. SDPs have been modelled on a bottom-up basis.

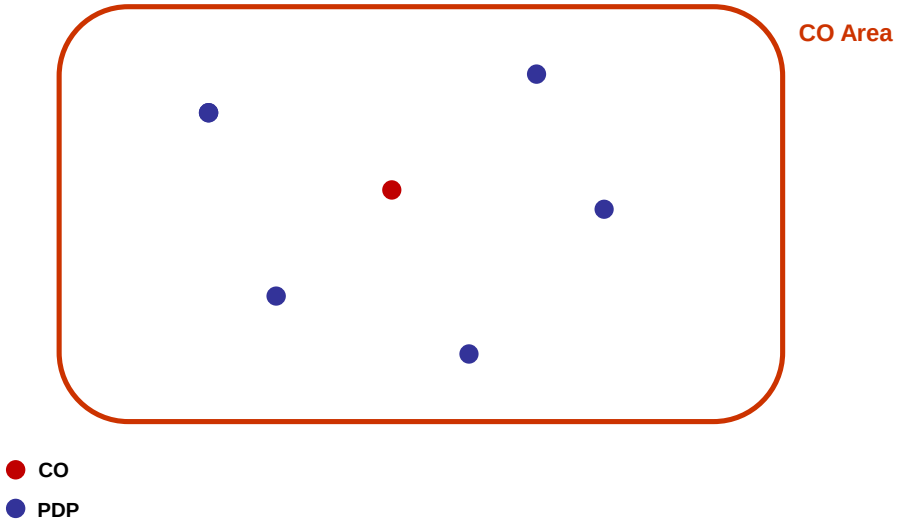
The following 2 road paths need to be determined:

- End-user / PDP;
- PDP / Central Office.

Based on the information provided by TDC, the starting point (step 1) of the graph algorithm is as follows (see Figure 15):

- Central office and PDP locations are known;
- Central office areas boundaries are known;
- PDP areas boundaries are to be determined.

Figure 15 – Copper graph (Step 1: STARTING POINT)



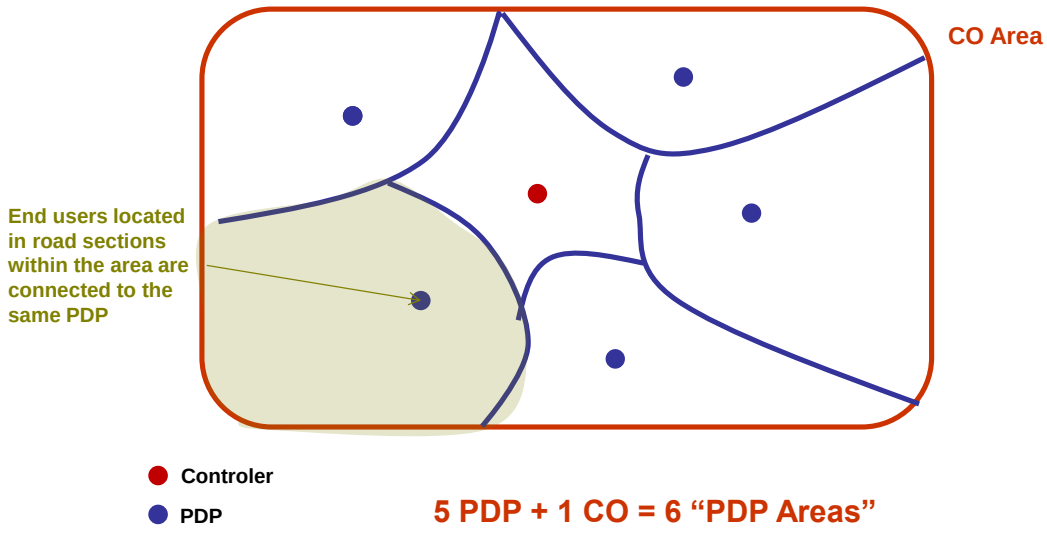
Source: DBA

TDC has been able to provide Central Offices' coverage areas but PDPs' coverage areas were not available.

The next step (step 2) is therefore to determine PDPs' coverage areas.

Every road section within the Central Office area has to be connected to a PDP. It is to be noted that a road section can be directly connected to the Central Office. As consequence, the Central Office also has a 'PDP' area. Each road section is allocated to the closest PDP[13].

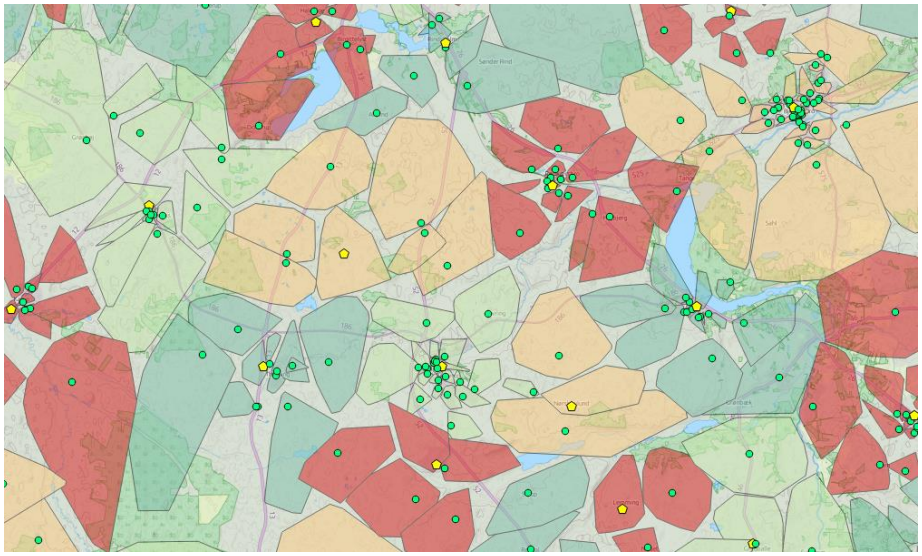
Figure 16 – Copper graph (Step 2: DETERMINING PDP AREAS)



Source: DBA

[13] Closest in terms of distance following the road network, not in terms of crow fly distance.

Figure 17 – Copper graph (Example of PDP areas)



Legend: COs in yellow, PDPs in green, one area color per CO

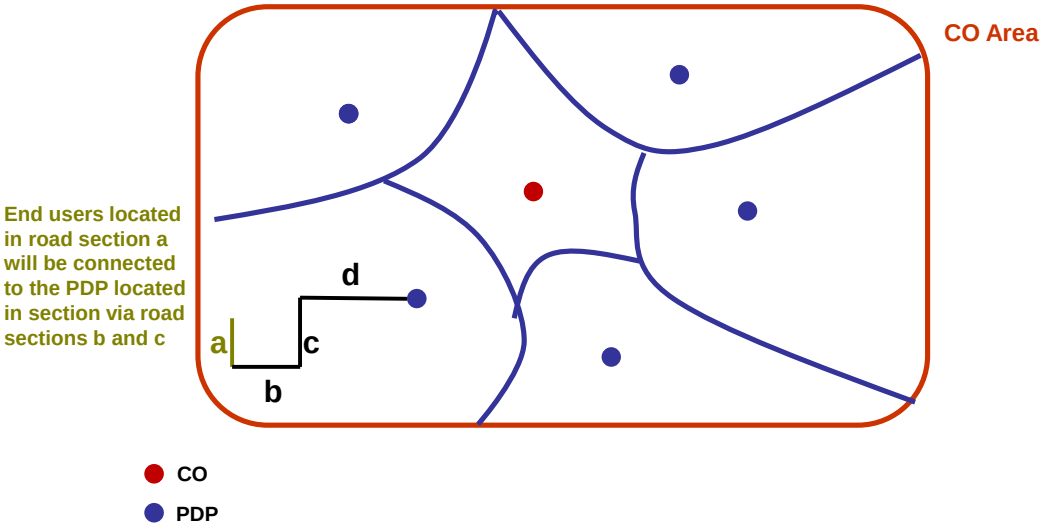
Source: DBA

Once PDP coverage areas have been determined, the next step (step 3) is to determine the “end user / PDP” route. For each road section within a PDP coverage area, a shortest path algorithm is used to set the path from each road section to the corresponding PDP (see Figure 18).

The KMS database includes 8 different types of roads. For the part between end-users and PDPs, all types of roads except highways or motorways are used by the algorithm[14].

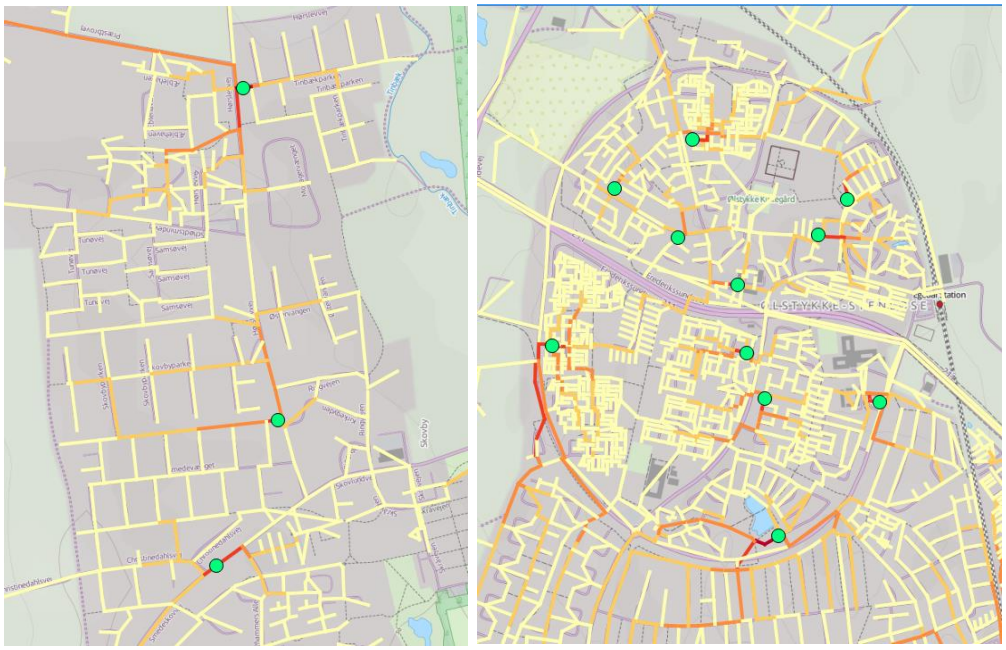
[14] If a connexity issue is identified when not considering the highways or the motorways (i.e. if not using highways lead to standalone roads), then these types of roads will be included.

Figure 18 – Copper graph (Step 3: DETERMINING end user / PDP paths)



Source: DBA

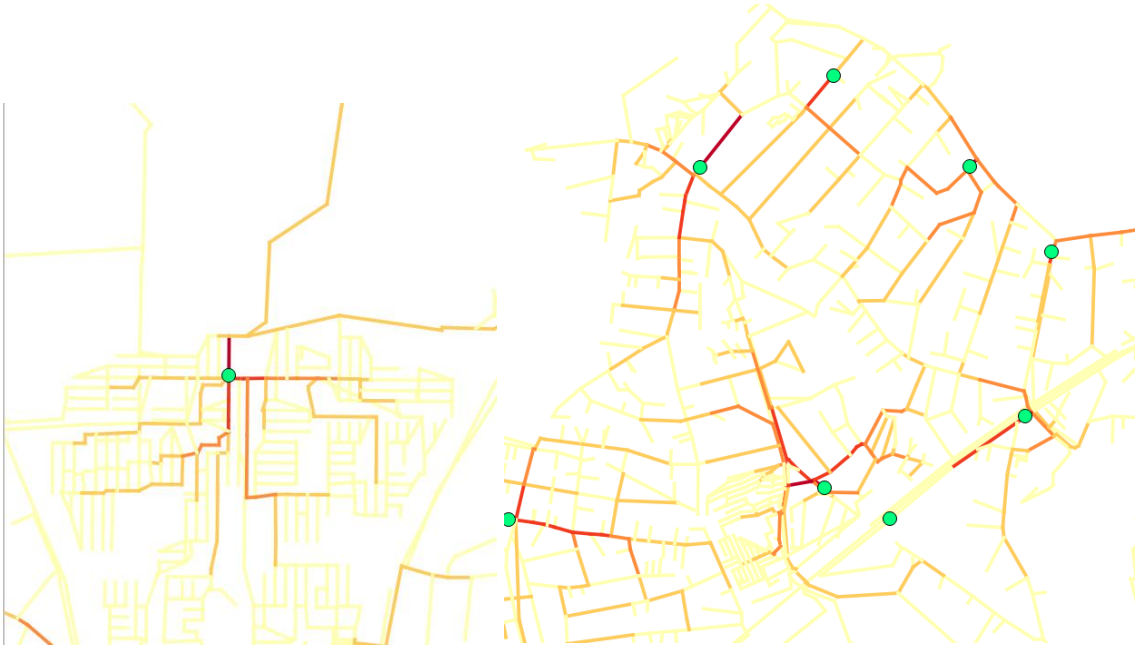
Figure 19 – Copper graph (Examples of End-User to PDP paths with map background)



Legend: COs in yellow, PDPs in green, Paths from light orange to red depending on usage

Source: DBA

Figure 20 – Copper graph (Examples of End-User to PDP paths without map background)

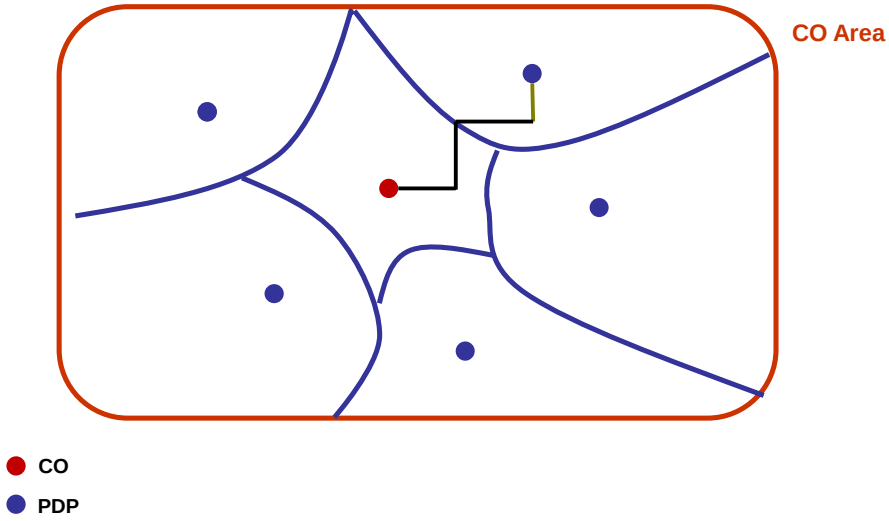


Legend: COs in yellow, PDPs in green, Paths from light orange to red depending on usage

Source: DBA

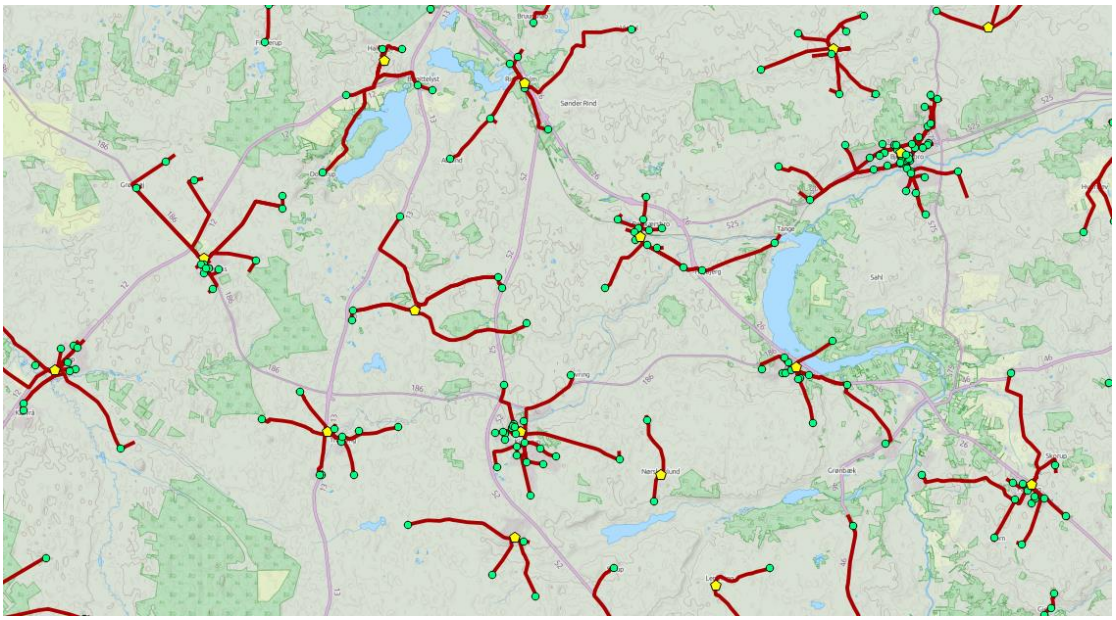
Then, a shortest path algorithm is used to set the path from each PDP to the corresponding Central Office (step 4, see Figure 21).

Figure 21 – Copper graph (Step 4: DETERMINING PDP / Central Office paths)



Source: DBA

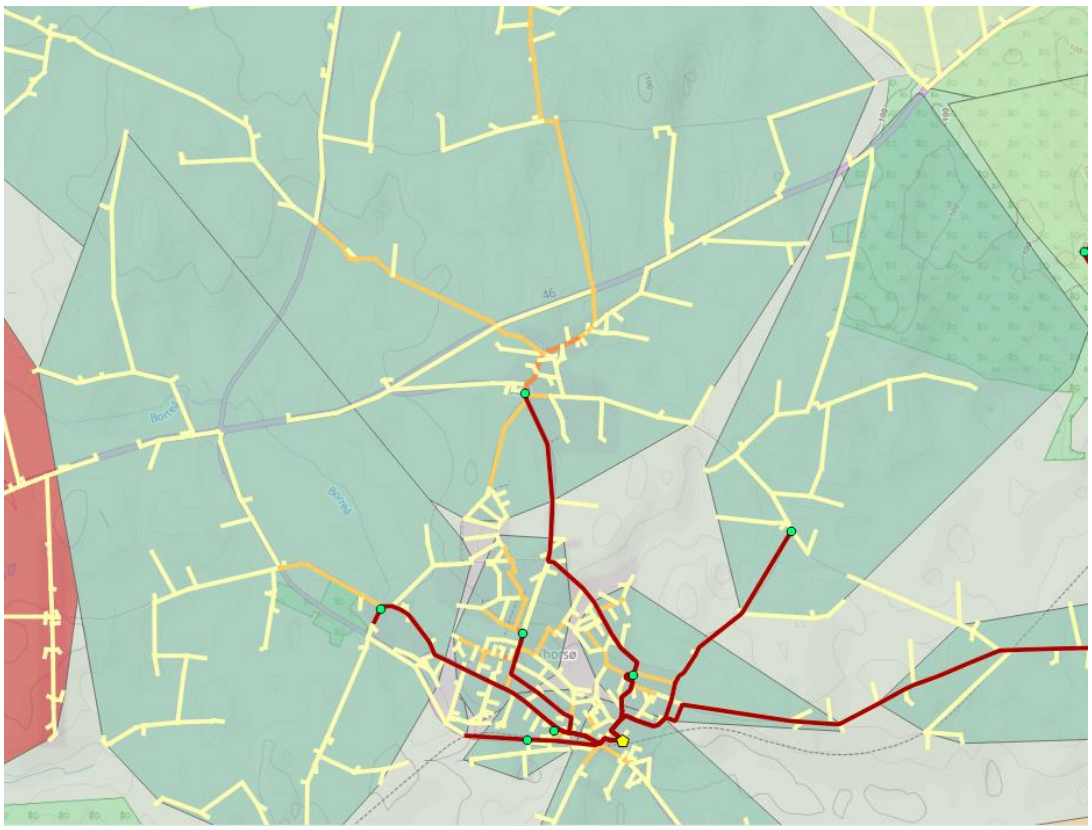
Figure 22 – Copper graph (Example of PDP to Central Office paths)



Source: DBA

After step 4, the End user / PDP and PDP / Central Office paths have been determined (i.e. the list of sections used by each path, see the structure of results table in §12.2).

Figure 23 – Copper graph (Example of End-User to Central Office paths, including PDP areas)



Source: DBA

3.4 Roll-out of the network

3.4.1 Different parts of the network modelled

From the premises to the Central Office, several elements have to be modelled:

- The equipment inside the building (referred as InBuilding);
- The equipment required to link the building to the road section (referred as Private), this consists of copper cables and trenches;
- The equipment required to link the road section to the SDP (referred as Aggregation), this consists of copper cables and trenches;
- The equipment required to link the SDP to the PDP including the SDP (referred as SDP), this consists of copper cables, trenches, joints and distribution points; and
- The equipment required to link the PDP to the Central Office including the PDP (referred as PDP), this consists of copper cables, trenches, joints and distribution points.

In addition, two networks are partly modelled in parallel to the copper network:

- The Core network, which links Central Offices together using fibre cables (referred as Core), this consists of fibre cables, ducts, trenches and joints;
- The BTO network, which links business buildings to the closest Central Office with fibre in order to provide leased lines (referred as BTO), this consists of fibre cables, ducts, trenches and joints.

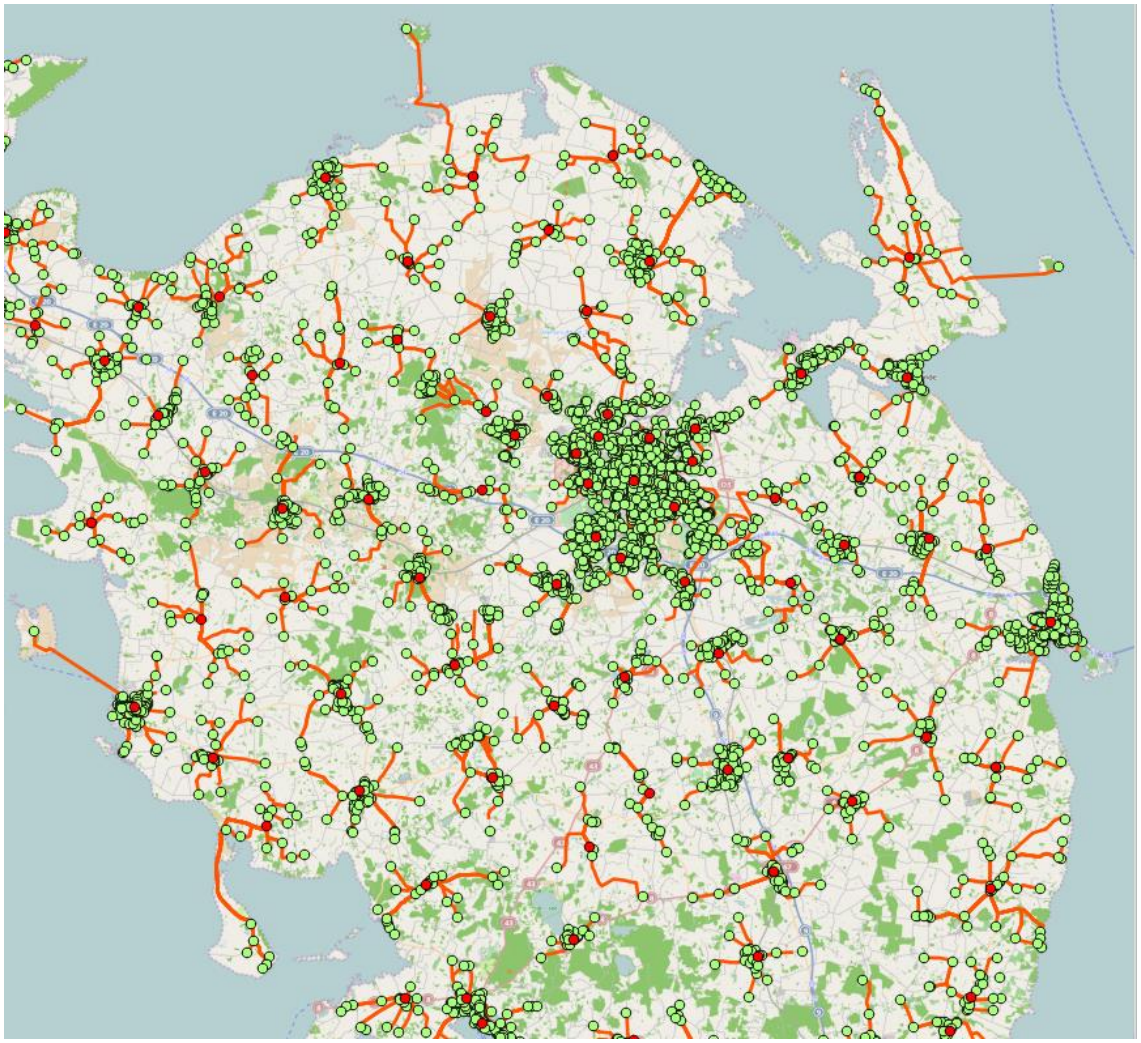
3.4.2 Copper Network Cables

Several cables, e.g. related to different parts of the network, have to be dimensioned for a given section. These different cables are not shared but they still use the same trench for the given road section.

Cables include:

- the final drop: part of the network that connects the distribution point to the construction door, that includes the Aggregation and Private parts;
- the cable linking the SDP to the PDP (in the category SDP in the model);
- the cable linking the PDP to the Central Office (in the category PDP in the model) (see figure below);

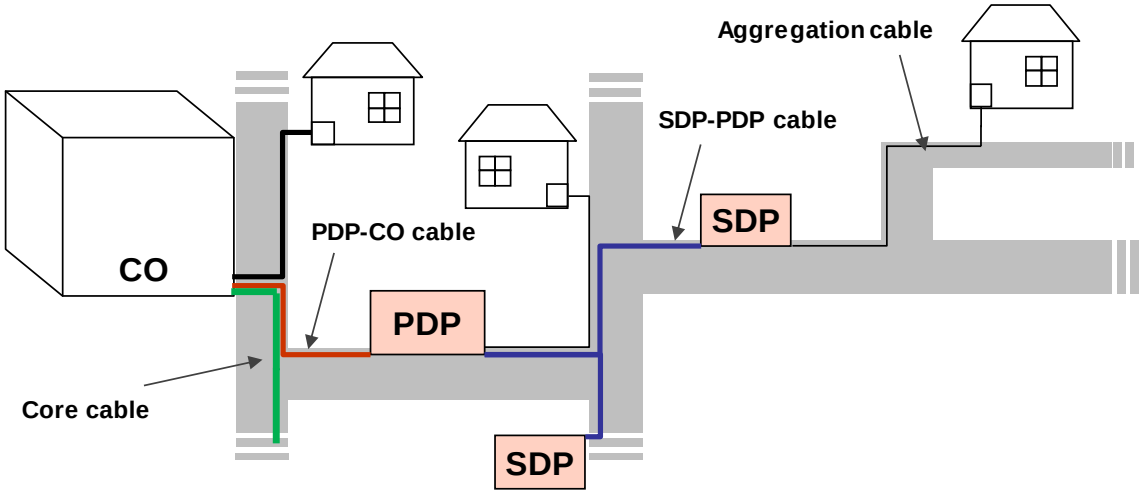
Figure 24 – Overview of PDP- Central Office segments



Source: DBA

- the Core network (in the category Core in the model); and
- the BTO network (in the category BTO in the model).

Figure 25 - Types of cables passing through a section



Source: DBA

For each section, and each cable category, the following has to be determined:

- How many copper pairs are required to meet the level of demand?
- What is the most suitable cable size based on the number of copper pairs?
- What type of cable should be used?

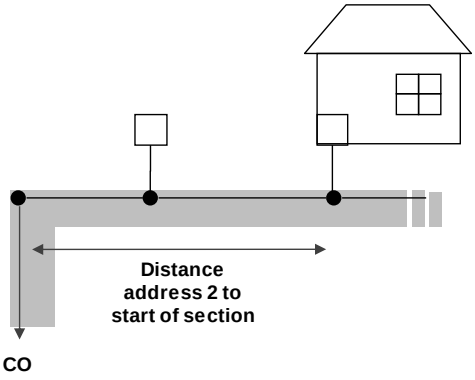
3.4.3 Final drop

This section describes the cost of the final drop, which includes the costs from the customer's building (outside of the building) to the next SDP.

The modelling has been performed on a "per-address" basis. Therefore, for each road section, the position of each address has been determined, i.e. the relative position of the address to the road node going to the Central Office, and the side of the address (left or right side of the road when looking from the extremity closest to the CO, see Figure 26); and for each address has been determined:

- The distance between the building of the address; and
- The number of premises passed for each address.

Figure 26 - Position of an address on the left side of a road section



Source: DBA

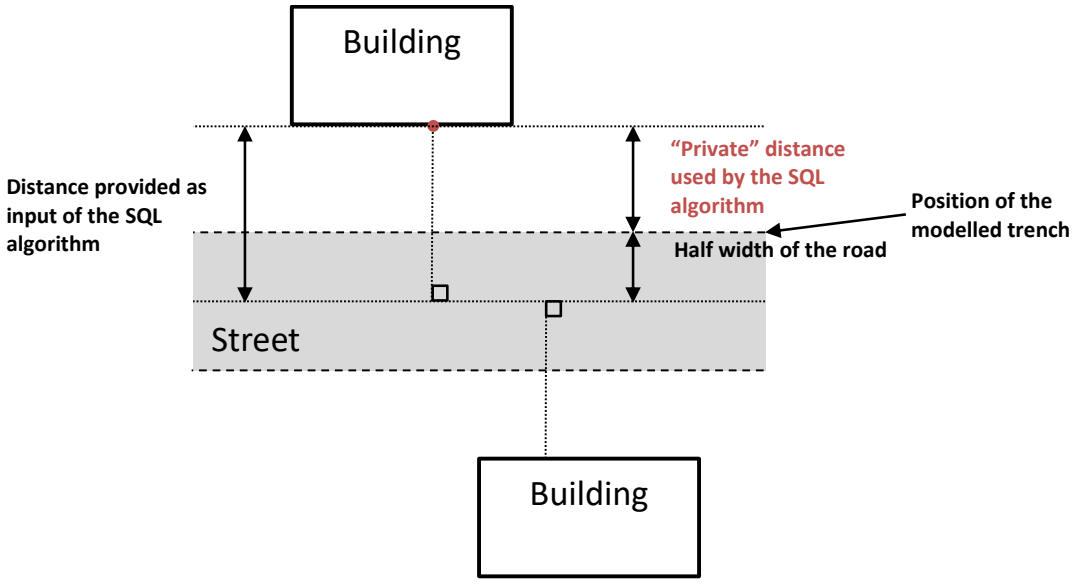
When several addresses are in a same building, and the building is on the same cadastre (supposed to be the same owner), it has been considered that only one trench is dug for the building. It is referred to as “Set of drop cable”

The cost of the final drop is composed of several components:

- The private part; and
- the aggregation part.

A dedicated cable is rolled out from the SDP to the premises. The aggregation part represents the trenches that are shared between all final drops and other levels of the network. The private part corresponds to the dedicated trench from the road to the buildings (see Figure 27 and Figure 8 to understand how is determined the distance used in the SQL).

Figure 27 - Private distance used



Source: DBA

The number of copper pairs deployed in the final drop is driven by the number of premises. As a general rule, 2 pairs are installed per premise.

In order to take into account obstacles that may encounter the operator while rolling out the final drop on the private property, a factor of 1.2 is applied to the equipment and trenches inventory of the private property.

3.4.4 SDP part

The SDP part is composed of the SDP distribution points, and cables and the related trenches between the SDP and the PDP.

Location of SDPs

SDPs are modelled bottom-up (i.e. their location is not based on TDC's data). The calculation process aggregates all sets of drop cables to the PDP.

Starting furthest from and moving towards the PDP, at each drop cable location, it is checked whether the number of premises aggregated – not already aggregated by a SDP – is equal to or above 20. If this is the case, a new SDP is installed.

Size of SDPs

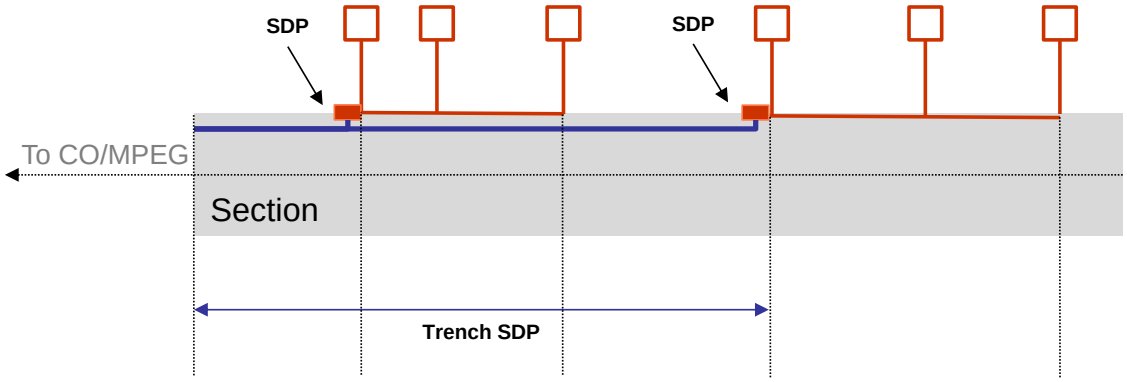
At the SDP, it is considered that 70% of incoming pairs are linked to the next PDP. The size of the SDP is then determined by the sum of the number of copper pairs aggregated by this SDP (incoming pairs) and the number of the outgoing pairs.

SDP cables

For a given section, the length required for the SDP cable (cable that connects SDPs to PDPs) is considered to be:

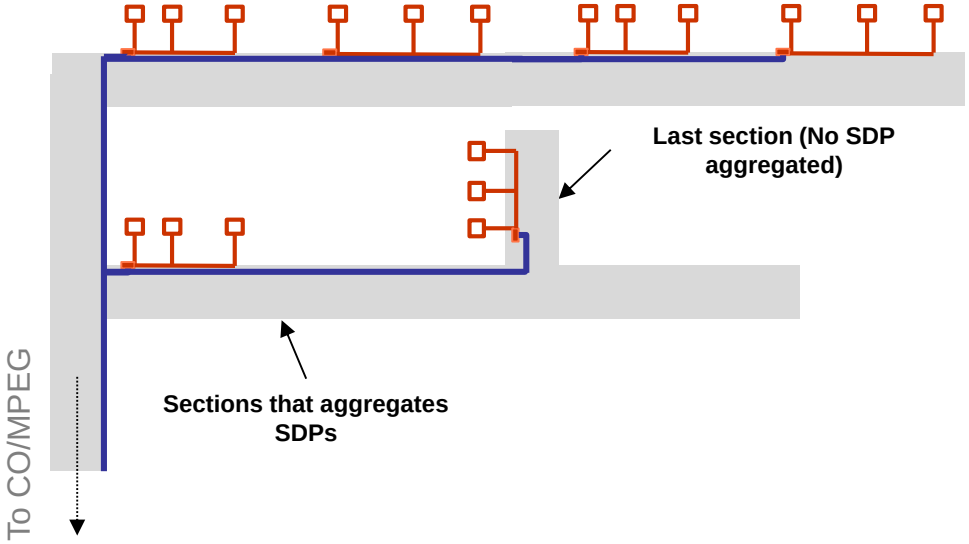
- The length of the section if some SDP cables have already been aggregated in previous sections;
- The length from the last SDP of the section to the node closest to the Central (see Figure 28) Office if the road section is a "last section" of the network (see Figure 29).

Figure 28 - Distance used for SDP



Source: DBA

Figure 29 - "Last section"



Source: DBA

The size of the cable used is the sum of all incoming SDP cables plus the sum of the size (outgoing copper pairs to the Central Office) of all SDPs of the section.

The choice of the cable is the smallest cable for which the size is higher than the required number of copper pairs. If the required size is bigger than the biggest cable, the cable type used is the biggest cable multiplied by the round-up of required-size divided by the size of the cable.

3.4.5 PDP part

The PDP part is composed of PDP distribution points, and cables and the related trenches between the PDP and the Central Office.

Location of PDPs

PDP locations have been provided by TDC. They have been located on sections of the network. In case many PDPs are present on a same section, it has been considered

that only one PDP was present and the other are modelled as SDPs if required following the SDP dimensioning rules.

Size of PDPs

At the PDP, it is considered that 75% of incoming pairs are linked to the next Central Office. The number of pairs is therefore the number of premises aggregated by the PDP x 2 (copper pairs per premises) x 70% (pairs followed by the SDP) for the incoming pairs, and the same number multiplied by 75% for the outgoing pairs to the Central Office.

The size of the PDP is then determined by the sum of the number of copper pairs aggregated by this PDP coming from SDPs and the number of the outgoing pairs.

PDP cables

For a given section, the length required for the PDP cable (cable that connects PDPs to Central Offices) is considered to be the length of the section.

The size of the cable used is the sum of all PDP copper pairs transiting on the section.

The choice of the cable is the smallest cable for which the size is higher than the required number of copper cable. If the required size is bigger than the biggest cable, the cable type used is the biggest cable multiplied by the round-up of required-size divided by the size of the cable.

PDP joints

A joint is installed at each section if the section length is longer than 40 meters. The size of the joint corresponds to the size of the PDP cable.

3.4.6 Trenches

There are two main types of trenches, trenches on private properties and trenches following the road network.

Trenches on private properties are trenches between buildings and point on the property closest to the road.

Trenches following the road network are split into two parts, the main side and the second side. A road section may have several configurations:

- (1) Drop cables only on one side of the road;
- (2) drop cables on both sides of the road, but with only few on the second side; or
- (3) dense drop cables on both sides of the road.

The main side of the road for a road section is determined as the side for which the length between the first drop cable and the last drop cable is the longest. The second side is the other.

In order to determine the cabling necessary for the second side, the model determines if it is most efficient to dig the whole second side and then cross the road once (case 3), or if it is most efficient to cross the road for each drop cable (case 2).

The length of the second side is therefore:

- In case 2, the width of the road multiplied by the number of drop cables; or
- In case 3, the length between the first drop cable and the last drop cable plus the width of the road.

The length of the main side is set as:

- The length between the last drop cable and the node of the road section closest to the Central Office if the section is an edge section of the network; or
- The length of the section if it is not an edge section or if the section is crossed by either a SDP, PDP, Core or BTO cable.

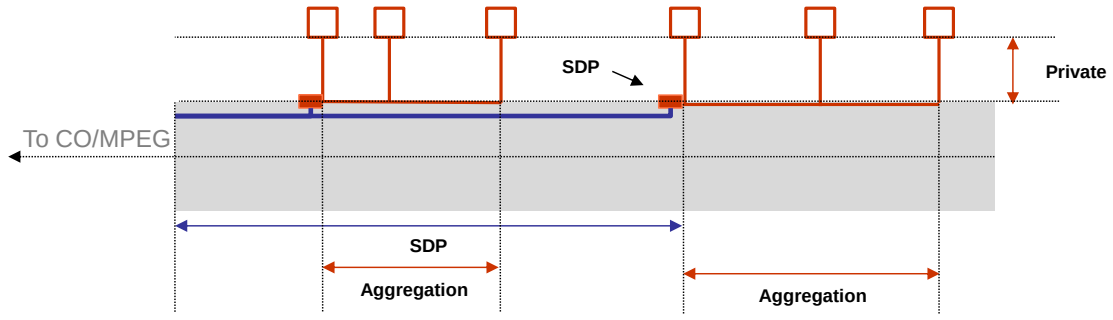
The trench size calculation is detailed in section 3.4.10

3.4.7 Final drops

The final drop is composed of 3 parts in the modelling:

- The InsideCabling part: it corresponds to the MDUs and all the cabling that is not underground. The MDU is dimensioned according to the section 3.4.6.3. of the documentation. The dimensioning is performed in the table “Results_InBuilding”;
- The Private part: it corresponds to the trench that is dug from the road border to the edge of the building (see Figure 30). It is dimensioned in the table “Sets_Of_DropCables”; and
- The aggregation part: it corresponds to the road border that is shared from the edge of the private property to the SDP (see Figure 30) . It is dimensioned in the table “Sets_Of_DropCables”.

Figure 30 - Private, Aggregation and SDP levels



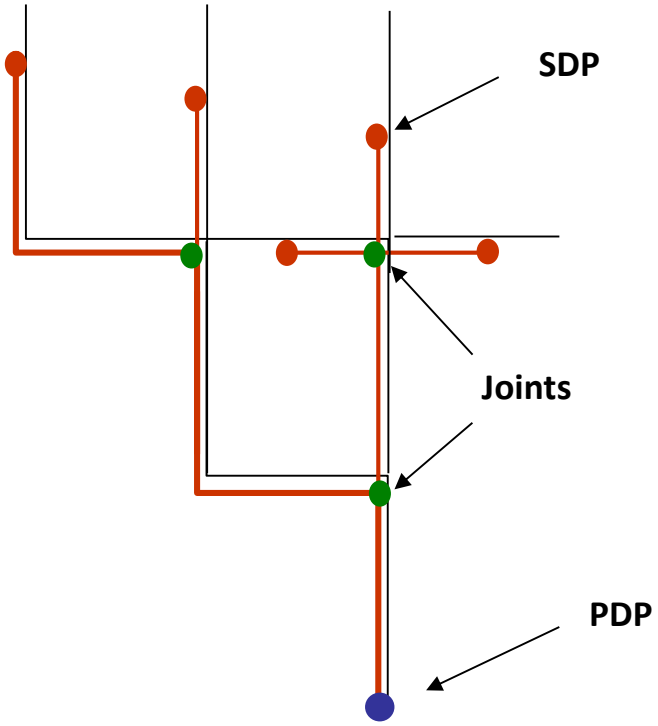
Source: DBA

3.4.8 Joints

Final drops from the SDP to the MDU are considered to be a single dedicated cable, therefore no joint is required between the SDP and the MDU.

From the SDP to the PDP, a joint is used every time two cables have to be aggregated as shown on the Figure 31 below. If the section is smaller than 30 meters, no joint is installed.

Figure 31 - Joints and joint holes

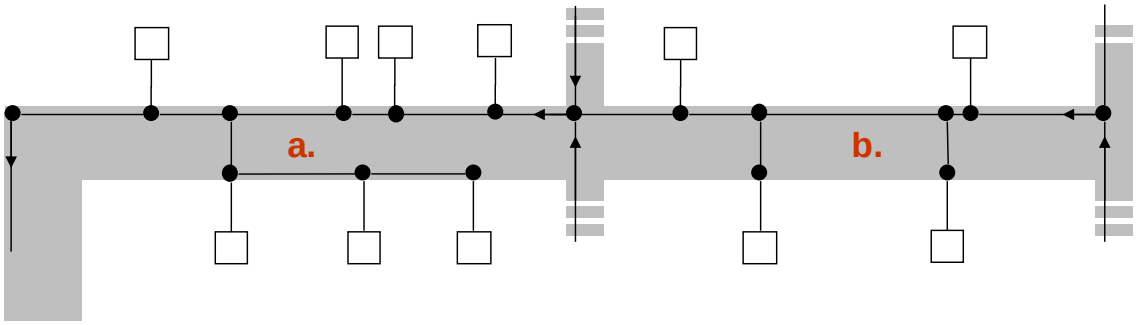


Source: DBA

3.4.9 Trench length calculation

When trenches have to be dug on both sides on the road, there are two main configurations for trenches length (see Figure 32 below)

Figure 32 – Road sections configurations



Source: DBA

The first case (a) corresponds to a situation where trenches are dug on both sides of the road, and then the road is crossed once, the case (b) corresponds to a situation where trenches are dug on the main side of the road and then the road is crossed once for each address on the second side.

This is calculated in order to minimize the length of trenches dug, by the following process:

1. Identifying on both sides the address closest to the Central Office and the address the farthest to the Central Office.
2. Identifying the number of addresses on both sides.
3. Calculating for both sides the length required to connect all addresses to the other side by using the case (a), and the case (b) (in the SQL referred as Left_OneCrossLength and Left_ManyCrossLength).
4. Identifying the main side, by identifying smallest combination left length + right length using the value described above (see Table 1, determining which of a1, a2, b1 or b2 is the smallest distance) and identifying the trench strategy (one cross or many crosses) by selecting the one minimizing the length. 4 lengths are defined:
    a. Left_OneCrossLength: length of linking all buildings on the left side (distance between the last and the first building) + crossing the road once
    b. Left_ManyCrossLength: length of crossing the road once for each building on the left side
    c. Right_OneCrossLength: length of linking all buildings on the right side + crossing the road once
    d. Right_ManyCrossLength: length of crossing the road once for each building on the right side

Table 1 - Trenching strategy determination

	1 (right is main side)	2 (left is main side)
A (One cross)	Left_OneCrossLength + Right length if main side	Right_OneCrossLength + Left length if main side
B (Many cross)	Left_ManyCrossLength + Right length if main side	Right_ManyCrossLength + Left length if main side

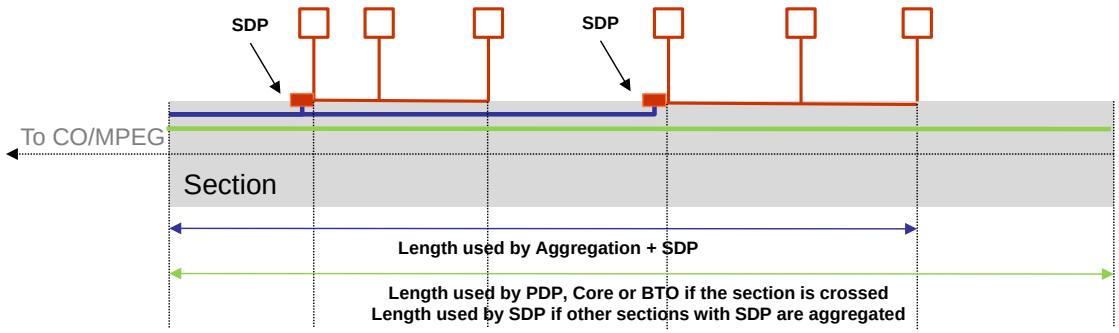
Source: DBA

The trench length on the second side is then the one selected (the one selected in the Table 1).

It has to be noted that the road width is weighted by a factor in order to take into account the additional cost for tunnelling compared to roadside trenches.

On the main side the length is either the length generated by aggregating houses to the next SDP and the SDP to the beginning of the section, or the section length if the road section is used by a route 'PDP to Central Office', 'Central Office to Central Office' or 'BTO' or if the section aggregates some other sections with SDPs (see Figure 33).

Figure 33 – Trench length used by different levels of the network



Source: DBA

3.4.10 Trench size calculation

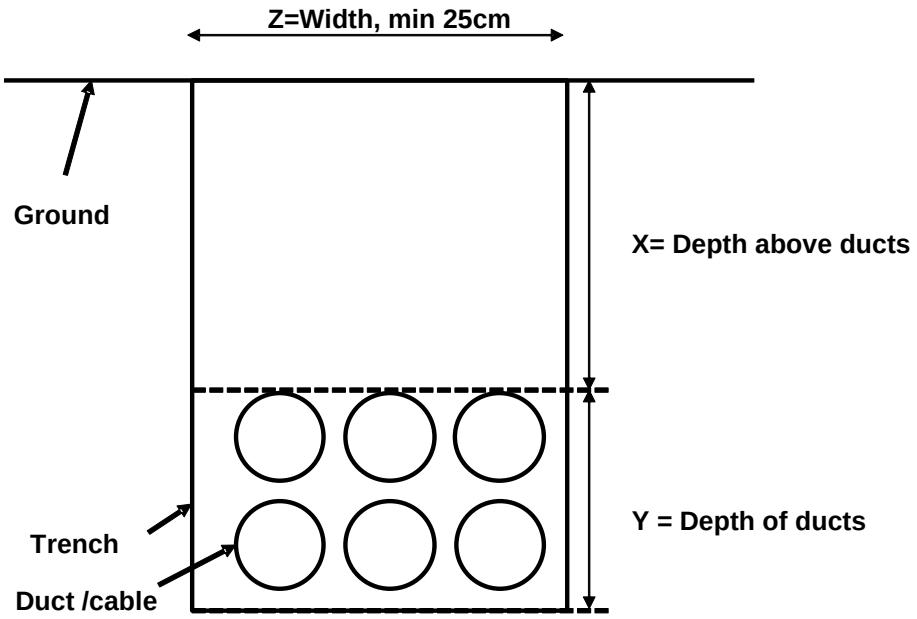
Trenches have a standard width and depth. These values are parameters present in the SQL in the table "Parameters_Technical".

The trench size is determined by using the following rules provided by TDC:

- A trench has a standard height of 60cm and a standard width of 25cm;
- A cable (or duct) must be at least 40cm under the ground (Figure 34,X = 40cm);

- The width of the trench must not be filled by more than 60%;
- The height of the trench where cables are located must not be filled by more than 60%.

Figure 34: A trench



Source: DBA

In order to estimate the space used by ducts in a trench, a volume is attributed to cables (or ducts). As there should be at least 60% of empty space between cables, the volume considered for cables, including this 60% of space is calculated by the formula: $((\frac{diameter}{60\%})^2$.

Following this diagram, one additional rule is considered: the value of Y should be twice the value of Z.

That leads to 3 scenarios:

- a. The size of the cables (or ducts) is less than 60% x 25cm. In this case, the size of the trench is the standard size.
  It means that the width of all cables (and ducts) in the trench aligned, spaced by 60% of their size do not reach 25cm.
- b. If the case a. is not relevant, the size of all cables (or ducts) aligned fill more 60% x 25cm, In this case, the depth is increased up to when Y = 2 x 25cm = 50cm.
  The trigger to ensure the depth do not exceed 50cm is that the sum of the volumes of cables (volume including free space as explained above) should be inferior to 25cm x 50cm.
- c. Y is more than 50cm. This is verified when the trigger described previously is reached. In this case, the width and the depth increase at the same time

following the rule Y = 2 x Z, by ensuring that the total volume of cables (calculated as explained above) fits in the trench.

On top of these rules, a cross-check rule has been applied: the two biggest cables (or ducts) must fit in the trench, and being spaced by 60% of space. The depth is therefore calculated as the maximum between the depth calculated above and (Diameter1 x 1.6 + Diameter2).

3.4.11 Trench length allocation

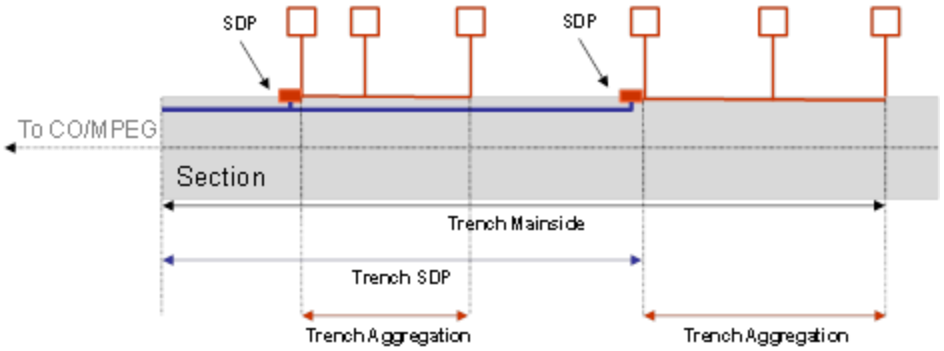
Trenches_Second_Side is allocated between Aggregation and SDP on based the following rules:

- If no SDP is installed on the second side, all is allocated to Aggregation
- If a SDP is installed on the second side, the length of trenches used by SDP length is calculated, the length of trenches used by the aggregation is calculated. The total trench length is allocated based on the ratios “LengthSDP”/(“LengthSDP”+”LengthAggregation”) and “LengthAggregation”/(“LengthSDP”+”LengthAggregation”)

For the main side, the same principle is used. The distances used are calculated as follow:

- If a core link uses the section, the core length is the section length.
- If a BTO link uses the section, the core length is the section length.
- If a PDP link uses the section, the core length is the section length.
- If the section aggregates a section that had a SDP, if the section holds a PDP, the length SDP to the PDP is used, otherwise the length of the section is used.
- If the section does not aggregate any section that has a SDP and has at least a SDP, if the section holds a PDP, the max length between the first and the last SDP and between the SDP and the PDP is used. If the section does not holds a PDP, the length between the last SDP and the beginning of the section is used (See Figure 35 below).
- If the section does not aggregate any section that has a SDP and no SDP is installed on the section, 0 is used for the SDP length.
- For the aggregation length, the length of trenches used between the premises and SDPs is used (see Figure 35 below).

Figure 35: Trenches length allocation



Source: DBA

For the copper network, it is considered that 10% of road-side trenches are shared with other service companies, and that when trenches are shared, it induces a reduction of costs of 40%. The “private part” trenches are not shared with any other service company.

Furthermore it is considered that for a national deployment, an operator could reach a discount of 5% on the unit costs as compared to TDC negotiated unit costs of trenches.

3.4.12 Multi dwelling unit (MDU) dimensioning

MDU equipment is installed in a building if the following two conditions are met:

- The building has at least 2 floors; and
- the building has at least 4 premises.

For the dimensioning, TDC dimensioning rules have been followed. The assets for cabling in MDU are composed of several pieces:

- A joint-box;
- A feeder cable;
- A feeder duct if required;
- An indoor distribution point;
- Trays in 30 % of all multi-storey buildings; and
- Cables linking the distribution point to the premises.

The calculation is performed for each building of the country.

The joint-box, the indoor DP and the feeder cable are dimensioned as a joint, a distribution point and a cable, in line with the total number of drop wires required in the building (copper, fibre or coax). The feeder duct is dimensioned as any other duct, in line with the size of the feeder cable.

The feeder cable length and the feeder duct length are set to the average basement length, 5 meters, as provided by TDC.

The size of premises cables is determined by the cable used as a drop cable, the length is determined by the following formula:

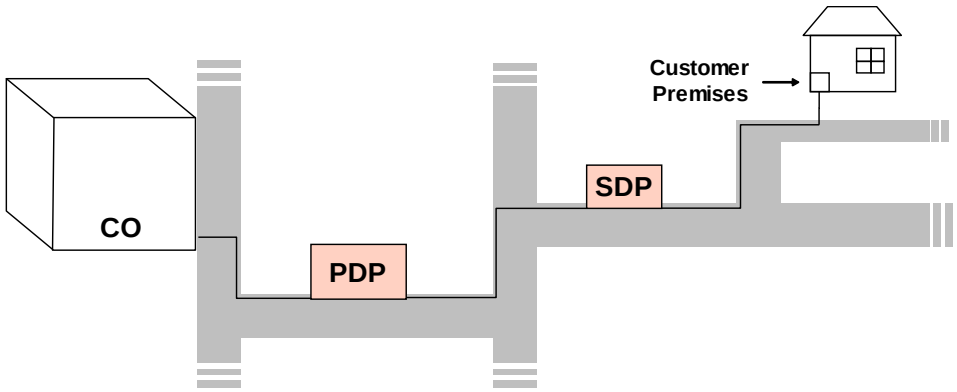
Average number of floor crossed in the specified building x floor height + number of premises x cable length per apartment.

It is considered that trays would be deployed and paid by the operator in 30% of buildings passed.

4 Equipping the fibre network

The modelled architecture follows the architecture of the copper network, that is to say the premises are aggregated on a SDP, SDPs are aggregated to a PDP and PDPs are aggregated to a Central Office.

Figure 36: Fibre network architecture



Source: DBA

Three fibre networks are modelled:

- A national network (based on total demand for all access technologies in Denmark), using a point to point (P2P) deployment, with the possibility of calculating the access cost for a specific geographical areas. A national network using a PON deployment;
- TDC's existing FTTH network in Northern Zealand (based on the previous DONG network) using a P2P deployment.

For the FTTH-P2P network, some PDPs have been deleted from the computation as no premises were connected to some those PDPs.

4.1 Reference files

The table below lists the files which have been considered as reference files to equip TDC's existing FTTH network (see Figure 37).

Figure 37 – Input tables for the fibre network

Ntw.	File type	Description	Source
Fibre	Excel	List of all the DN, the DS, the FS and the LDS	TDC *FTTH distribution points.xlsx*
Fibre	Shapefile	Location of all the DN	TDC *DN_punkter_font_point.shp*
Fibre	Shapefile	Boundaries of the fibre network (DNs' coverage areas)	TDC *DN_områder_region.shp*

Source: DBA

4.2 Fibre graph (national coverage)

For the nationwide FTTH network and in accordance with the MRP, DBA uses the coverage areas of the copper network:

- Fibre ODFs are located at the same location as copper Central Offices;
- Fibre PDPs are located at the same location as copper PDPs.

As a consequence, no additional geo-marketing processing is required for this network modelling (copper network inputs will be used).

4.3 Fibre graph (TDC's footprint)

For TDC's existing FTTH network, only the parts of Northern Zealand covered by TDC's FTTH network is taken into account.

The DNs nodes are considered as Central Offices and DS nodes as PDPs.

Therefore a new set of routes are to be determined.

The following 2 paths are to be determined:

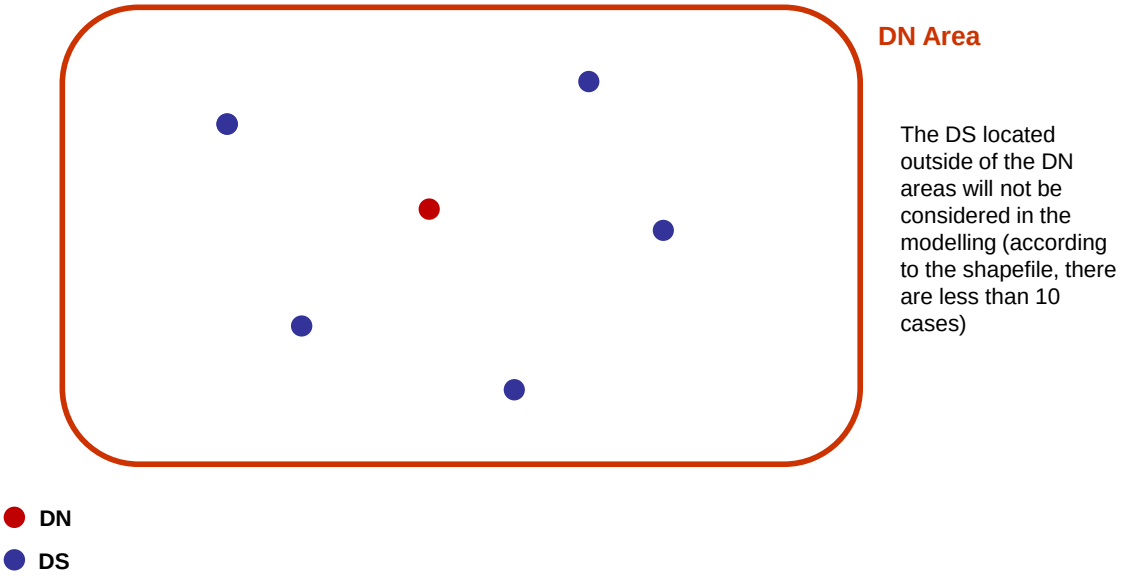
- End-user / PDP (DS);
- PDP (DS) / Central Office (DN).

Based on the information provided by TDC, the starting point (step 1) of the graph algorithm is as follows (see Figure 38):

- Central Office (DN) and PDP (DS) locations are known;
- Central Office (DN) areas boundaries are known;

- Central Office (DS) areas boundaries are to be determined.

Figure 38 – TDC's footprint fibre graph (Step 1: STARTING POINT)



Source: DBA

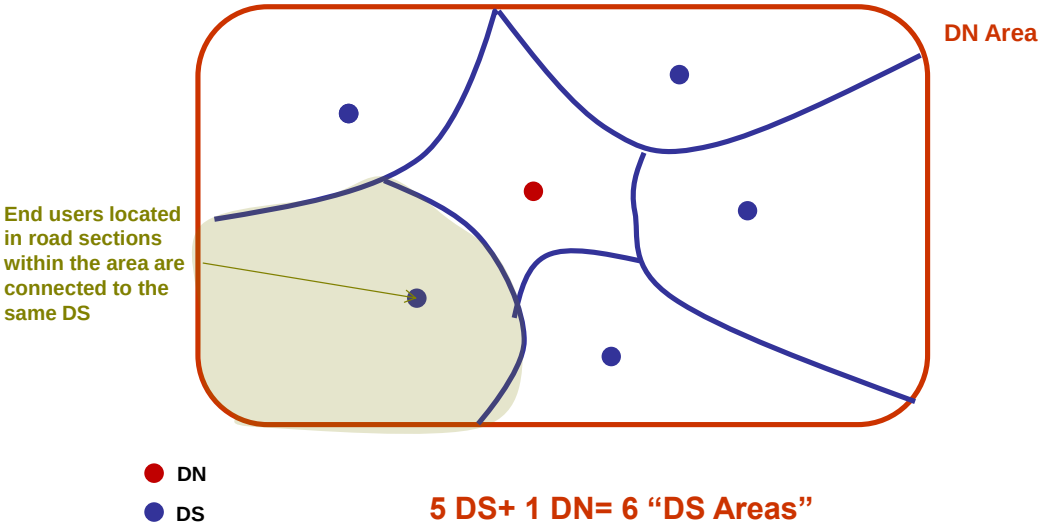
TDC has been able to provide ODF (DN) coverage areas but consistent PDP (DS) coverage areas were not available.

The next step (step 2) is to determine PDP (DS) coverage areas.

Every road section within the DN area has to be allocated to a DS. It is to be noted that road sections can be directly connected to the DN. As consequence, the DN also has a 'DS' area.

Each road section is allocated to the closest PDP (closest in terms of distance using the road network, not in terms of the crow fly distance).

Figure 39 – TDC's footprint fibre graph (Step 2: DETERMINING PDP 'DS' AREAS)



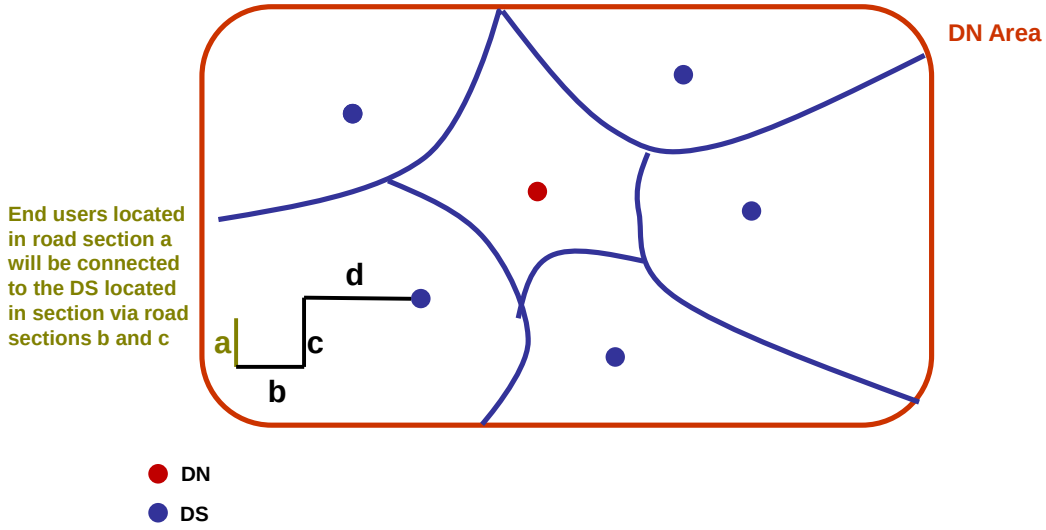
Source: DBA

Once PDP (DS) coverage areas have been determined, the next step (step 3) is to determine the "end user / PDP (DS)" paths. For each road section within a PDP (DS) coverage area, a shortest path algorithm is used to set the path from each road section to the corresponding PDP (DS) (see Figure 40).

The KMS database includes 8 different types of roads. For the part between end-user and PDP, all types of roads except highways or motorways are used by the algorithm[15].

[15] If a connexity issue is identified when not considering the highways or the motorways (i.e. if not using highways lead to standalone roads), then these types of roads will be included.

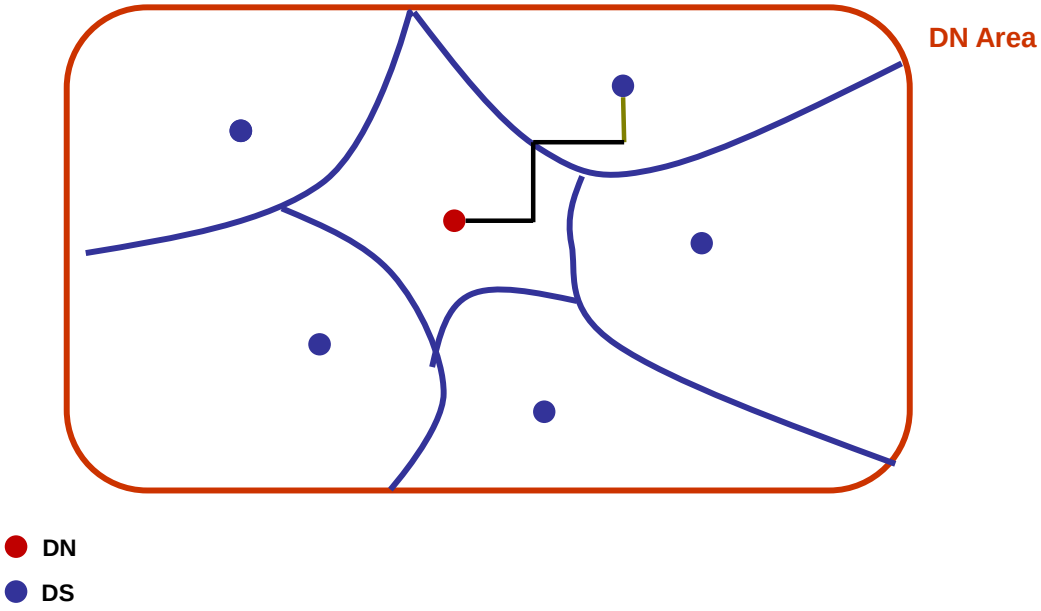
Figure 40 – TDC's footprint fibre graph (Step 3: DETERMINING end user / PDP 'DS' paths)



Source: DBA

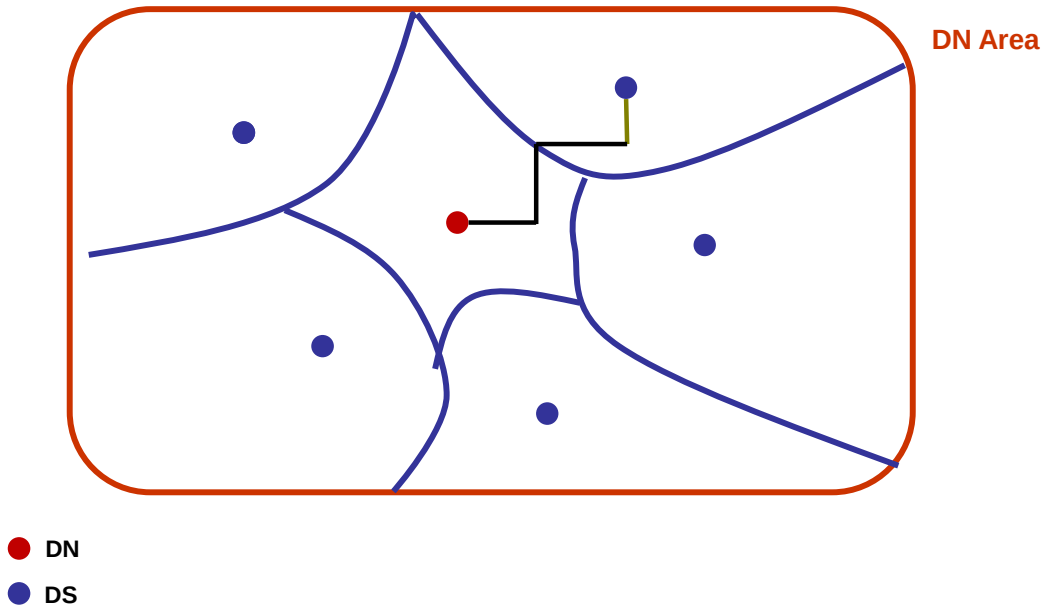
Then, a shortest path algorithm is used to set the path from each PDP (DS) to the corresponding ODF (DN) (step 4, see Figure 41).

Figure 41 – TDC's footprint fibre graph (Step 4: DETERMINING PDP 'DS' / ODF 'DN' paths)



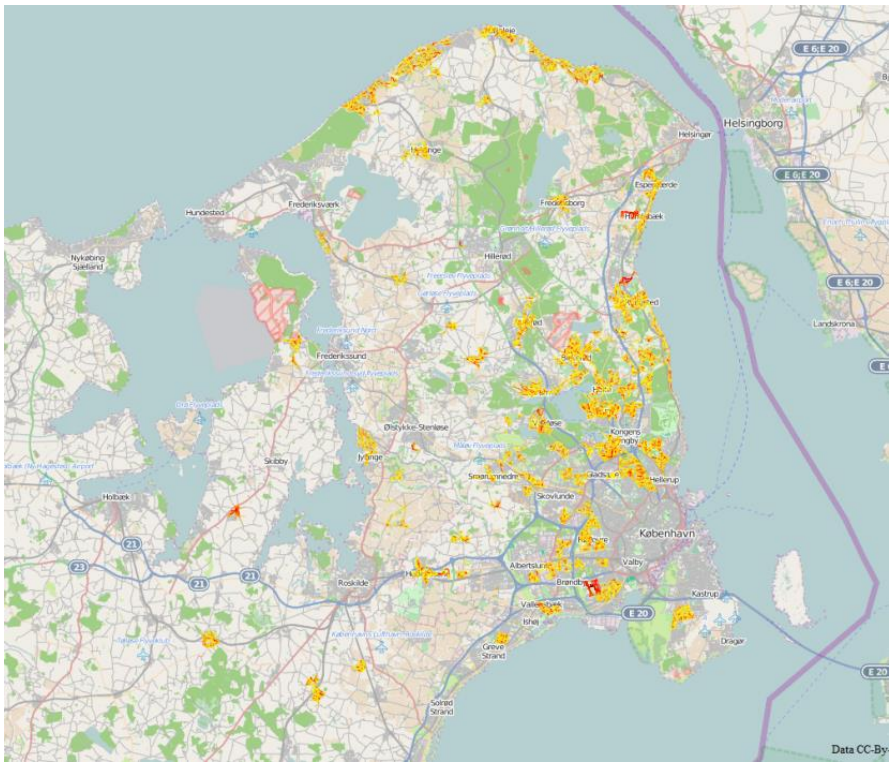
Source: DBA

Figure 42 – TDC's footprint fibre graph (Step 4: DETERMINING PDP 'DS' / ODF 'DN' paths)



Source: DBA

Figure 43 – Dong network footprint



Source: DBA

4.4 Roll-out of the network

The principles followed to roll-out the network are the same as for the copper network:

- 2 fibres per premises are assumed;
- Fibre cables are used instead of copper cables;
- Fibre DPs are used instead of copper DPs;
- Fibre ducts are used.

For SDP and PDP cables, the jointing rules are the same as for the copper network.

In the PON scenario, the SDP is replaced by a splitter, which aggregates 32 fibres.

For the Dong network as for the copper scenario, 75% of the lines aggregated by a SDP are passed to the PDP; and 70% of the lines aggregated by a PDP are passed to the Central Office.

For the FTTH Point to point network, 100% of the lines aggregated by a SDP are passed to the PDP; and 60% of the lines aggregated by a PDP are passed to the Central Office.

For the FTTH PON, at SDP level, the number of lines required to be passed to the PDP is the number of lines aggregated divided by 32. At PDP level, the number of lines required to be passed to the Central Office is the number of lines aggregated divided by 32.

The Dong trenches are considered as being shared with utilities companies. Sharing ratios are consistent with the former model:

Table 2 - Dong trenches sharing ratios with utilities

Dong: Part of the network shared with utilities (except private property part)	90%
Dong: Share of trenches costs for TDC when shared with utilities (except private property part)	25%
Dong: Trenches sharing ratio with utilities (except private property part)	**33%**
Dong: Part of the final drops shared with utilities	0%
Dong: Share of final drop trenches costs for TDC when shared with utilities	25%
Dong: Final drop trenches sharing ratio with utilities	**100%**

Source: DBA

For the FTTH Point to Point and FTTH PON networks, it is considered that 10% of trenches are shared with other service companies, and that when trenches are shared, it induces a reduction of costs of 40%. The “private part” of trenches is not shared with any other service company, and therefore 100% of costs are included in the local loop cost.

Furthermore it is considered that for a national deployment, an operator could reach a discount of 5% on the unit costs as compared to TDC negotiated unit costs of trenches.

4.4.1 Ducts

Three rules are applied when dimensioning the ducts network:

- A duct can be shared between core and BTO;
- SDPs and PDPs can share ducts;
- Final drops have dedicated ducts.

Therefore, for the fibre network, for each section, three types of ducts are dimensioned, based on the length of the cables on the section: Core-BTO paths, SDP and PDP paths and final drop paths.

The duct size is determined by the surface of cables that have to be passed. The total surface of cables is considered, and ducts are dimensioned in order to be filled up to 75% of their total surface by the total surface of cables.

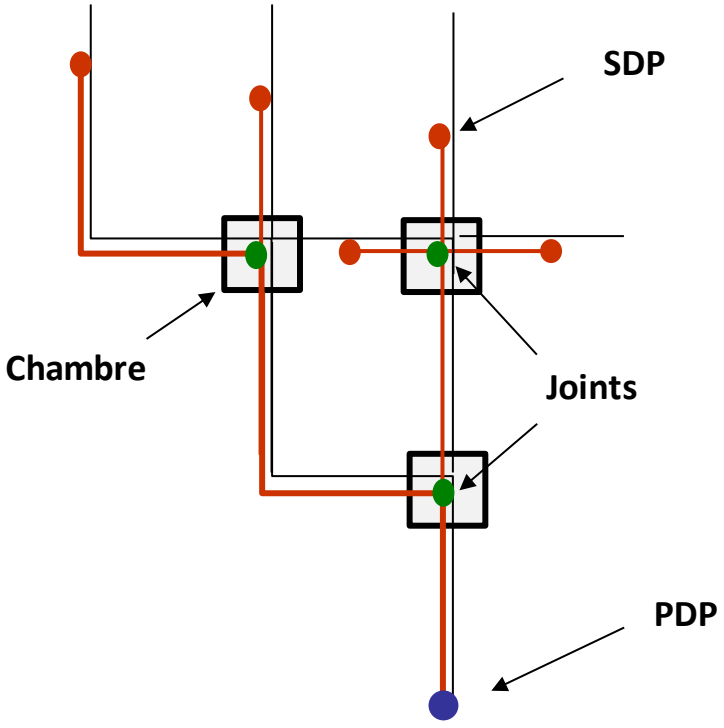
4.4.2 Joints

Final drops from the SDP to the MDU are considered to be a single dedicated cable; therefore no joint is required between the SDP and the MDU.

From the SDP to the PDP, a joint is used every time two cables have to be aggregated.

A chamber is installed at every cross-road where a joint is installed. A chamber can be shared for multiple joints.

Figure 44 - Joints and chambers

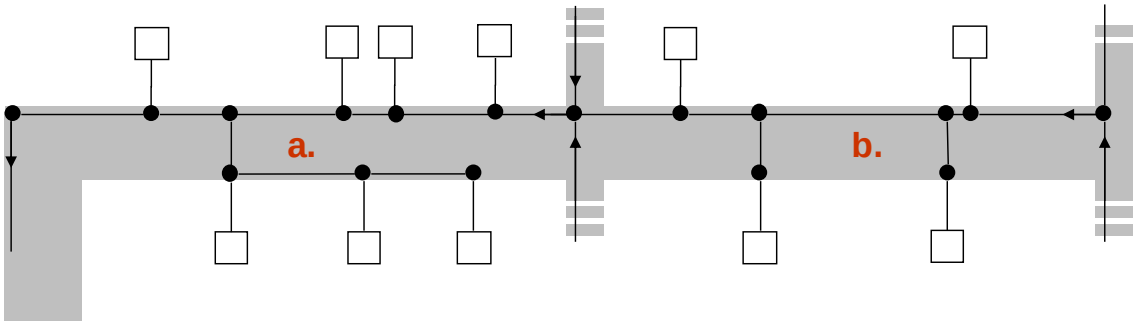


Source: DBA

4.4.3 Trenches length calculation

When trenches have to be dug on both sides on the road, there are two main configurations for trenches length (see Figure 32 below)

Figure 45 – Road sections configurations



Source: DBA

The first case (a) corresponds to a situation where trenches are dug on both sides of the road, and then the road is crossed once, the case (b) corresponds to a situation where trenches are dug on the main side of the road and then the road is crossed once for each address on the second side.

This is calculated in order to minimize the length of trenches dug, by the following process:

1. Identifying on both sides the address closest to the Central Office and the address the farthest to the Central Office.
2. Identifying the number of addresses on both sides.
3. Calculating for both sides the length required to send all addresses to the other side by using the case (a), and the case (b) (in the SQL referred as Left_OneCrossLength and Left_ManyCrossLength).
4. Identifying the main side, by identifying smallest combination left length + right length using the value described above (see Table 1, determining which of a1, a2, b1 or b2 is the smallest distance) and identifying the trench strategy (one cross or many crosses).

The trench length on the second side is then the one selected (the one selected in the Table 1).

It has to be noted that the road width is weighted by a factor in order to take into account the additional cost for tunnelling compared to roadside trenches.

On the main side the length is either the length generated by aggregating houses to the next SDP, or the section length if the road section is used by a route PDP to Central Office, Central Office to Central Office or BTO.

4.5 Geographical split of the access FTTH-P2P network

As presented above, the model is able to calculate costs for the areas that are subject to price regulation. To identify those areas, the user can select the relevant geographic areas at three possible levels :

- The building level using the SQL database “Denmark_FTTH_RegulatedArea” and assigning a regulation status (regulated or unregulated) for each building. This method of selection can be challenging as the number of buildings exceed 1.9 million.
- The zip code level using the SQL code generated in the Excel model.
- The Central Office level using the SQL code generated in the Excel model.

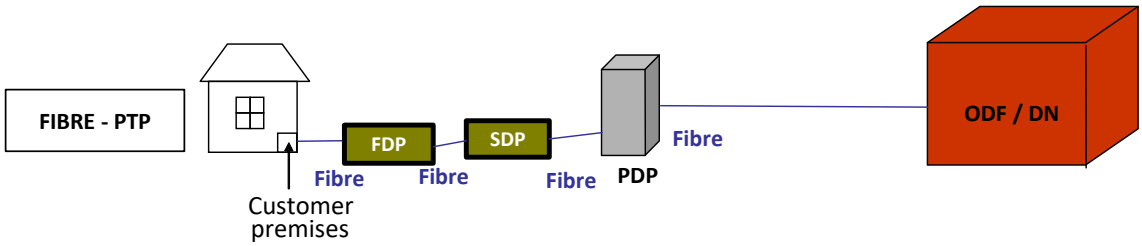
In the access network, all the costs are specific to a CO-area: the access network of a given CO-area does not share network elements with the access network of another CO-area. Hence, there is no cost allocation issue between CO-areas.

By adding the capability to compute the cost for a specific area at the zip code or the building levels, cost elements need to be allocated between regulated and non-regulated areas. A PDP-SDP fibre cable can for example be used to serve both end-users in the regulated and non-regulated areas. Hence, an additional cost allocation step is required in order to split each element in proportion to the number of regulated and non-regulated end-users it serves.

When a network is deployed, several cost elements are considered (see Figure 46) in order to allocate its cost to the served building within the regulated and non-regulated area:

- Ducts;
- Trenches;
- Joints;
- Cables;
- DPs;
- Core costs;
- OPEX.

Figure 46 – Structure of the fibre PTP access network



Source: DBA

Depending on the cost element, the cost allocation is based on the strict proportion of end-users, the number of buildings served or other levels of aggregation on the access

network (e.g. number of cables used). The right base for the cost allocation of each cost element is the cost driver that dictates the cost of an activity and the reason a cost occurs.

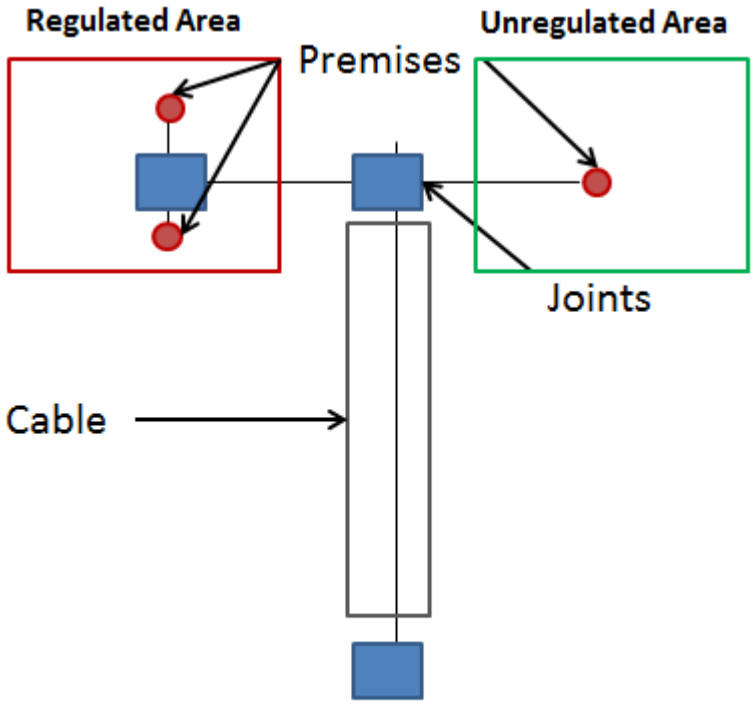
For each network item presented, the cost driver and allocation key would be presented below.

4.5.1 Cables

The cost of cables is directly linked to the number of premises passed that need to be connected to the CO. As a result, the main cost driver of cables is the aggregated number of lines in each section.

This means that for a CO serving both regulated and unregulated areas, the cost of the cables depend on the number of the premises they connects in each area as shown in the Figure 47.

Figure 47 – Cables



Source: TERA Consultants

4.5.2 Ducts

Ducts are dimensioned based on the cables that they contain. As a result, the cost of ducts is directly linked to the size of cables crossing the section.

The cost driver of this network element is the size of each cable in the duct. As discussed in the section 4.5.1, cables are allocated between regulated and non-

regulated areas based on the actual split of lines passed. Accordingly, the same rule should apply to allocate the cost of ducts.

4.5.3 Trenches

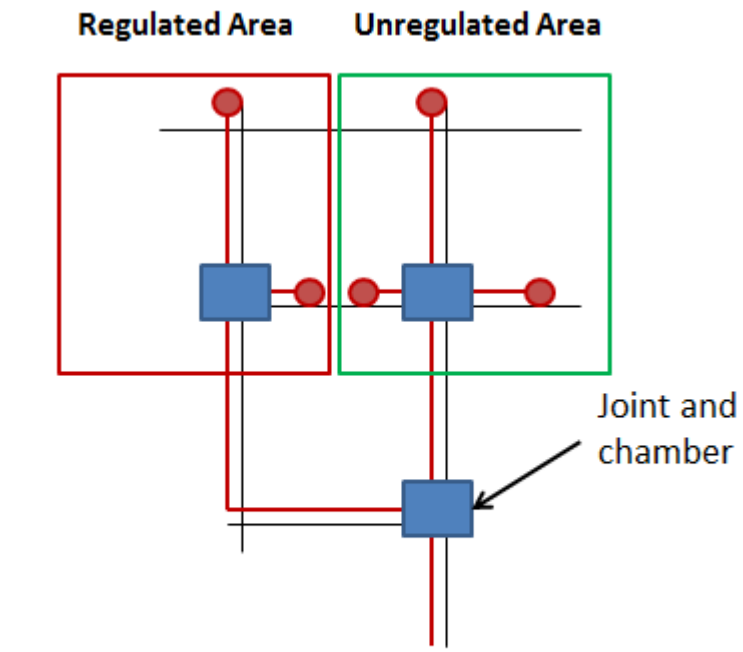
Trenches are dug to fit the ducts. The size of trenches is directly linked to characteristics of ducts that need to be passed. As a result, the cost driver of this network element is the size of ducts occupying the section.

Once trenches are allocated to a network level, the result will be split into regulated/non-regulated inventories. Considering the homogeneity of cables at a same level of aggregation, this implies that the most suitable key to split the cost between regulated and non-regulated areas would be the split of lines crossing the section at the same level of aggregation.

4.5.4 Joints and chambers

A chamber is installed at every cross-road where a joint is installed. A chamber can be shared for multiple joints. The size of a joint depends on the number of lines aggregated by the joint. As a result, the cost driver of this item is the number of lines passed as shown in the Figure 48.

Figure 48 – Joints and chambers



Source: TERA Consultants

4.5.5 OPEX

In the access model, OPEX derived as a mark-up to the CAPEX based on the annual depreciation of the asset. As a result of the allocation activities described above, the inventory will be allocated between the regulated and the non-regulated areas, which means that the OPEX will be correctly distributed between the regulated and non-regulated areas.

However, few steps had to be added to the initial model in order to maintain this distribution of the cost:

- The building OPEX uses the number of active lines the regulated area as drivers for NTP installation. The number of active lines is calculated as described in the section below.
- The OPEX for design, planning, support and overheads had to be allocated to each regulated area and network section based on the length of the cables used. To do so, an intermediate calculation computing the weight of each section of the network and the total length of the network in the regulated areas was required.

4.5.6 The number of active lines in regulated areas

In order to compute the cost per line, the total cost per area has to be divided by the number of active lines in the regulated areas.

The LRAIC-model only contains information about TDC's number of active lines on national level. Since the revised LRAIC-model will remove costs from deregulated areas from the cost base, the number of active lines covering this cost base must be reduced accordingly. Hence, to ensure the correct amount of active lines is deducted, this total number of active lines has to be allocated to each zip code by using an allocation key. This will be estimated based on DBA's annual data collection of sale of wholesale lines on markets 3a and 3b (zip code level).

For each zip code, DBA will aggregate TDC's sold wholesale lines for copper and fibre on wholesale market 3a and for coax on wholesale market 3b. To correct double counting of number of active coax lines for customer having both a CATV and a copper broadband subscription, the number of active coax lines is by the same factor as used in the LRAIC-Access model in the 'Parameters' sheet cell 'F76' – 'Overlap correction factor for Copper and CATV active lines in copper scenario'.

This final sum will be divided by the corresponding national sum of active wholesale lines to estimate the allocation keys for each zip code, e.g. if a zip code has 15,000 sold wholesale lines compared to the national total of 1,500,000 sold wholesale lines, the estimated share of total active lines in the LRAIC-model for the given zip code will be 1 pct.

Estimated shares for each zip code area will then be multiplied by the total number of active lines in the LRAIC-model to estimate the number of active lines in each zip code. E.g. if the total number of active lines in the LRAIC-model is 2.2M and using same example as above, the given zip code will contain 22,000 active lines.

For the regulated areas, these estimated active lines will be summed up and used for allocating the total cost of the regulated fibre P2P network

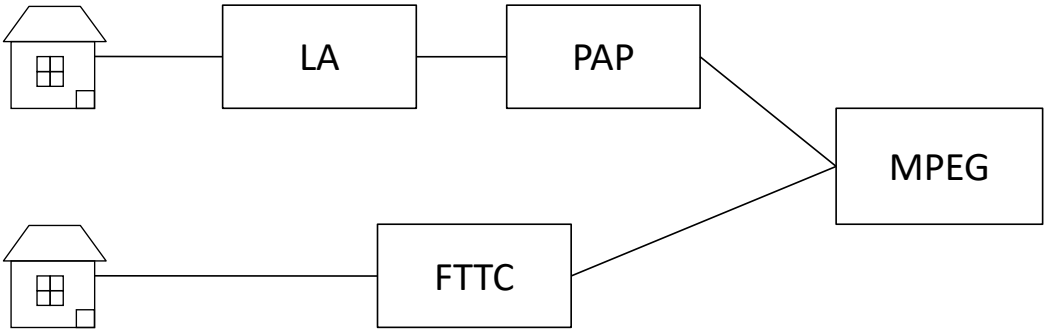
Please note that this calculation is considered confidential on zip code level. For the public version of the model, DBA will instead use number of LRAIC-modelled premises in each zip code (the SQL-output) as an alloca-tion key for all zip codes. This share will be multiplied by TDC's total number of active lines to estimate active lines to each zip code. For the regulated areas, these estimated active lines will be summed up and used for allocating the total cost of the regulated fibre P2P network.

5 Equipping the cable-TV network

YouSee uses mainly two cable-TV architectures (see Figure 49):

- The end-user is connected to the MPEG station via the last amplifier and the PAP;
- The end-user is connected to the MPEG station via the FTTC node.

Figure 49 – Cable-TV network architecture implemented in YouSee's network

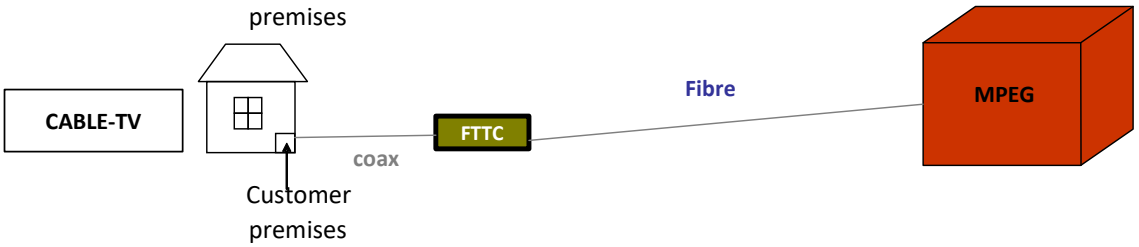


Source: YouSee

DBA considers that a modern efficient operator would deploy the second configuration ("FTTC"). Furthermore, when studying the maps sent by YouSee, it appears that the first configuration cannot be modelled due to the lack of information regarding the location of last amplifiers in certain areas.

Based on above, the second configuration ("FTTC") has been implemented (see Figure 50). The PAP locations that have been provided have been kept and considered as FTTC nodes.

Figure 50 – Cable-TV network architecture



Source: DBA

5.1 Reference files

The table hereafter lists the files which have been considered as reference files to equip the cable-TV network (see Figure 51).

Figure 51 – Input tables for the cable-TV network

Ntw.	File type	Description	Source
CATV	Excel	XY of the cable-TV nodes (MPEG stations, PAP, FTTC and D3)	YouSee *AND data LRAIC version 0.37.xlsx*
CATV	Excel	Boundaries of the cable-TV network (PAPs' coverage areas)	YouSee *Main_dist_Nodes_YouSee_final.xls*

Source: DBA

5.2 Preliminary work on cable-TV network inputs

When studying the list of addresses provided by YouSee, it appears that many cable-TV active lines are located far from the closest PAP/FTTC node and that some PAPs/FTTCs are located far from the closest active line.

These issues are due to a lack of correlation between YouSee's technical systems and YouSee's customer systems.

As a consequence, the following rules have been proposed by YouSee:

- Very small customer areas (<10 Homes passed) that are far (> 2 km) from the nearest home passed are disregarded;
- Small customer areas (< 100 Homes passed) that are far (> 5 km) from the nearest active construction (PAP, FTTC) are disregarded;
- For big customer areas (≥ 100 Homes passed) that are far (> 5 km) from the nearest active construction (PAP, FTTC), a FTTC node will be added.

YouSee's network consists of both PAP and FTTC nodes. By looking at the maps of coverage of nodes and the clients' database, it appeared that there were some nodes missing. Moreover those two types of nodes do not follow the same dimensioning rules. In order to model a consistent network, FTTC nodes have been calculated bottom-up.

In order to reflect a consistent cable-TV network to the greatest extent, the following modelling steps have been used:

- Determine zones where customers are located by isolating road sections having customers and group all road sections within 100 meters of crow fly distance;
- once zones are determined, create a graph that links all zones to the closest MPEG station, by minimizing the length of road used (e.g. if two zones are close, the second zone may be linked to the first zone, which will be linked to the MPEG station);
- for each zone, determine the exit point to the MPEG station corresponding to the intersection of the route determined above, and the zone. This exit point is considered as an aggregation point.

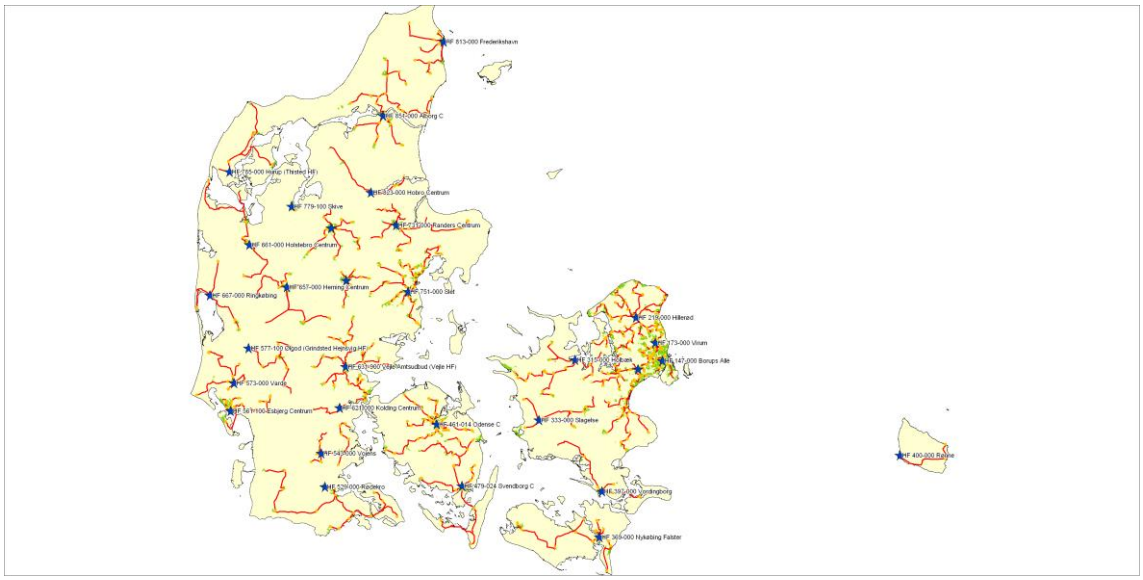
The result is a set of zones, aggregation points of the zones, and path from the zones to the MPEG stations.

5.3 Cable-TV graphs

The following 2 paths are to be determined:

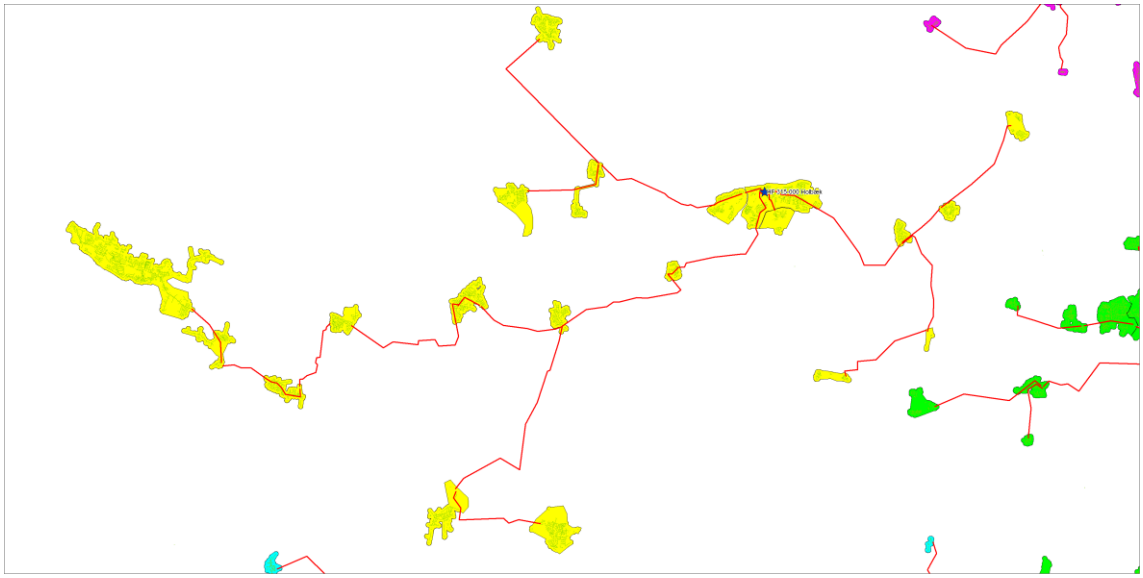
- End-user / Aggregation point;
- Aggregation point / MPEG station.

Figure 52 – Overview of the aggregation point – MPEG station network



Source: DBA

Figure 53 - Overview of the aggregation point – MPEG station network (zoom)



Source: DBA

As the cable-TV network does not have the same constraints of cable lengths as the copper network, the paths end-user/Aggregation point have been calculated in order to optimize the length of trenches of the network. The shortest path algorithm has been amended in order to use mainly the roads where customers are located or where trenches have already been dug for the aggregation point to the MPEG station cabling. This amendment leads to an increase in the length of each line but as the trench sharing increases, the total length of the trench network decreases. This is therefore the most cost efficient methodology.

The KMS database includes 8 different types of road. For the part between end-users and FTTC nodes, all types of roads except highways or motorways are used by the algorithm[16].

5.4 Roll-out of the network

5.4.1 General rules for deploying the CATV network

The paths End-user/Aggregation point are determined in all zones. Coax cables are installed from the premises to the FTTC nodes and a fibre cable is used from the FTTC node to the MPEG station.

Equipment has been modelled on the following process:

- A coax distribution point is installed for every 4 premises;

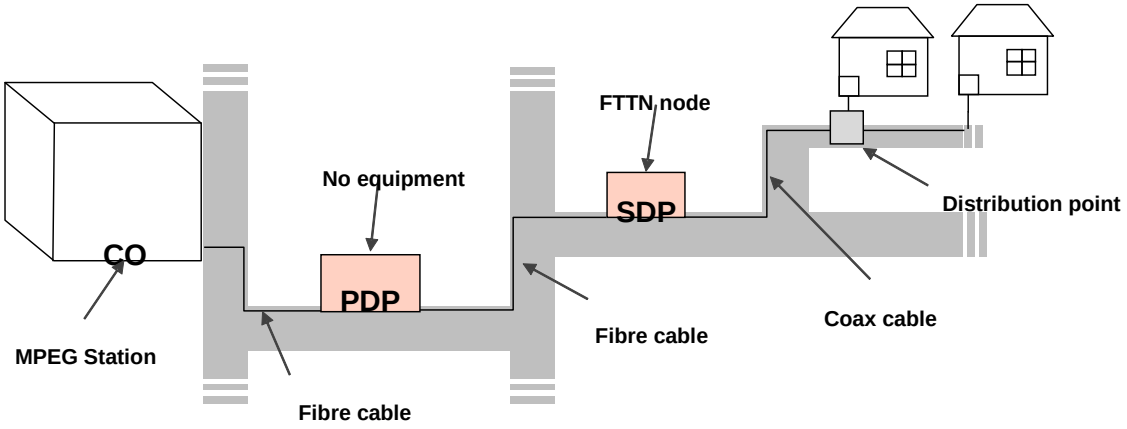
[16] If a connexity issue is identified when not considering the highways or the motorways (i.e. if not using highways lead to standalone roads), then these types of roads will be included.

- FTTC nodes are modelled bottom-up. Starting from the edge of the network down to the aggregation point, every time the number of premises aggregated is above 50, a FTTC node is installed;
- From each FTTC node, a fibre is linked to the aggregation point;
- At the aggregation point, if some premises are not aggregated by a FTTC node, a new node is added; and
- From the aggregation point to the MPEG station, fibre cables are deployed. These are dimensioned to handle the fibres connected to all FTTC nodes.

The ducts are distinct for the coax network, for the FTTC/Aggregation point path, and the Aggregation point/MPEG station path.

It has to be noted that on the following graph, the CO is the CO holding a MPEG station and not the closest CO from TDC. The assets deployed are further detailed in the section 10.2.2.4 of this documentation.

Figure 54 – Cable-TV network rolled out



Source: DBA

For the CATV network, it is considered that 10% of road-side trenches are shared with other service companies, and that when trenches are shared, it induces a reduction of costs of 40%. The “private part” trenches are not shared with any other service company.

Furthermore it is considered that for a national deployment, an operator could reach a discount of 5% on the unit costs as compared to TDC negotiated unit costs of trenches.

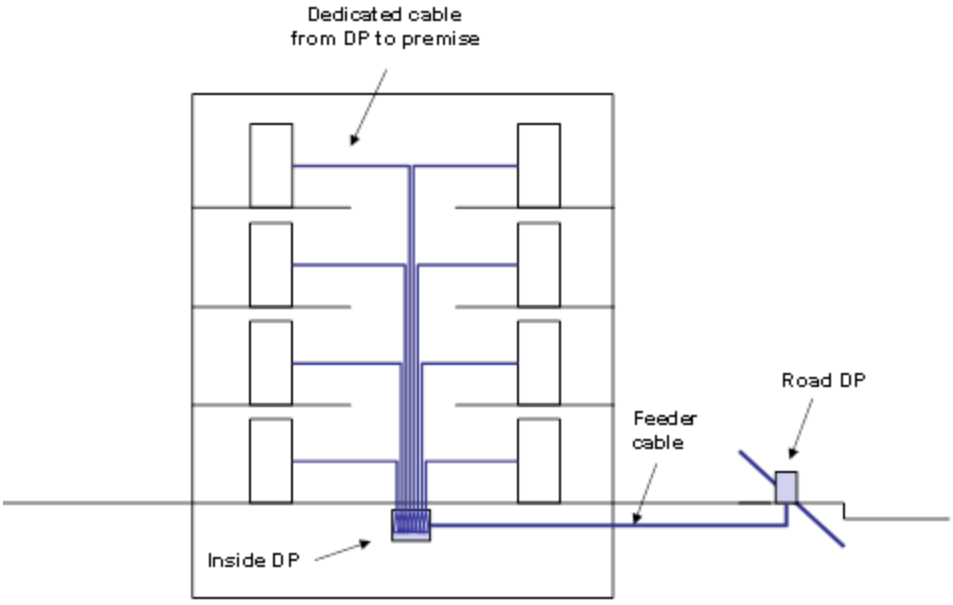
5.4.2 MDU cabling

The internal cabling of MDU is handled in a similar way as for the copper network.

A distribution point is installed in the basement of the building, it is fed by a single cable coming from the street.

A dedicated cable is installed from this distribution point up to each flat. The length of each cable calculated based on the height per floor, the number of floors and the distance between the staircase and the apartment (See Figure 55 below).

Figure 55 - Internal cabling for COAX



Source: DBA

6 Modelling the Core/BTO civil engineering and cables requirements

This section aims at explaining the dimensioning process for the core (inter-Central Office fibre links) and the BTO (build-to-order fibre links for business customers) networks.

6.1 Reference files

The table hereafter lists the files which have been considered as reference files to equip the core/BTO network (see Figure 56).

Figure 56 – Input tables for the core / BTO network

Ntw.	File type	Description	Source
BTO / Core	Excel	List of BTO and core cables (cables ends, type cable)	TDC *Main_dist_Nodes_YouSee_final.xls*

Source: DBA

6.2 Core/BTO graphs

TDC has provided for the core and BTO network the following data:

- The cable ID;
- The cable type;
- The length of the cable;
- For the starting point:
- The ID;
- The coordinates;
- For the ending point:
- The ID;
- The coordinates.

For each Core / BTO network link, a shortest path algorithm has been used to build the path between ends A and B.

Links that are not complete (at least one end location missing or incorrect) are disregarded.

Having the path between each end makes it possible to determine which sections are used by BTO and core networks and thereby which trenches that can be used by BTO, core and access networks.

6.3 Roll-out of the network

A list of core links has been provided by TDC. This file provides end nodes of each link used by TDC. This makes it possible to identify the two Central Offices corresponding to the ends of a given link and perform a shortest path algorithm to determine all road sections used to link both Central Offices.

A list of BTO links has been provided, for each of these links a node has been linked to a Central Office and a shortest path algorithm has been performed to determine all road sections used to link both extremities.

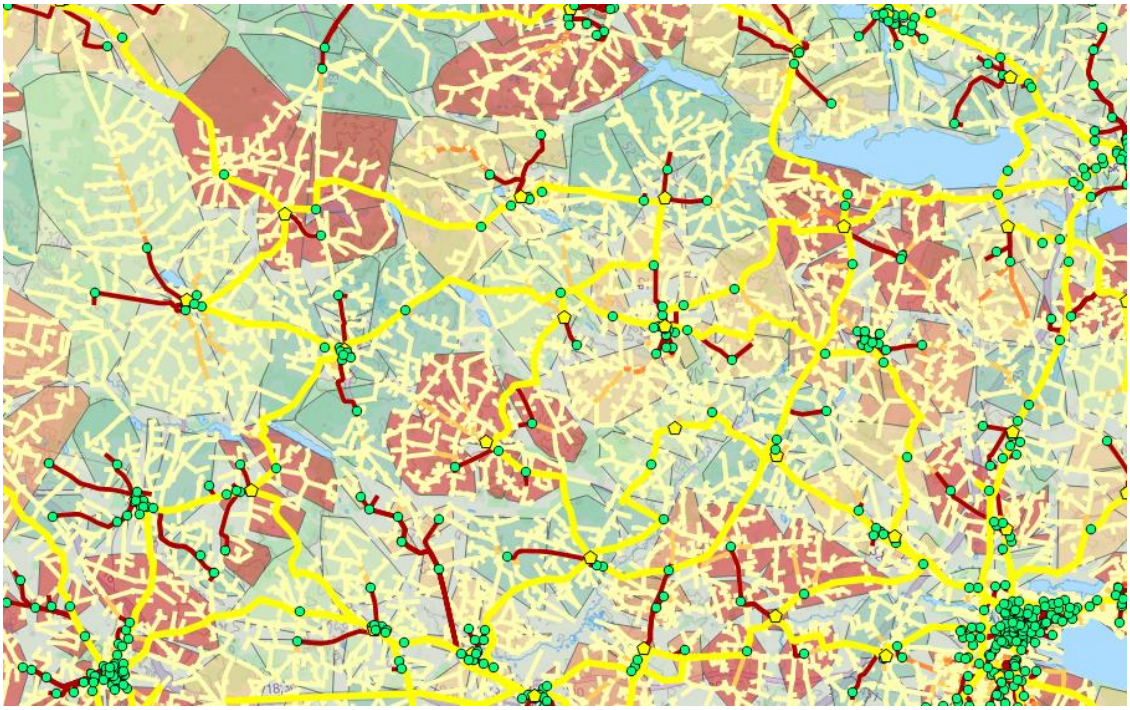
As a national average, each core link provided by TDC has been considered to support 24 fibres and each BTO link has been considered to support 4 fibres. On each section, the cable length corresponds to the length of the whole section.

Core link fibres are installed in specific ducts with BTO links.

Trench and duct costs allocated to the core and the BTO networks are used as an input in the core network cost model.

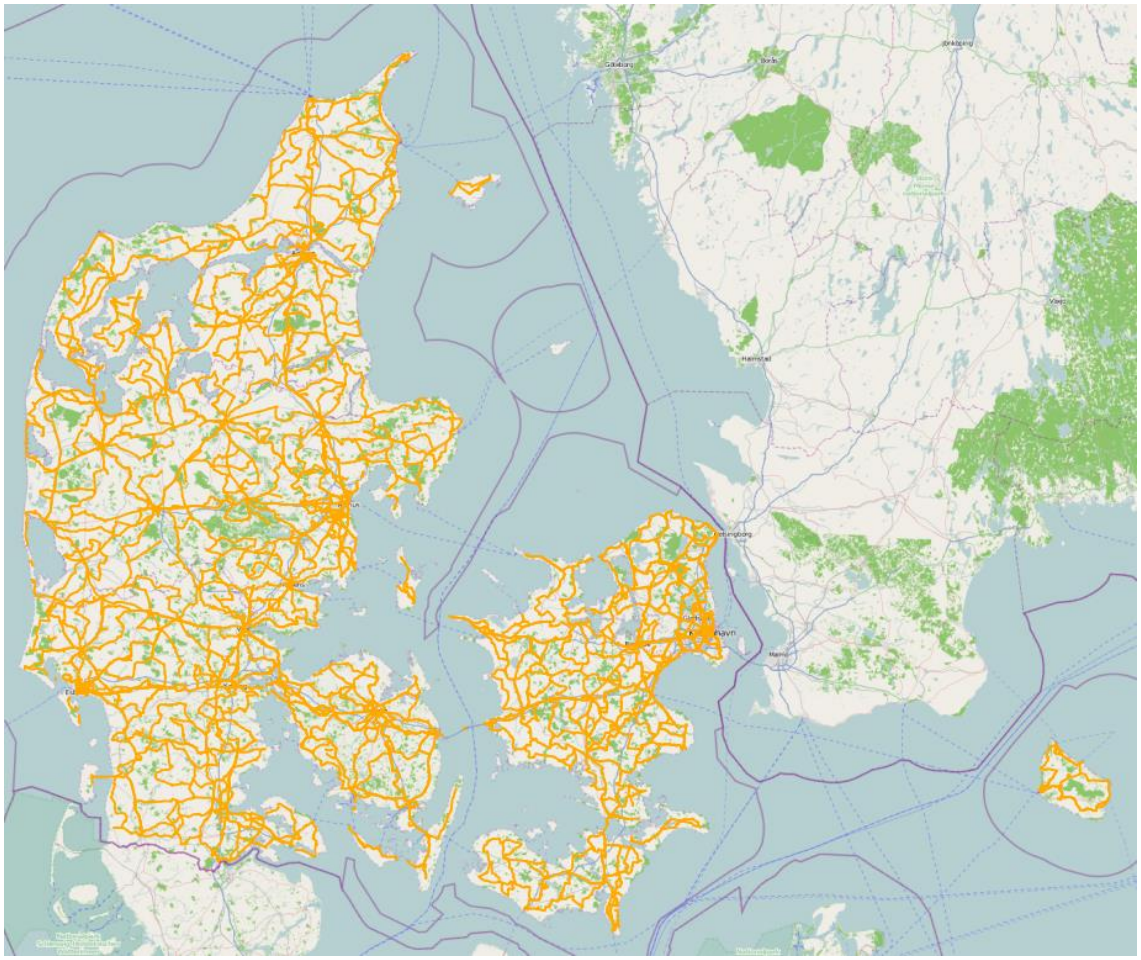
A markup of 5% applied on ducts, chambers and trenches has been introduced in order take into account reinforcement on trenches that are shared for several core routes.

Figure 57 – Local view of TDC's network – Core links in yellow



Source: DBA

Figure 58 – General view of TDC's core network



Source: DBA

7 Equipping the core network

This section describes the core network cost modelling approach.

7.1 Structure of the network

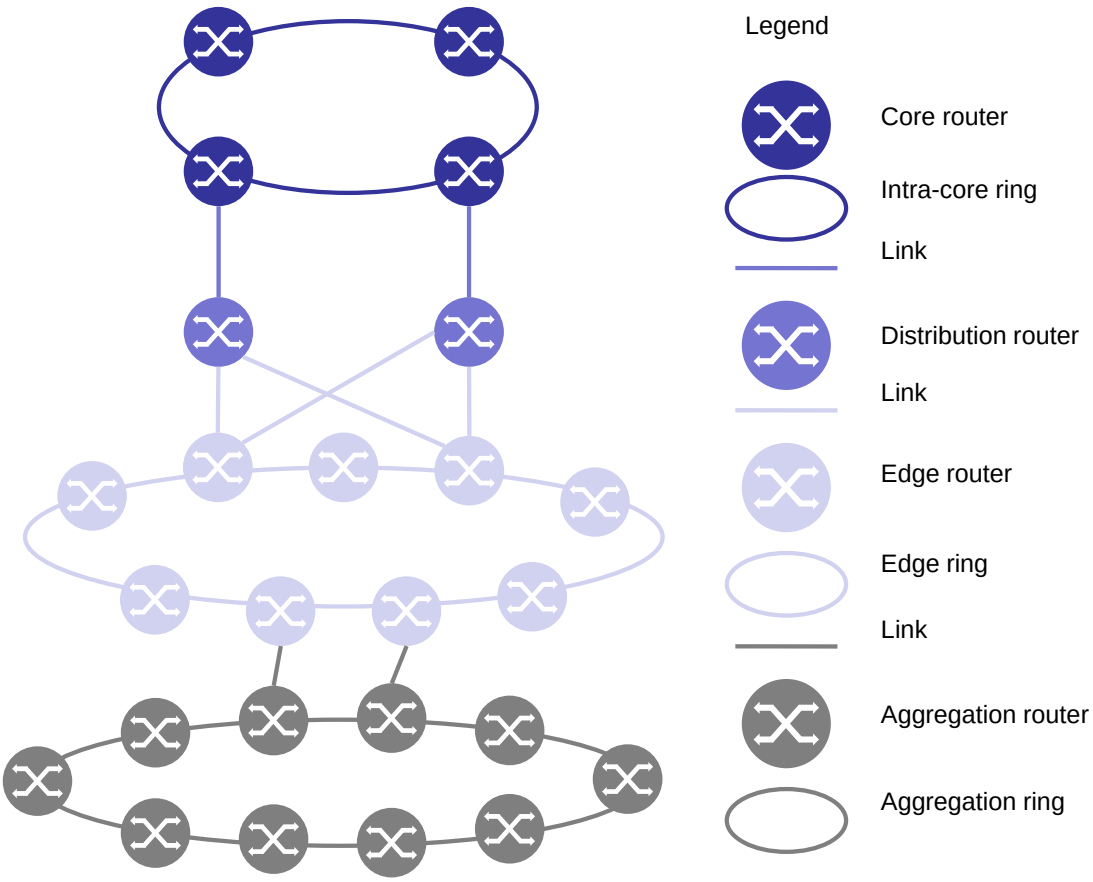
7.1.1 Network architecture

In accordance with the MRP, the modelled core network is an “all-IP” core network common to all access technologies (copper, fibre PTP, fibre PON and cable-TV). In accordance with the previous model, the network architecture is based on a four-layer hierarchy:

- The core layer which is made of two sub-layers:
  - The (super) core sub-layer;
  - The distribution sub-layer;
- The edge layer;
- The aggregation layer;
- The MSAN layer.

The core network is organized according to the following figure:

Figure 59 – core network topology



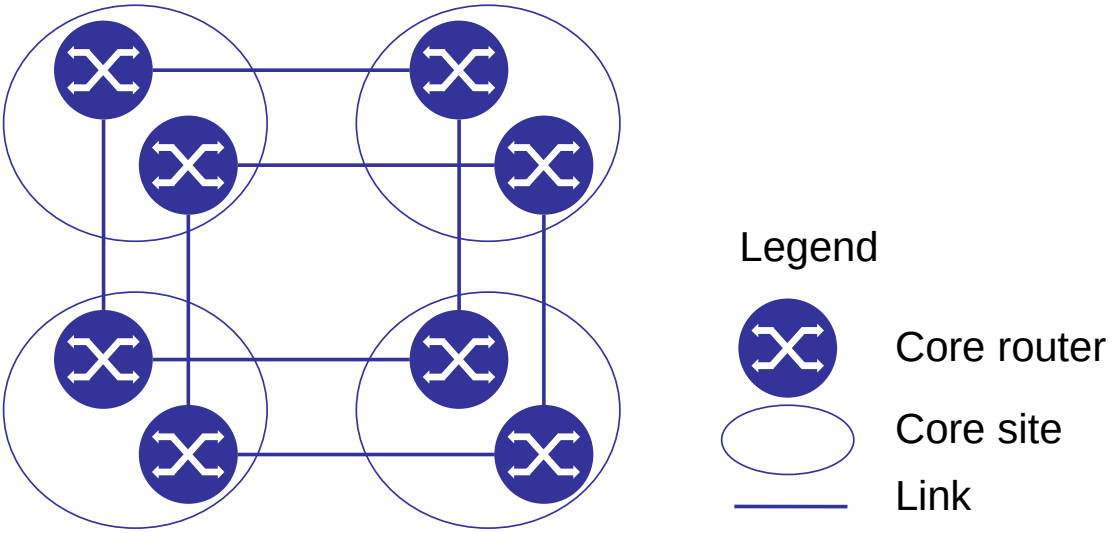
Source: DBA

The Core layer is made of:

- 4 core sites;
- 13 distribution sites.

In line with the previous model, on each core site, two core routers are rolled-out for resilience. These four core sites are linked on a ring:

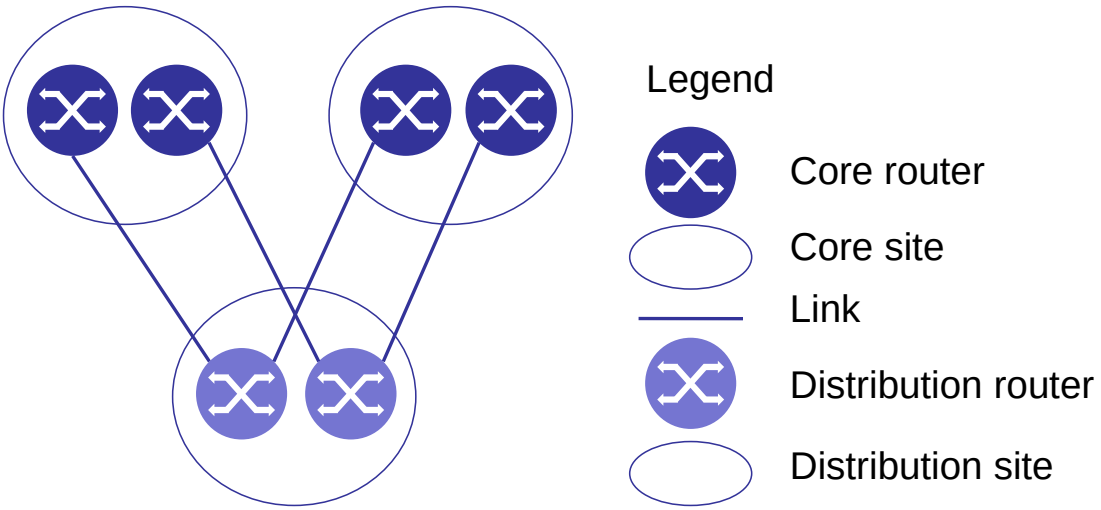
Figure 60 – core layer structure



Source: DBA

As in the previous model, each distribution site is linked to two core routers located on different core sites:

Figure 61 – Link between distribution and core layers

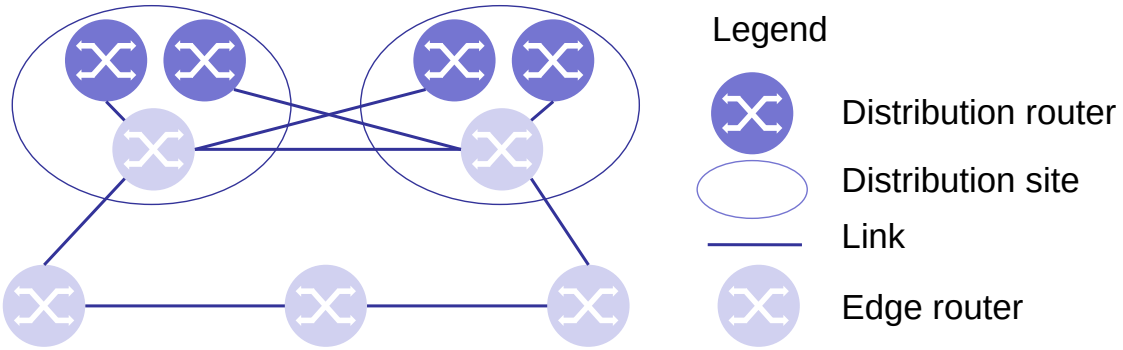


Source: DBA

In line with the previous model, each core site is collocated with one distribution site. Therefore there are 9 standalone distribution sites. There is no direct link between the distribution routers.

In accordance with the previous model, the edge layer is organized into rings of various sizes with a total of 97 edge sites. Each edge ring has two parent edge sites that are both collocated with a distribution router. Each parent edge site is connected to both distribution routers:

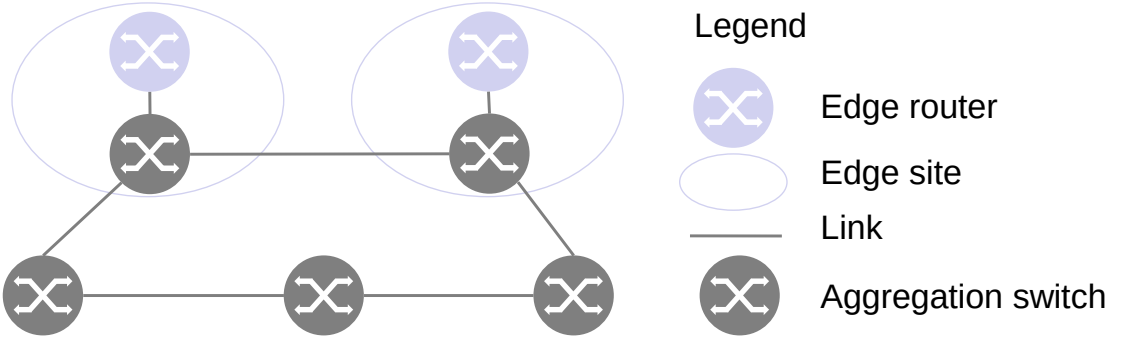
Figure 62 – Edge layer structure and link between edge ring and distribution routers



Source: DBA

As it has been carried out in the previous model, the aggregation layer is structured the same way as the edge layer: the aggregation switches are grouped into rings of various sizes. Each aggregation ring has two parent nodes that are collocated with two edge routers. However, there is no cross link compared to the edge rings:

Figure 63 – Aggregation layer structure and link between aggregation ring and edge routers



Source: DBA

Finally, as in the previous model, the last layer is used to connect the subscribers to the core network. It is made of MSANs and MPEG stations. They are all connected to a single aggregation switch.

- The MSANs are collocated with the aggregation switch when they are located in the Central Offices. There are some MSANs located in street cabinets. These MSANs require a specific link to be connected to the aggregation switch.

- There are 30 MPEG stations and they are all collocated with aggregation switches.

7.1.2 Location of the servers

The network includes servers dedicated to some services or to some access technologies:

- In the new LRAIC model, the IMS platforms are located on the core sites whereas they were located on distribution sites in the previous model. As there are 4 core sites, there are now 4 IMS platforms instead of 13 platforms in the previous model. They are collocated with the core sites. This choice has been made because:
    - According to the operators' answers to the data request, there are no technical issue rolling-out the IMS platforms at the core sites instead of the distribution sites;
    - This network topology is more cost efficient;
    - This network topology simplifies the routing factor calculation, making the cost model more transparent.
    - This network topology is consistent with the approach followed by the ARCEP (2 IMS platforms), the French NRA and the HAKOM (4 IMS platforms), the Croatian NRA, i.e. for similar or bigger countries.
- There are 4 intelligent network platforms collocated with the core sites;
- There are 4 PSTN gateway platforms collocated with the core sites;
- There are 4 PLMN gateway platforms collocated with the core sites;
- In line with the previous model, there are 2 international gateways collocated with two core sites;
- There are servers dedicated to services provided only with cable-TV. These are located on only one core site.

7.2 Traffic data and number of subscribers

7.2.1 Traffic data

7.2.1.1 List of services

The model includes all of TDC's current traffic which has been split according to the following categories:

- Voice services;
- Broadband services;
- Bitstream services;
- Unicast services;

- Multicast services;
- Leased lines services.

Compared to the previous model, the number of services has been reduced, especially in the voice services category, in order to make the model both more transparent and easier to update.

Figure 64 – List of services included in each traffic categories

Voice services	Broadband services	Bitstream services	Unicast services	Multicast services	Leased lines services
On-net	Internal VULA/BSA	External VULA/BSA - Cabinet	Unicast – Layer 2	Multicast - uplink - Distr-Edge	LL <= 2 Mbps
IN		External VULA/BSA - Layer 2	Unicast - Layer 3	Multicast - uplink - POI2-POI1	LL <= 1 Gbps & > 2 Mbps
International - Incoming		External VULA/BSA - Layer 3	Unicast - National	Multicast - Core-Core	LL > 1 Gbps
International - Outgoing		Ethernet Transport - National		Multicast - Core-Distr	
International - Transit				Multicast - Distr-Edge	
Incoming fixed off-net - Local interconnection				Multicast - POI2-POI1	
Incoming fixed off-net - National interconnection				Multicast - POI1-DSLAM	
Transit - Local interconnection				Multicast - DSLAM-End user	
Transit - National interconnection					
Outgoing off-net					
Incoming Mobile to fixed					

Source: DBA

In section §12.5 a mapping between the services of the previous model and the services included in the new model is provided.

TDC offers three types of leased lines services:

- Leased lines over SDH (they are considered as it is supposed the full traffic is on NGN);
- IP via leased lines;
- IP via fibre.

In the new model, the split between the different leased lines services differs from the split listed above which were the split used in the previous model. The following leased line services are now used in the updated model:

- The SDH leased lines with a capacity below 2 Mbps are part of the service “LL <= 2 Mbps”;
- The SDH leased lines with a capacity between 2 Mbps and 1 Gbps and the non-SDH leased lines are part of the service “LL <= 1 Gbps & > 2 Mbps”;
- All leased lines with a capacity above 1 Gbps are part of the service “LL > 1 Gbps”.

This categorization has been carried out due to different engineering rules being applied to these three groups as explained in section §7.3. It should be noted that even if the services have changed, all of the leased lines traffic is still consider in the model.

7.2.1.2 Busy hour traffic

The core network modelled is dimensioned based on the network busy hour.

For all services except the leased lines and the multicast services, the computation of the busy hour traffic remains the same in the new model as in the previous model[17].

7.2.1.2.1 Voice busy hour traffic

The core network modelled is an “all-IP” core network, therefore only VoIP services are modelled. The yearly VoIP traffic is therefore the sum of the PSTN traffic and of the VoIP traffic of the previous model.

The busy hour traffic in Erlangs is obtained by converting the yearly traffic into the average number of Erlangs and then applying a peak to mean ratio:

Figure 65 – Yearly traffic to busy hour traffic conversion

$$BH_{Erlangs} = \frac{Yearly\ traffic_{minutes}}{Number\ of\ minutes\ per\ year} * peak\ to\ mean\ ratio$$

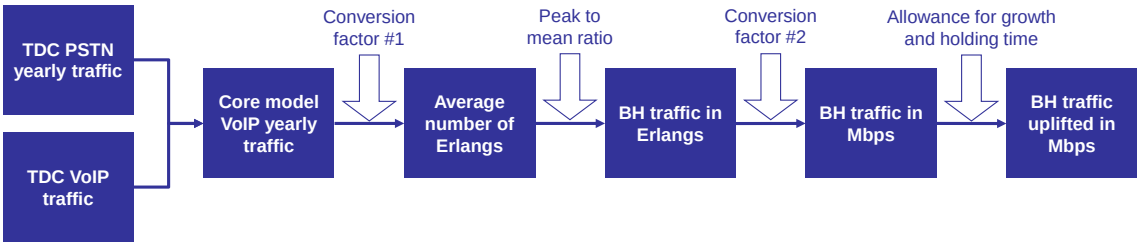
Source: DBA

The traffic is then converted into Mbps using the traffic parameters defined in the previous model (sampling rate, sample size, headers size). And finally the traffic is uplifted by two factors:

- The allowance for growth: this parameter allows the dimensioning of the network based on future demand;
- The holding time.

[17] The only difference in the busy hour traffic calculation between the new and the previous model is the number of days per year. In the previous model, the number of days per year was 364 (7 days a week and 52 weeks a year). It has now been set to 365.

Figure 66 – VoIP busy hour traffic



Source: DBA

7.2.1.2.2 Broadband busy hour traffic

The broadband (internal and external) busy hour traffic is obtained by converting the yearly traffic (in GB) into the average number of Mbps and then applying a peak to mean ratio:

Figure 67 – Yearly traffic to busy hour traffic conversion

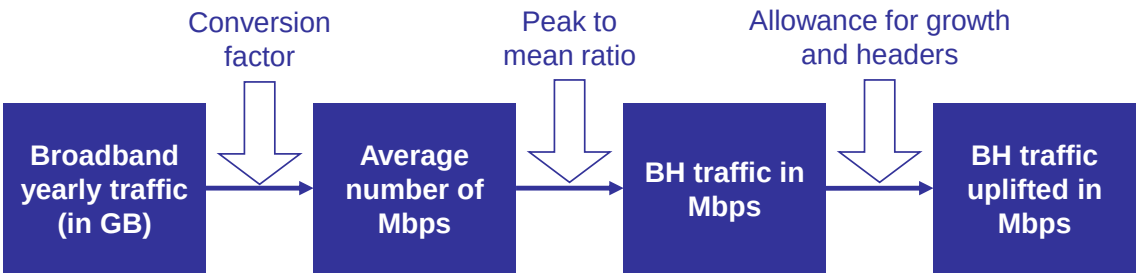
$$BH_{Mbps} = \frac{Yearly\ traffic_{GB} * Number\ of\ megabits\ per\ GigaBytes}{Number\ of\ seconds\ per\ year} * peak\ to\ mean\ ratio$$

Source: DBA

The busy hour traffic is then uplifted by two factors:

- The allowance for growth: as for the VoIP traffic, this parameter allows dimensioning the network on future demand;
- The size of the headers.

Figure 68 – Broadband busy hour traffic



Source: DBA

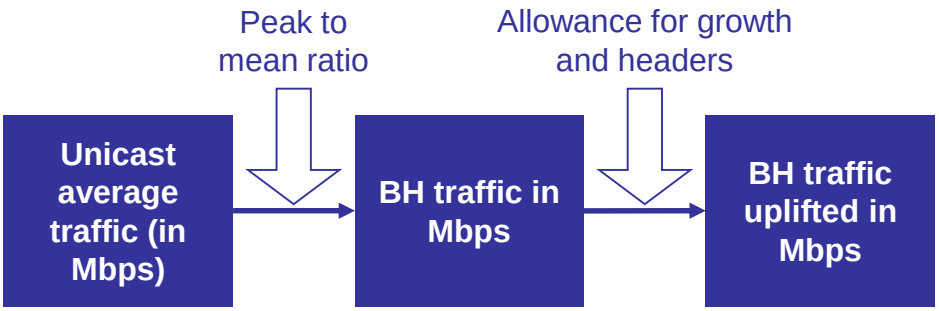
7.2.1.2.3 Unicast services busy hour traffic

The unicast services busy hour traffic is obtained by multiplying the average traffic by the peak to mean ratio:

The busy hour traffic is then uplifted by two factors:

- The allowance for growth: as for the VoIP traffic, this parameter allows the dimensioning of the network based on future demand;
- The size of the headers.

Figure 69 – Unicast services busy hour traffic



Source: DBA

7.2.1.2.4 Multicast busy hour traffic

The multicast busy hour traffic has been revised in the new core network cost model. The computation of the busy hour traffic is based on the number of channels, the average speed of the channel, the multicast traffic sent to Yousee and the analysis of the propagation knowing that each channel is sent only once:

- As each channel is sent only once, the traffic due the TV channels (number of channels multiplied by average speed) is the same in each node of the network except for the MSANs. Here, it is considered that in each MSAN, all the TV channels are not watched by at least one customer during the busy hour. Therefore the multicast traffic is reduced by a parameter named “Share of TV channels accessed by a DSLAM during peak hour” which was part of the previous model;
- The multicast traffic sent to Yousee is also sent only once in the network. However, this traffic is not sent everywhere as there are only 30 MPEG stations. These MPEG stations are located on 18 different edge rings out the 21 existing. Therefore the multicast traffic sent to Yousee will be sent only to those 18 rings and will neither be sent to the aggregation nodes nor to the MSANs;
- The total traffic at the core level is therefore the traffic in each core ring multiplied by the number of core rings;
- The total traffic at the distribution level is therefore the traffic in each distribution ring multiplied by the number of distribution rings;
- The total traffic at the edge level is the sum of:
    - the traffic in the edge rings receiving traffic for Yousee customers multiplied by the number of edge rings concerned;
    - the traffic at the edge rings not receiving traffic for Yousee customers multiplied by the number of edge rings concerned;
- The total traffic at the aggregation level is therefore the traffic in each aggregation ring multiplied by the number of aggregation rings;

7.2.1.2.5 Leased lines busy hour traffic

Leased lines traffic has been completely updated in the new core network cost model. The modelling of the leased lines traffic is described in details in section §7.2.3.

7.2.2 Number of subscribers

The number of subscribers for each service is based on the data provided by TDC during the yearly annual update except for the number of VoIP customers.

The number of VoIP customers has been updated as there is no PSTN traffic in the new model. The number of VoIP customers has therefore been defined as the sum of the number of PSTN customers and the number of broadband customers without a PSTN subscription.

7.2.3 Leased lines

TDC offers three types of leased lines services:

- Leased lines over SDH;
- IP via leased lines;
- IP via fibre.

The leased lines traffic and number of customers are therefore respectively the traffic and the number of customers of these three services.

7.2.3.1 Leased line traffic

The leased lines traffic is based on the analysis of:

- The capacity subscribed by each leased line customer;
- The traffic propagation in the core network of each leased line.

For each leased line, TDC has provided:

- The entry node in the network (the aggregation or the edge node);
- The leased line capacity.

TDC has also provided:

- The exit node of the network for SDH leased lines;
- The local leased lines for IP via fibre leased lines.

Thanks to the network topology (described in section §7.1.1), and to the entry and exit nodes of the SDH leased line, the traffic due to SDH leased lines at each network node has been computed:

- If the entry node and the exit node are the same nodes, then the leased line is a local leased line. The leased line is not connected to any port and is not feeding the core network with some traffic.
- If the entry node and the exit node are different nodes, then the parent nodes are identified (with the network topology) and compared until a common parent

is found. If no common parent is found, then this means the leased line feeds the intra-core link.

Knowing the traffic at each node, it is therefore possible to compute traffic propagation statistics, i.e. knowing the leased lines traffic at one given node of the aggregation level, it is possible to compute how much of this traffic is left at the parent network levels (edge, distribution, core and intra-core).

As the exit node has been provided only for the SDH leased lines, the traffic propagation statistics computed for the SDH leased lines have been applied to the IP via fibre and IP via leased lines.

For IP via fibre and IP via leased lines, only the capacity has been provided by TDC although the traffic at busy hour is not equal to the sum of the capacities as a contention ratio is applied (this is not the case for SDH leased lines). Nonetheless, TDC has provided the busy hour traffic for IP via fibre at the edge level and comparing this to the leased lines capacity at the edge level, has allowed computing a 7.3% contention ratio[18]. This contention ratio has been applied to both the IP via fibre and the IP via leased line traffic.

7.2.3.2 Number of leased line customers

All the non-local leased lines are feeding traffic into the core network. These leased lines require two ports (one at the entry node and one at the exit node).

The traffic propagation analysis described in the previous section allows computing the number of ports required at each network node. As explained in section §7.3, the number of ports has to be computed for the three leased lines services.

7.3 Engineering rules

The roll-out of the core network assets is based directly or indirectly on two drivers:

- The number of lines (only active lines or all lines rolled-out);
- The traffic.

The assets are dimensioned based on the number of lines including street cabinets, MDFs (ODFs for fibre) and the MSANs.

All the switches and routers are dimensioned based on the traffic. MPEG stations are also dimensioned based on the traffic.

The full list of assets to be dimensioned is provided in section §12.4.1

[18] A 7.3% contention ratio means that if a 100 Mbps capacity is rolled-out, then there is 7.3 Mbps traffic fed in the core network.

7.3.1 Lines driven assets

7.3.1.1 The four roll-out scenarios

The model includes four different scenarios for the sake of consistency with the access network cost model:

- The first scenario is a nationwide copper network: all lines rolled-out are copper lines;
- The second scenario is a nationwide fibre point-to-point network: all lines are point-to-point fibre lines;
- The third scenario is a nationwide fibre PON network;
- The fourth scenario is TDC actual network with copper, fibre and cable-TV (including customers passed by networks not owned by TDC).

The number of lines (only active lines or all lines rolled-out) per access technology depends therefore of the scenario selected.

7.3.1.2 Street cabinets, MDF and ODF

Street cabinets, MDF and ODF are dimensioned based on the total number of lines rolled-out and not only on the number of active lines.

For each asset, several sizes exist in TDC inventory. In accordance with the previous model, the appropriate asset is selected based on its capacity.

7.3.1.3 MSANs

MSANs (for xDSL at street cabinet and at Central Office, for fibre PTP and for fibre PON) include the following assets:

- Cards;
- Racks;
- SFPs;
- MDF cables;
- Patch cables.

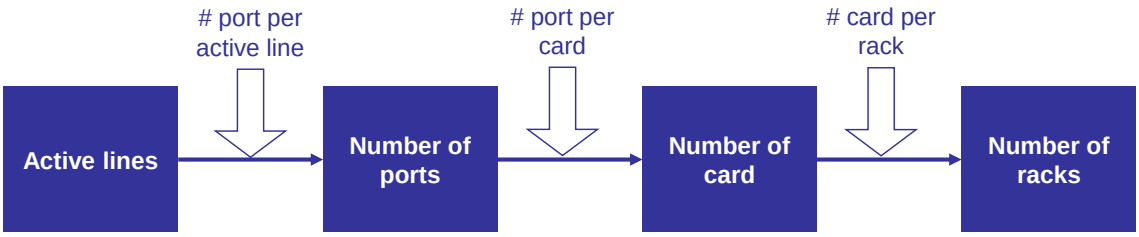
Dimensioning the MSANs requires dimensioning all the different assets of the MSANs.

Several configurations are available as:

- Different types of cards may exist. E.g.: xDSL cards, vectoring cards or SDSL cards;
- Different types of capacity may exist. E.g.: cards with 1G ports versus cards with 10G ports.

All MSANs assets are dimensioned based (directly or indirectly) on the number of active lines:

Figure 70 – MSAN dimensioning rules



Source: DBA

The number of ports is calculated based on:

- The number of active lines;
- The number of active lines per port.

The number of cards is calculated based on:

- The number of ports;
- The maximum number of ports per card.

The number of racks is calculated based on:

- The number of cards;
- The maximum number of cards per rack.

The SDH leased lines with a capacity of 2 Mbps or below, which corresponds to the “LL <= 2 Mbps” service, are, unlike all other leased lines, connected to the xDSL MSAN on a SDSL card. This is why there is a dedicated service for this type of leased lines.

Source: DBA

7.3.2 Traffic in the network

The traffic in the network is one of the two drivers used to dimension the network assets.

7.3.2.1 The routing table

The traffic at each network node is computed based on the busy hour traffic and on the routing table.

Figure 71 – routing table

Routing matrix	Service category	Aggregation node equi	Edge node equipment	Distribution node equip	Core node equipment	Tx path: aggregation ri	Tx path: aggregation to	Tx path: edge ring	Tx path: edge to Distrib	Tx path: distribution to	Tx path: intra Core	IMS platform	Inteligent network	PSTN GW	PLMN GW	International GW
Voice																
Voice - On-net	Voice	2.0	2.0	4.0	2.2	2.0	2.0	2.0	2.0	4.0	0.2	1.1	-	-	-	-
Voice - IN	Voice	2.0	2.0	4.0	4.0	2.0	2.0	2.0	2.0	4.0	2.0	1.0	2.0	-	-	-
Voice - International - Incoming	Voice	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	-	1.0	-	-	-	1.0
Voice - International - Outgoing	Voice	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	-	1.0	-	-	-	1.0
Voice - International - Transit	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	2.0
Voice - Incoming fixed off-net - Local interconnection	Voice	1.0	2.0	4.0	1.0	1.0	1.0	1.0	2.0	4.0	-	1.0	-	1.0	-	-
Voice - Incoming fixed off-net - National interconnection	Voice	1.0	2.0	4.0	2.0	1.0	1.0	1.0	2.0	4.0	1.0	2.0	-	1.0	-	-
Voice - Transit - Local interconnection	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	2.0	-	-
Voice - Transit - National interconnection	Voice	-	-	4.0	2.0	-	-	-	2.0	4.0	-	2.0	-	2.0	-	-
Voice - Outgoing off-net	Voice	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	0.7	0.3	-
Voice - Incoming Mobile to fixed	Voice	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	1.1	-	-	1.0	-
Voice - Incoming Mobile to Outgoing International	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	-	1.0	1.0
Broadband																
Broadband - Internal VULA/BSA	Broadband	1.0	2.0	2.0	1.5	1.0	2.0	1.0	2.0	2.0	0.5	-	-	-	-	-
Broadband - External VULA/BSA - PIO0	Bitstream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Broadband - External VULA/BSA - POI1	Bitstream	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Broadband - External VULA/BSA - POI2	Bitstream	1.0	1.0	-	-	1.0	2.0	-	-	-	-	-	-	-	-	-
Broadband - Ethernet Transport - National	Bitstream	-	1.0	2.0	2.0	-	1.0	2.0	2.0	2.0	1.0	-	-	-	-	-
Prioritised																
Prioritised - Unicast - Layer 2	Unicast	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prioritised - Unicast - Layer 3	Unicast	1.0	-	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Unicast - National	Unicast	1.0	1.0	2.0	2.0	1.0	1.0	1.0	2.0	4.0	2.0	-	-	-	-	-
Prioritised - Multicast - uplink - Distr-Edge	Multicast	-	-	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-
Prioritised - Multicast - uplink - POI2-POI1	Multicast	-	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - Core-Core	Multicast	-	-	-	1.0	-	-	-	-	-	1.0	-	-	-	-	-
Prioritised - Multicast - Core-Distr	Multicast	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-
Prioritised - Multicast - Distr-Edge	Multicast	-	-	1.0	-	-	-	1.0	1.0	-	-	-	-	-	-	-
Prioritised - Multicast - POI2-POI1	Multicast	-	1.0	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - POI1-DSLAM	Multicast	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - DSLAM-End user	Multicast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leased lines																
LL <= 2 Mbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-
LL <= 1 Gbps & > 2 Mbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-
LL > 1 Gbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-

Source: DBA

The routing table sets how much a given service uses a given network asset. Therefore the traffic at busy hour produced by a given service at a given node is its busy hour traffic times the routing factor of the selected service at the network level of the node.

Due to the decrease of the number of services in the core network cost model and to the change of the network topology as explained in section §7.1.2, the routing matrix has been modified. Nonetheless, most routing factors have not changed between the previous and the new model.

The main changes in the routing matrix are due to:

- The list of services has been reduced, therefore the number of entries in the routing matrix has decreased (as detailed in section §7.2.1.1);
- The number of routing factors per service (the 'columns') has also decreased a lot due to several reasons:
    - The routing matrix is used to dimension and then allocate the costs of traffic driven assets. Therefore no routing factors are needed for lines driven assets (all routing factors associated to 'Subs' except those for the servers).
    - The allocation of traffic driven assets is based solely on traffic, i.e. 'Gbps' and never on 'Mpps' (packets). Therefore no routing factors based on Mpps are kept.

- The routing factors regarding servers have been aggregated in order to simplify the routing matrix. The level of details provided in the new model is sufficient to properly allocate the costs.
- The routing factors associated to line cards for rings ("Layer 2 Aggregation : Line Card : L2 Ring – Gbps" and "Layer 3 Edge : Line Card : L3 Edge Ring – Gbps") have been removed as the aggregation switches and edge routers used in the model have a built-in port.
- The routing factors dedicated to leased line traffic ("Layer 2 Aggregation : Line Card : Customer" and "Layer 3 Distribution : Line Card : L3 Core Uplink – Gbps") are removed as the modelling of the leased line services has been completely revised.
- The routing factors dedicated to bitstream cards ("Layer 2 Aggregation : Line Card : L3 Uplink - Bitstream – Gbps" and "Layer 3 Edge : Line Card : Layer 2 Bitstream – Gbps") are removed as the bitstream cards are not in the scope of the modelling. Even if these cards were in the scope of the model, as bitstream cards are assets that are dedicated to a specific service, the routing factors are not needed.
- The routing factors used to differentiate the services that are based on fibre and copper are removed as the services model in the network do not differentiate between these.

Nonetheless, there are also several changes in the value of the routing factors due mainly to the change in the network topology:

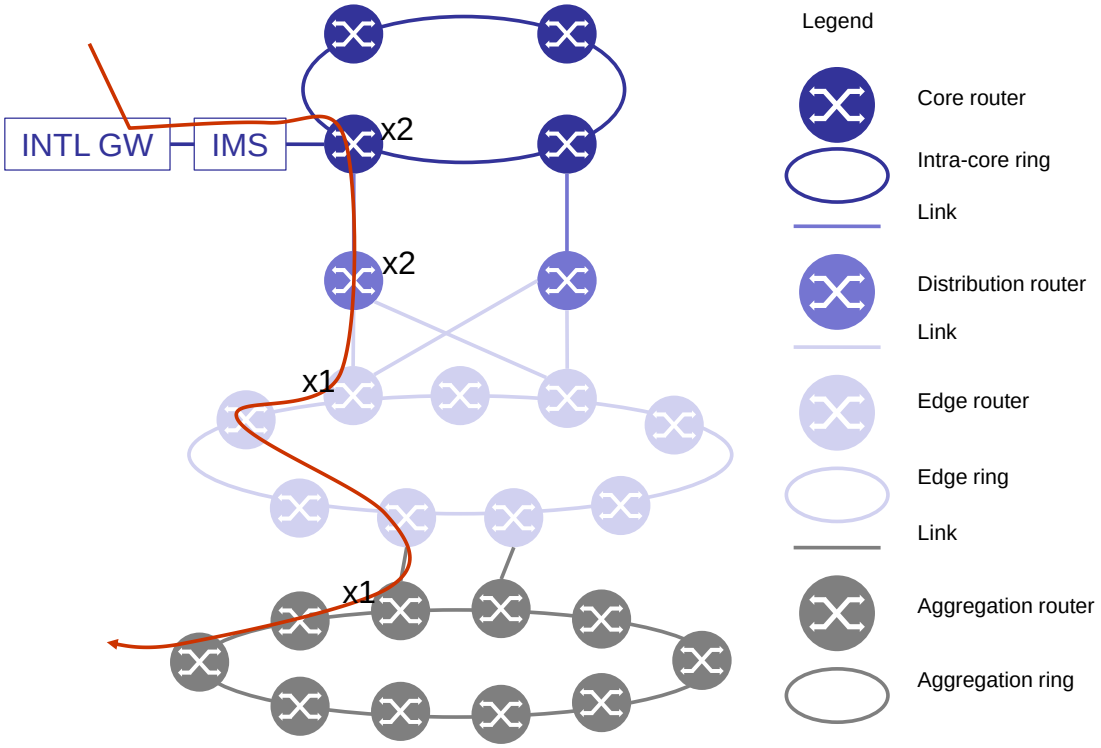
- The routing factors associated to the leased lines services have been completely updated as the modelling approach has been entirely revised.
- The routing factors of the voice services have been updated following the change in the network topology described in section §7.1.2.
- The routing factors of the service "Broadband - External VULA/BSA – POI2" have been updated. Given the technology being modelled, it is not efficient to define the point of interconnection at the edge layer when the traffic can be retrieved at the aggregation layer. The routing factors associated to using the aggregation to the edge link and to using the edge router have been set to 0.

7.3.2.2 Worked examples of the routing matrix

In order to illustrate the routing factors of the voice services, several examples have been selected showing the path through the network.

The following figure shows the route followed by the "Voice – International – Incoming" service:

Figure 72 – The route followed by the "Voice - International – Incoming" service



Source: DBA

The routing factors of this service are:

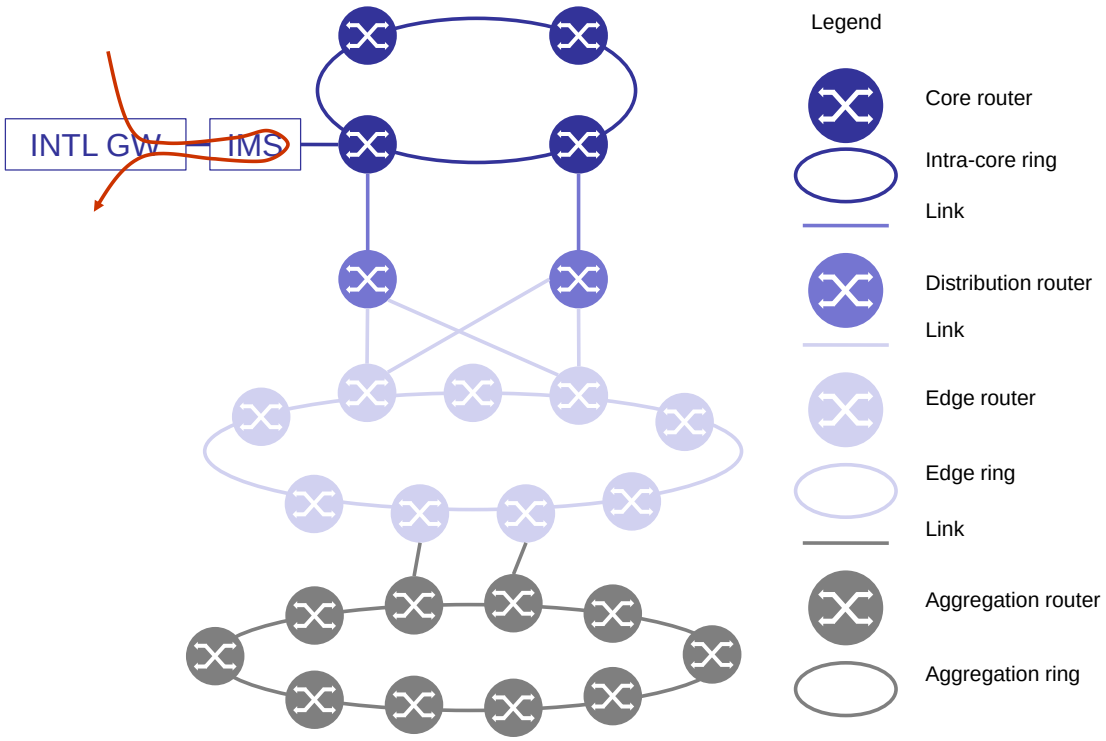
Figure 73 – routing factors of the "Voice - International – Incoming" service

Aggregation node equipment	Edge node equipment	Distribution node equipment	Core node equipment	Tx path: aggregation ring	Tx path: aggregation to Edge	Tx path: edge ring	Tx path: edge to Distribution	Tx path: distribution to Core	Tx path: intra Core	IMS platform	IN	PSTN GW	PLMN GW	International GW
1	1	2	2	1	1	1	1	2	-	1	-	-	-	1

Source: DBA

The following figure shows the route followed by the "Voice – International – Transit" service:

Figure 74 – The route followed by the "Voice - International – Transit" service



Source: DBA

The routing factors of this service are:

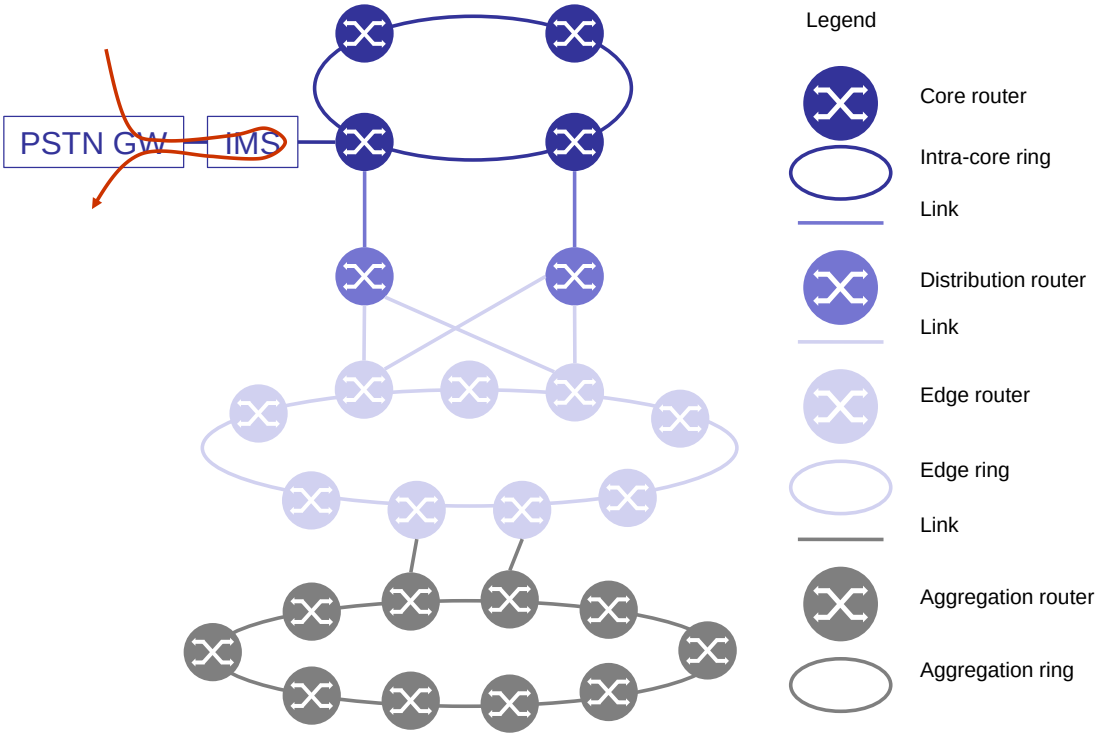
Figure 75 – routing factors of the "Voice - International – Transit" service

Aggregation node equipment	Edge node equipment	Distribution node equipment	Core node equipment	Tx path: aggregation ring	Tx path: aggregation to Edge	Tx path: edge ring	Tx path: edge to Distribution	Tx path: distribution to Core	Tx path: intra Core	IMS platform	IN	PSTN GW	PLMN GW	International GW
-	-	-	-	-	-	-	-	-	-	1	-	-	-	2

Source: DBA

The following figure shows the route followed by the "Voice - Transit - Local interconnection" service:

Figure 76 – The route followed by the "Voice - Transit - Local interconnection" service



Source: DBA

The routing factors of this service are:

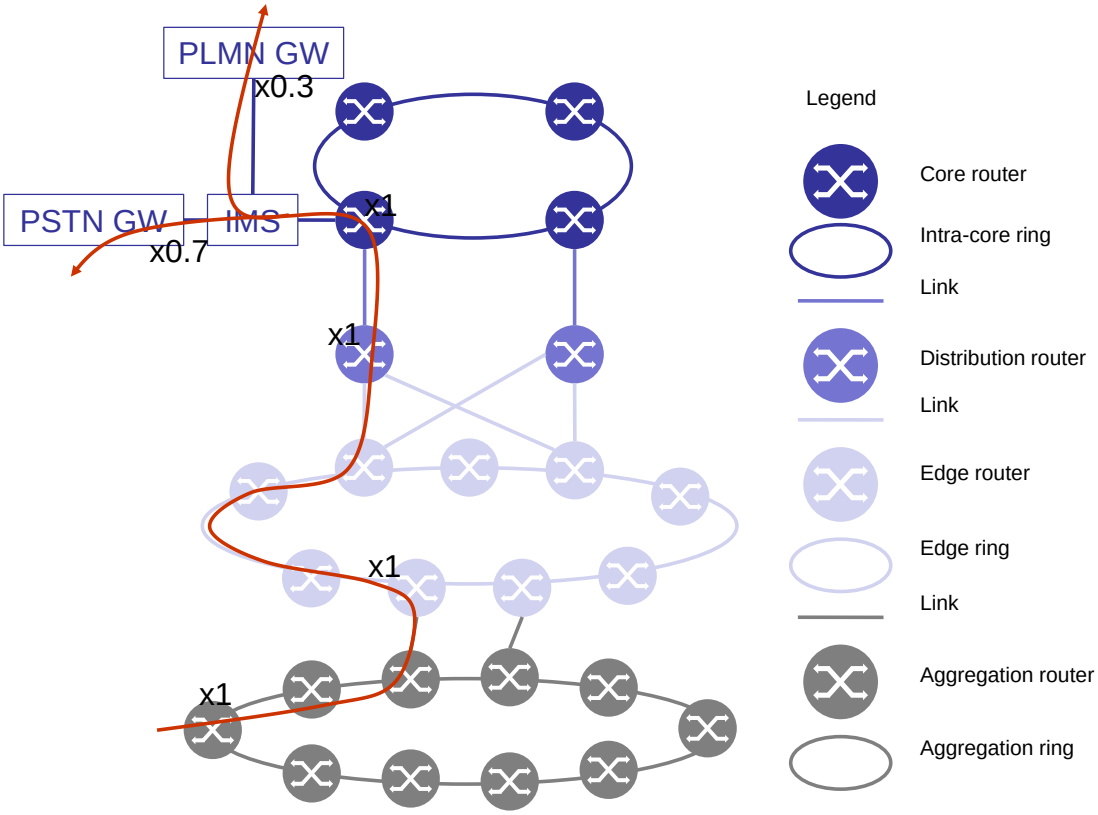
Figure 77 – routing factors of the "Voice - Transit - Local interconnection" service

Aggregation node equipment	Edge node equipment	Distribution node equipment	Core node equipment	Tx path: aggregation ring	Tx path: aggregation to Edge	Tx path: edge ring	Tx path: edge to Distribution	Tx path: distribution to Core	Tx path: intra Core	IMS platform	IN	PSTN GW	PLMN GW	International GW
1	2	4	1	1	1	1	2	4	-	1	-	1	-	-

Source: DBA

The following figure shows the route followed by the "Voice - Outgoing off-net" service:

Figure 78 – The route followed by the "Voice - Outgoing off-net" service



Source: DBA

The routing factors of this service are:

Figure 79 – routing factors of the "Voice - Outgoing off-net" service

Aggregation node equipment	Edge node equipment	Distribution node equipment	Core node equipment	Tx path: aggregation ring	Tx path: aggregation to Edge	Tx path: edge ring	Tx path: edge to Distribution	Tx path: distribution to Core	Tx path: intra Core	IMS platform	IN	PSTN GW	PLMN GW	International GW
1	1	1	1	1	1	1	1	1	-	1	-	0.7	0.3	-

Source: DBA

7.3.2.3 The aggregated services

In order to simplify the modelling of the traffic driven assets, 6 generic services have been created:

- Voice;

- Broadband;
- Bitstream;
- Unicast;
- Multicast;
- Leased lines.

These 6 generic services match exactly with the 6 categories of services described in section §7.2.1.1.

The traffic of these 6 generic services is the sum of the traffic of the services included in each category.

The routing factors of these 6 generic services are the weighted average of the routing factors of the services included in each category, the weights being the traffic.

Figure 80 – routing table of the aggregated services

Aggregated routing matrix	Aggregation	Edge	Distribution	Core	Aggregation ring	Aggregation to Edge	Edge ring	Edge to Distribution	Distribution to Core	Intra Core	IMS platform	Intelligent network	PSTN GW	PLMN GW	International GW
Voice	0.96	1.22	2.22	1.26	0.96	0.96	0.96	1.23	2.22	0.25	1.06	0.18	0.62	0.21	0.21
Broadband	1.00	2.00	2.00	1.50	1.00	2.00	1.00	2.00	2.00	0.50	-	-	-	-	-
Bitstream	0.99	1.00	0.01	0.01	0.99	1.99	0.01	0.01	0.01	0.01	-	-	-	-	-
Unicast	1.00	1.00	2.00	2.00	1.00	1.00	1.00	2.00	4.00	2.00	-	-	-	-	-
Multicast	0.32	0.23	0.08	0.00	0.15	0.23	0.04	0.08	0.04	0.00	-	-	-	-	-
Leased lines	1.00	1.00	1.00	1.00	0.50	1.00	0.50	1.00	1.00	1.00	-	-	-	-	-

Source: DBA

The use of these 6 generic services is therefore completely equivalent to the use of the full list of services defined in section §7.2.1.1.

7.3.3 Traffic driven assets

7.3.3.1 Aggregation switches

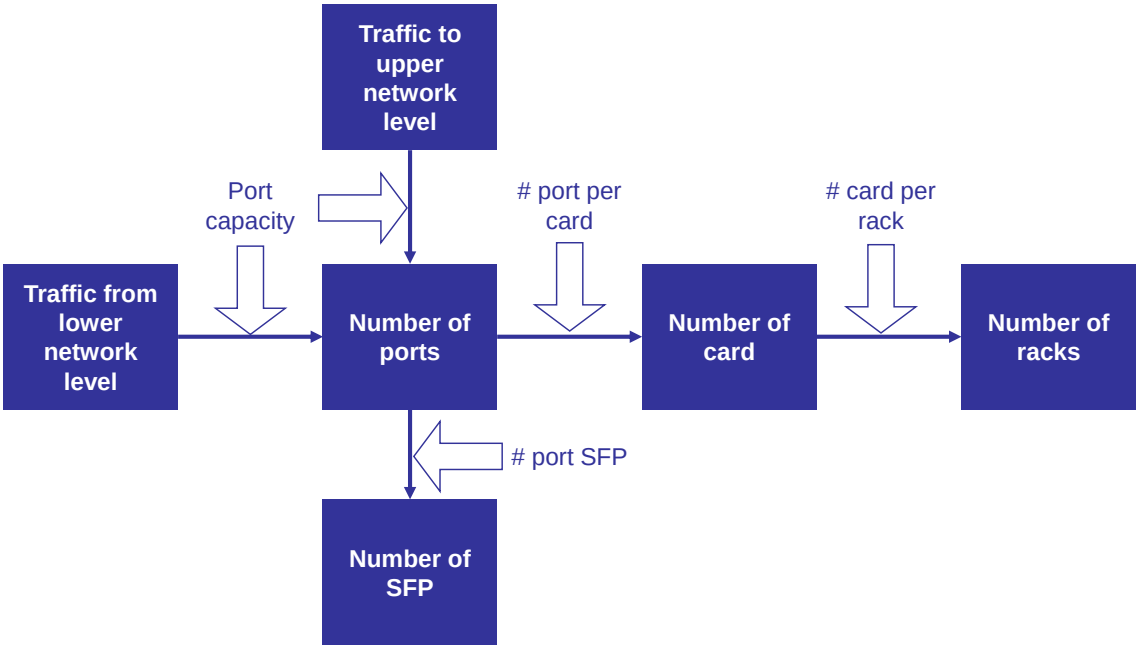
The aggregation switches are rolled-out in aggregation sites. Their configuration includes three types of assets:

- SFP;
- Card;
- Rack.

The dimensioning of the aggregation switches is very similar to the dimensioning of MSANs. The number and type of ports required is driven by:

- The traffic for the uplink and the link to create the aggregation rings;
- The number of MSANs that need to be connected to each aggregation switch;
- The number of leased lines part of the “LL <= 1 Gbps & > 2 Mbps” and the “LL > 1 Gbps” as they are directly connected to the aggregation switches unlike the “LL <= 2 Mbps” that are connected to the MSANs (see section §7.3.1.3);

Figure 81 – Switch dimensioning rules



Source: DBA

The aggregation switches are following the single point of failure norm which imposes to have a maximum number of 1536 customers per switch.

Several configurations are available as:

- Different port capacities exist. There are typically 1 Gbps or 10 Gbps ports;
- Different types of racks exist. Racks have different throughput capacity and some have built-in ports. These are assumed to be dedicated to the ring traffic.

The racks that have been selected in the model are bundles that include

- 4 10Gbps built-in ports;
- 2 10 Gbps SFP.

Given the SPOF norm, the number of aggregation switches that need to be rolled-out at a single aggregation site can be quite high. Stacking multiple switches is not an efficient network design and is not what would be rolled-out by an efficient operator. An efficient alternative is to roll-out routers with a bigger capacity, offering the same level of redundancy. This allows in particular decreasing the complexity of handling and interconnecting the routers. This alternative approach is achieved by rolling-out edge routers instead of aggregation switches at the aggregation sites in the following cases:

- The number of MSANs and leased line customers connected at one aggregation site is higher than 20;
- The number of 10Gbps leased line customers connected at one aggregation site is higher than 2.

The dimensioning of the edge routers is detailed in the following section.

7.3.3.2 Routers

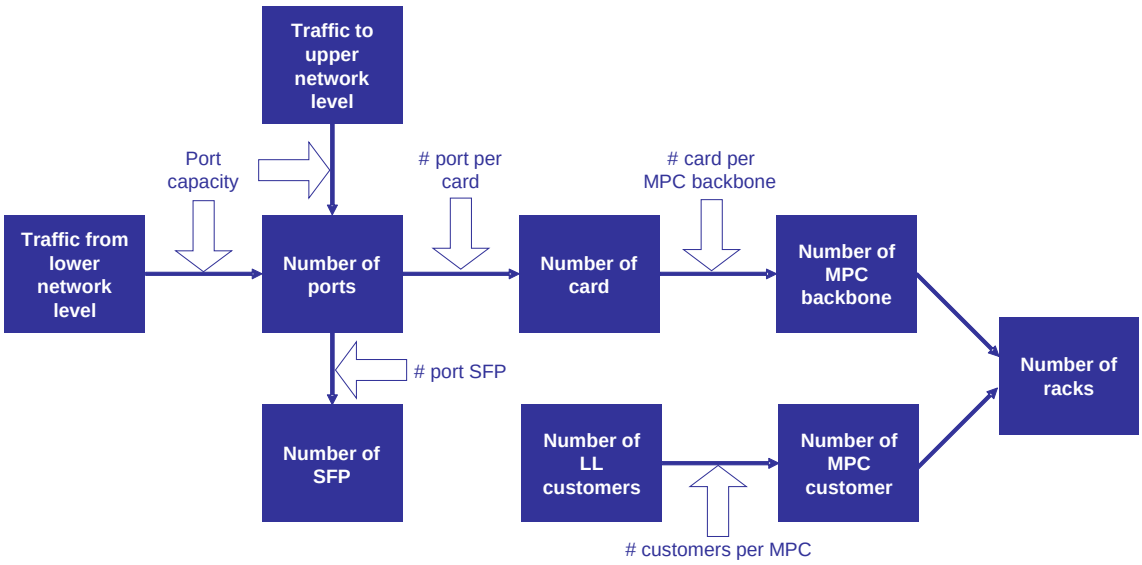
7.3.3.2.1 Edge routers

The edge routers include five types of assets:

- Rack;
- MPC customer;
- MPC backbone
- Card
- SFP;

The dimensioning of edge routers is very similar to the dimensioning of the aggregation switches. The main difference is that the number of ports required is based solely on traffic:

Figure 82 – Edge routers dimensioning rules



Source: DBA

The edge routers include also another type of asset, the MPC, (Modular Port Concentrator) which holds the cards. There are two types of MPC:

- MPC customer which is used to connect leased lines customers directly on the router;
- MPC backbone which is used to connect the cards used for backbone links (rings or layers interconnection).

Several configurations are available as different port capacities exist. There are typically 1 Gbps or 10 Gbps ports. The model includes therefore 1 Gbps and 10 Gbps SFPs and cards.

The racks that have been selected in the model are bundles that include:

- 2 MPC backbone;
- 2 10 Gbps cards;
- 2 10 Gbps SFPs.

The SPOF norm impacts the dimensioning of the edge routers as a maximum of 4 aggregation rings can be connected at a single MPC backbone.

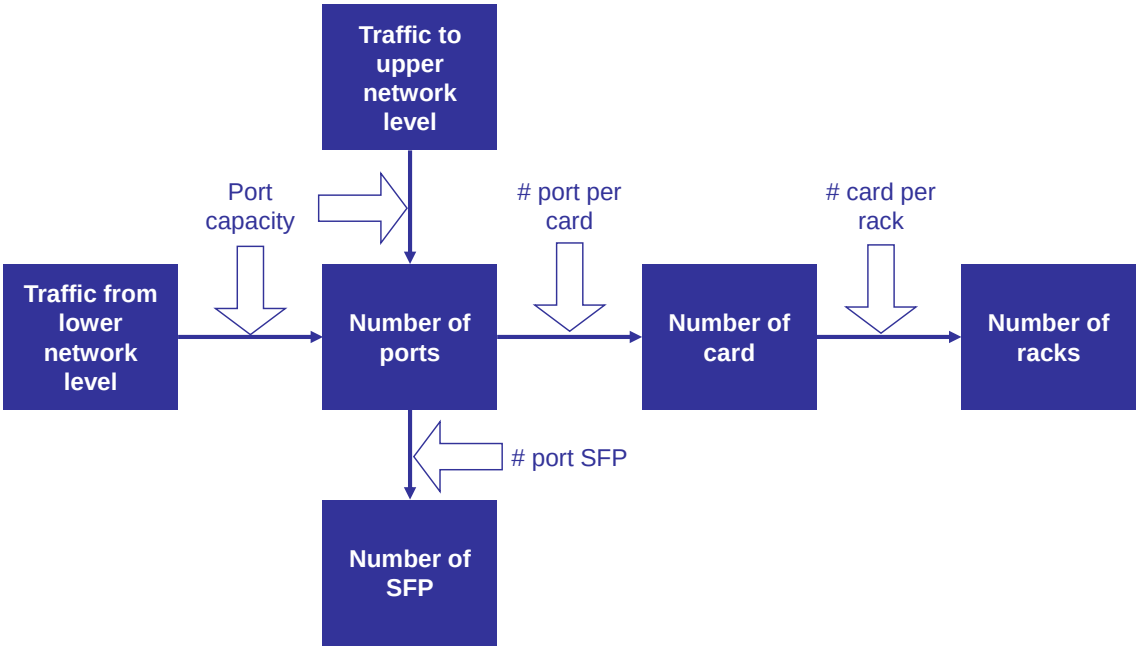
7.3.3.2.1 Distribution and core routers

The distribution and core routers include three types of assets:

- SFP;
- Card;
- Rack.

The dimensioning of the distribution and core routers is very similar to the dimensioning of the edge routers. The only difference is that there is no MPC.

Figure 83 – Switch and routers dimensioning rules



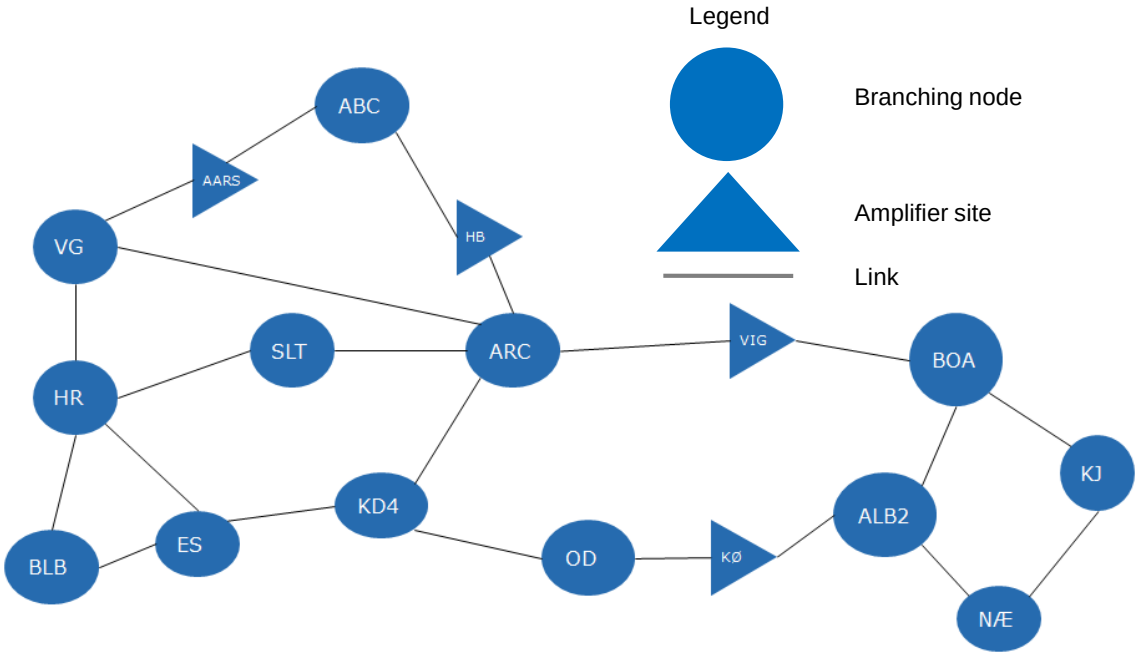
Source: DBA

Several configurations are available as different port capacities exist. There are typically 1 Gbps or 10 Gbps ports.

7.3.3.3 DWDM

The DWDM network topology has been provided by TDC, therefore dimensioning the DWDM only requires dimensioning the assets on each node where a DWDM platform has been deployed.

Figure 84 – DWDM network topology



Source: TDC

The DWDM is made of the following assets:

- A branching node;
- Client (traffic) cards;
- Line modules
- Multiplexers/de-multiplexers “mux/demux”.

The branching node is selected depending on the number of directions required, i.e. how many nodes are directly connected to the branching node. A branching node can have up to 5 directions. A branching node also has a maximum capacity in terms of line modules.

Each direction needs its own set of client cards, line modules and mux/demux. The number of each asset is directly derived from the traffic that needs to be carried out from the actual branching node to the other end of the link.

For very long distance (above 100 km), an amplifier is needed. This amplifier is installed on an existing network node.

7.3.4 Servers

The core network includes several platforms:

- The IMS;
- The intelligent network;
- The PSTN gateway;

- The PLMN gateway;
- The international gateway;
- And several servers dedicated to cable-TV.

7.3.4.1 IMS

As described in section §7.1.2, the core network modelled includes 4 IMS platforms located at each core site.

Each IMS platform consists of the following assets:

- An IMS core platform per site;
- IMS core licences for residential and business customers (1 per customer, price depends on the type of customer);
- An IMS services platform per site;
- IMS services licences for residential and business customers(1 per customer, price depends on the type of customer);
- An OSS/BSS platform per site;
- OSS/BSS licences (1 per site);
- SBC depending on its capacity ;
- A monitoring setup per site

There are two different types of SBC, one with a capacity of 75k customers and another with a capacity of 200k customers.

For redundancies purpose, all IMS sites are duplicated.

7.3.4.2 Intelligent network

The intelligent network consists of three different platforms. Each intelligent network site requires one of each platform.

All intelligent network sites are duplicated for redundancies purposes.

7.3.4.3 PSTN gateway

The PSTN gateway consists of:

- A platform for up to 148k busy hour call attempts;
- A licence based on the busy hour traffic.

Each PSTN gateway site is duplicated for redundancies purposes.

7.3.4.4 PLMN gateway

The PLMN gateway consists of:

- A platform per site;
- A licence based on the busy hour traffic.

Each PLMN gateway site is duplicated for redundancies purposes.

7.3.4.5 International gateway

The international gateway consists of one platform per site. These gateways are not duplicated.

7.3.5 CATV assets

The CATV network requires some dedicated assets located either in the MPEG stations or in the head-ends. There are several types of CATV assets:

- TV dedicated assets: these assets are used only by unicast and multicast services. These are therefore only allocated to these services;
- Broadband dedicated assets: these assets are used only by internal and external broadband services. These are therefore only allocated to these services;
- VOD dedicated assets: these assets are used only by the unicast services.

7.3.5.1 MPEG stations

The MPEG stations, in accordance with the previous model, are located at the same geographical location as the Central Office.

The MPEG stations include 12 different assets:

- L3 routers;
- L3 router line card;
- Service Control Engine
- CMTS rack;
- CMTS line card;
- Timing Server;
- Edge QAM;
- Edge QAM line card;
- EDFA;
- Appear TV setup;

There is one EDFA per fiberpair in each MPEG station.

The Edge QAM line card is based on the number of active subscribers. There is one card per 500 subscribers. The Edge QAM can hold up to 9 line cards.

The CMTS line card can hold up to 5000 subscribers or 3*1G of downstream traffic. The CMTS can hold up to 8 line cards.

There are a maximum of 2 CMTS per service control engine.

The L3 router line card has 8 10G port and the L3 router can hold up to 8 line cards.

7.3.5.2 Decentralized system

The VOD setup is an IP based setup. It uses a network of 16 CDN servers that are located either at some MPEG stations or at some core nodes.

7.3.5.3 Head-ends

The head-ends are made of 2 sites, one being a small redundant set-up in case the main one faces a breakdown in order to ensure service continuity.

The head-end configuration is made of the following assets:

- DHCP server;
- DNS server;
- Satellite dishes;
- Satellite reception equipment;
- Fibre termination equipment;
- SDI router;
- ASR;
- HE network;
- Management systems;
- Rack and cabling;
- DCM;
- Encoders and transcoders;
- CAS;
- UZI;
- Harmonic platform (transcoders and storage)
- SI insertion;
- EPG generator;
- Plus services.

There is one of each asset in the main head-end site.

The redundant head-end site is made of the following assets:

- Satellite dishes;
- Satellite reception equipment;
- Fibre termination equipment;
- SDI router;
- ASR;
- HE network;
- Encoders and transcoders;
- Management systems;
- Rack and cabling;
- DCM.

7.4 Vectoring

The model enables vectoring on some active street cabinet. In order to do so, the model includes the following assets:

- A vectoring line card with a 48 port capacity;
- Two vectoring processor cards with a capacity of respectively 192 and 384 ports.

Each site that is vectorised requires enough vectoring line cards to handle the capacity required and the vectoring processor card with enough capacity.

The computation of the exact cost of vectoring would require having the exact list of active street cabinets that enable vectoring meaning a huge amount of data would be required to be collected each year.

In order to simplify the yearly update, the approach followed is to compute the average cost of enabling vectoring on an average active street cabinet:

- The average number of “xDSL line card” per active street cabinet is computed. This enables to compute the average port capacity of the active street cabinets;
- Due to technical requirements, only one vectoring processor card can be installed on each active street cabinet. The vectoring processor card that is selected is the one with enough capacity to match with the average number of ports per active street cabinet;
- As the capacity of the vectoring line cards is the same as the capacity of the xDSL line cards, the number of vectoring line cards is the average number of xDSL line car per active street cabinet;
- The cost of enabling vectoring is therefore the yearly cost of the vectoring cards plus the yearly cost of the vectoring processor card.
- The total cost of vectoring is finally the cost of vectoring an average site multiplied by the number of sites enabling vectoring (as completed in the yearly update).
- As the xDSL line cards are no more required and according to the bottom-up approach, the cost of the xDSL line cards is removed from the total cost of the network.

This total cost is then added to the total cost borne by the active street cabinets. The cost of vectoring will therefore be allocated to all active lines.

7.5 Civil engineering

7.5.1 Trenches, ducts and cables

The passive part of the core network is modelled in the access network because the core network and the access network share the same infrastructure.

The cost of the trenches, the ducts and cables is therefore not computed in the core model. However it has to be allocated to the different network levels, i.e. between the following different transmission links:

- Aggregation rings;
- Edge rings;
- Distribution to Core
- Intra-Core.

The links between aggregation and edge sites and the links between edge sites and distribution sites are always collocated therefore no trench is required.

The cost of the civil engineering has been split according to the trench length needed for each transmission rings. This length has been estimated in the previous model and the same estimation has been used in the new model.

Figure 85 – Allocation of civil engineering costs

Transmission link	Share allocated
Aggregation rings	81%
Aggregation to Edge	0%
Edge rings	12%
Edge to Distribution	0%
Distribution to Core	7%
Intra-Core	1%

Source: DBA

7.5.2 Submarine links

The core network requires to build links between different COs separated by the sea. Submarine links are therefore required.

The cost of building such a link is made of two elements:

- Rolling-out the submarine cable;
- Building landing sites on both extremities of each submarine link.

The submarine links needed have been identified by TDC. However the total length of the submarine links is the result of the access modelling.

The cost allocation of each link is based on the length of each submarine link and on the identification of each transmission link category, i.e. each submarine link belongs to one of the following category:

- Aggregation rings;
- Aggregation to Edge
- Edge rings;
- Edge to Distribution
- Distribution to Core
- Intra-Core.

Figure 86 – Allocation of the submarine links

Transmission link	Share allocated
Aggregation rings	61%
Aggregation to Edge	37%
Edge rings	2%
Edge to Distribution	0%
Distribution to Core	0%
Intra-Core	0%

Having allocated the cost of the different transmission links, and having dimensioned all network elements thanks to the engineering rules described in previous sections, it is then possible to compute the total network cost as described in section §9.

8 Co-location modelling (incl. other services)

The aim of this section is to derive the bottom-up costs of all the co-location and other services. The costs of these services are mainly based on the regulatory accounts.

8.1 Definition

The Executive Order number 930 (Section 1 (1)) defines co-location as the "sharing of facilities such as buildings, exchange equipment, etc." and includes co-location as an interconnection product linked to the three other interconnection products:

- Exchange of traffic;
- Lease of infrastructure capacity;
- Service provider access.

8.2 Cost inputs

Co-location costs are made of human work and capex. This section summarizes the inputs used to calculate the costs related to both categories.

8.2.1 Wages

The yearly wages are split by worker category:

Figure 87 – Yearly wages

General costs		Value	Unit
Wage			
	Technician	514,180	DKK per year
	Administrative	386,266	DKK per year
	Academic	635,924	DKK per year

Source: Previous version of the BU model

Default inputs are derived from the previous version of the co-location model[19].

The hourly wages are deduced from the yearly wages based on the number of effective working days per annum and to the number of working hours per day:

[19] Co-location Fv4.2.2.xls

Figure 88 – Working days and working hours

Working days	Total working days	day	**201**
	Days in year	day	365
	Potential working day	day	252
	Days of week-end	day	104
	Bank holidays (excl.	day	9
	Absence (sickness,	day	8
	Holidays	day	30
	Administration	day	10
	Courses	day	3
Average number of hours per working day			
	Technician	hour	7,4
	Administrative	hour	7,4
	Academic	hour	7,9

Source: Previous version of the BU model

The wages are uplifted by the inflation each year.

8.2.2 Capex

The unit capex of the assets required to provide co-location services has been set by DBA based on the following sources:

- Previous BU LRAIC model;
- Regulatory accounts;
- TDC inputs.

8.3 Times spent and asset count

For each co-location service, the time required for each activity (in minute) is detailed in the "Resources" sheet (Figure 89). These times are detailed by worker category (Technician, Administrative, and Academic).

Figure 89 – Times spent for the different services (minutes) - extract

Resources per service	Unit	Administrative	Administrative
		Processing of order	Customer service
LLU			
New Installation- Unassisted	man-min	6	-
New Installation- Ingineer assisted	man-min	6	-
Inquiry	man-min	-	-
New setup	man-min	-	-
Physical rearrangement	man-min	-	-
Change to trunk number	man-min	10	-

Source: Previous version of the BU model

For example, "LLU new installation – Unassisted" requires the following tasks:

- Processing of order: 6 minutes (Academic);
- Installation: 23 minutes (Technician);
- Transport: 30 minutes (Technician).

For each co-location service, the number of different assets required is detailed in the "Resources" sheet (Figure 90).

Figure 90 – Asset count for each co-location service

Resources per service	Unit	Unproductive interconnection in distributor	Unproductive interconnection in socket
LLU backhaul			
Interconnection of fibre pairs in optic distributor between poin	man-min	-	-
Interconnection of fibre paris in socket (splicing) between poir	man-min	-	-
Cancellation fee pr. fibre pair or tube	man-min	1	1
Debugging per hour	man-min	-	-
Measurement report for fibre pairs	man-min	-	-

Source: Previous version of the BU model

For example, co-location, specifically for closets service called "1x100 pair cables and fibre trunk incl. digging and termination of 1x100 copper pairs and 4 fibres" requires:

- 1 "Copper trunk, 1x100 pair 10m. , materials"
- 1 "Fibre trunk, cable+tube 10m. + connector"
- 1 Fibre trunk, termination of 4 fibres in the end (TDC)
- 4 Fibre splicing
- Cost of digging per meter

The time spent and the asset counts are then multiplied by corresponding unit costs in order to derive the yearly unit cost of each service.

8.4 Services demand and total co-location cost

The yearly demand for all co-location services (Figure 91) has to be filled in as part of the yearly update (see “Historical Inputs” sheet).

Figure 91 – Co-location services demand, extract

Shared raw copper - full loop	Unit	2013
Additions		
New Installation- Unassisted	#	13,414
New Installation- Ingineer assisted	#	1
Inquiry	#	1
New setup	#	1
Physical rearrangement	#	1
Change of trunk number	#	264
Visit by technician	#	1,714
Cancellation-fee II	#	860
Calculation of attenuation on the line	#	4
Unproductive fault handling	#	1
Shared raw copper -full loop: migration to shared full loop from BSA with telephor	#	12,754

Source: Core BU model, sheet “Historical Inputs”

By multiplying it by the unit cost of each service, the total cost of co-location services is calculated (Figure 92):

Figure 92 – Co-location Total yearly cost, extract

Resources per service	Additions	Stock	Unit	TOTAL YEARLY COST /EARLY COST PER UNI
LLU				
New Installation- Unassisted	79,736	263,614	DKK	21,258,955	267
New Installation- Ingineer assisted	1	1	DKK	472	472
Inquiry	1	-	DKK	262	262
New setup	12,342	-	DKK	2,050,311	166
Physical rearrangement	766	-	DKK	194,226	254
Change to trunk number	2,044	-	DKK	351,279	172
Visit by technician	12,886	-	DKK	6,760,052	525
Cancellation-fee II	9,402	-	DKK	1,053,986	112
Calculation of attenuation on the line	16	-	DKK	2,378	149
Unproductive fault handling	1	-	DKK	204	204
Raw copper -full loop: migration to full loop from BSA	1	-	DKK	144	144
Raw copper -full loop: migration to full loop from Shared Raw C	1	-	DKK	35	35

Source: Core BU model, sheet “Colocation services costing”

8.5 Mark-ups for non-network costs

The models compute the network costs of the different services. However, relevant non-network costs have to be taken into account. In order to do so, mark-ups are computed to uplift the costs of the different services.

The non-network costs include the following cost categories:

- NMS (network management system) costs;
- Overhead costs;
- IC specific and commercial costs;
- Compensation received due to third party damage.

The network management system costs include all the cost related to IT platforms or IT systems needed to design, plan, operate and maintain the network. There are around 100 IT platforms, each having a specific functionality such as:

- System administrating a fault;
- System allowing wholesale customers to report a fault;
- System used for the access network inventory;
- System to manage the workforce;
- Reporting system.

The overhead costs include all the cost (staff and material) related to the non-network teams. Typical costs that are included are the pay costs of the CEO, the CFO, the COO, the CTO, the finance team, the regulatory team, the legal team, the HR team etc. It would also include the headquarters of the company.

The IC specific and commercial costs include all the costs related to selling wholesale products. This includes the cost of the wholesale billing platforms but also the pay cost of the wholesale team.

The compensation received due to third party damage is an income perceived by TDC following a damage done by a third on TDC network. A typical damage would be a cable cut.

These non-network costs include:

- Some Opex;
- Some Capex that are depreciated in order to obtain a yearly cost;
- The cost of working capital.

These non-network costs have been derived from TDC's regulatory accounts. Each of these costs is then split on an asset basis. This split is done using TDC's regulatory account allocation keys. Each asset of TDC's regulatory account has been assessed in order to determine whether it is relevant to the LRAIC cost models. This assessment allows including in the LRAIC cost models only the relevant costs. This assessment has been carried out according to the following approach:

- Assets have first been assessed whether they are relevant to the LRAIC models or not;
- For assets relevant to the LRAIC models, they have then been assessed whether they are relevant to the access network or the core network;
- For assets relevant to the core network; they have finally been assessed whether they are relevant to the IP core network or to other platforms.

- Costs that have been kept are the costs relevant to the LRAIC models and relevant to the access network or to the IP core network.

For some IT platforms part of the NMS costs, it was not possible to obtain the costs split by asset. Therefore the allocation keys have been directly derived by TDC.

The LRAIC cost models include therefore only the relevant share of the non-network costs.

9 Depreciation, cost allocation and costing results

This section describes the costing calculations used within the LRAIC access network and the LRAIC core network cost models.

The costing calculations determine the investments required to build the different networks. Investments are then annualised using a tilted annuity calculation, the results of which are used to determine the capital cost recovery profile for each of the services modelled.

9.1 Unit input costs

The costs considered as investments are those corresponding to the purchase of durable assets expected to be in use for several years. Operating costs are recurring costs.

This section summarizes the general principles used to set the unit costs. Detailed unit costs inputs are listed in the appendix (see §12.3 for the access network and §12.4 for the core network)

9.1.1 Investment

The capital unit cost for a network element corresponds to the cost incurred to:

- Plan of the roll-out of the network asset;
- Purchase one unit of equipment;
- Install this unit of equipment.

Unit cost inputs in the model are mainly based on the latest available information from TDC (i.e. 2013 data if available) that are more likely to be reflective of the bargaining power of an operator rolling out a nationwide network in Denmark.

As a consequence, these unit costs do not correspond to manufacturers' price lists but to TDC's bills (i.e. including discounts).

These costs have been extensively audited and compared to:

- The previous LRAIC model;
- Benchmark data;
- Data supplied by the alternative operators.

In case of discrepancies between figures provided by TDC and the cross-checks figures listed above, DBA has conducted further investigations in interaction with the operators in order to set the unit prices to be used as model inputs. For example, there

have been extensive talks with Telia and TDC on the core network structure of an efficient operator.

9.1.2 Price trends

To asses price trends used in the depreciation formula, the inputs provided by TDC, from benchmark information or from DBA's former LRAIC model have been used.

9.1.3 Operating expenditures

The operating expenditures for a network element correspond to the cost incurred for:

- The equipment maintenance (computed based on a mark-up or fixed amount);
- The supplier annual support (computed based on a mark-up);
- The rental cost of the space required;
- The power consumption;
- The cooling;
- The power production maintenance;
- The cooling production maintenance.

Corresponding percentage or amounts depend on the type of assets.

In the absence of any more up-to-date data, default inputs are derived from the values from DBA's previous LRAIC model.

Due to productivity gain, the operating expenditures using man-work (equipment maintenance, power production maintenance and cooling production maintenance) is corrected by a productivity factor each year.

9.2 Asset lives

The access and core network cost models use the following values for network asset economic lifetimes (see **Figure 93**):

Figure 93 – Economic asset lives

Ntw.	Asset category	Asset life
Access	Trench routes, ducts, manholes in the copper scenario	30
Access	Copper, Fibre and Coax cables and joints in the copper scenario	30
Access	Trench routes, ducts, manholes in other scenarios	35
Access	Copper, Fibre and Coax cables and joints in other scenarios	35
Access	Distribution frames, distribution points, splitters, and wireless assets,	20
Access	Network termination points, amplifiers	10
Access	Cable modems, MPEG station equipment (CMTS, servers etc.)	8
Core	MDF/ODF	15
Core	Active equipment	8
Core	International Media Gateway	10
Core	Sites – Power supply, A/C	15
Core	Sites – Security, site preparation	10

Source: DBA

9.3 Weighted average cost of capital (WACC)

The model enables the use of different cost of capital (WACC) assumptions for:

- The copper access network;
- The fibre access network;
- The cable-TV access network;
- The IP core network.

The default values used for the WACC are set to 5.8 % (Figure 94):

Figure 94 – Cost of capital inputs

Network	WACC
Copper access network	5.80%
Fibre access network	5.80%
cable-TV access network	5.80%
IP core network	5.80%

Source: DBA, LRAIC pricing decision, November 2013

As described in the MRP, the model includes the possibility to consider a risk premium (to be added to fibre network WACC) to take into account the specific risks incurred by FTTH operators.

9.4 Annuity calculations

The tilted annuities depreciation approach is implemented in the LRAIC model. The following formula is used:

Figure 95 – Tilted annuities formula

$$A_t = \frac{I}{(1+\omega)^{1/2-T}} \times \frac{(\omega - p)(1+p)^t}{1-(\frac{1+p}{1+\omega})^n}$$

Source: DBA

In this formula:

- I, is the investment which is obtained by multiplying the number of assets by the unit price of asset;
- ω is the cost of capital (see §9.3);
- n is the asset life (see §9.2);
- p is the price trend (see §9.1.2);
- T is the "time to build" (i.e. the time between asset is built and the first annuity).

The 'time to build' should also be considered as it generates working capital. The 'time to build' is the period between the payment of an asset and its first time use. The formula above already includes a 'time to build' of 6 months.

9.5 Cost allocation

9.5.1 LRAIC Access network cost model

In the access network cost model, as there is a unique service (the local loop), the only cost allocation issue relates to the allocation of trench costs between the core, the access and the BTO network.

The part of trenches on private property is not shared; therefore no allocation is required for this length.

The allocation of trenches alongside the road among the different levels of the network is performed on a length basis, e.g. if the core network uses 100m of trenches and the aggregation level uses 50m of trenches, the length of trenches will be allocated 100/(100+50) = 2/3 for the core and 50/(100+50) for the aggregation level.

9.5.2 LRAIC Core network cost model

As determined in the MRP, DBA has implemented both the required capacity and the Shapley-Shubik allocation methods for joint and common network costs in the LRAIC core network cost model.

The required capacity approach allocates common and joint costs based on the capacity used by each service at the busy hour (i.e. a 60-minute period during which the maximum total traffic load occurs), this method is detailed on sheet “Capacity based”. This means that:

- Routers costs are shared based on the capacity used at peak hour by the different services (expressed in Mbit/s);
- MSAN (frame, rack…) costs are shared based on the capacity used at peak hour by the different services (expressed in Mbit/s);
- MSAN access cards are allocated to the services they provide;
- Asset specific to some services (BRAS for Internet, etc.) are directly allocated to the corresponding services.

The Shapley-Shubik approach consists of setting the cost of a service equal to the average of the incremental costs of the service after reviewing every possible order of arrival of the increment.

The Shapley-Shubik rule requires running the LRAIC model several times. The complexity of the calculation rises exponentially with the number of services considered. In general, in order to simplify the approach, broad increments are used. The Shapley-Shubik has been modelled based on the following service aggregates:

- Voice;
- Broadband (internal and external);
- Prioritised traffic (unicast and broadcast);
- Leased lines.

The outcome of the Shapley-Shubik allocation depends on the number of increment chosen. The choice of these 4 aggregations of services has been carried out in order to have a good balance between:

- Model complexity;
- Consistency.

The 4 aggregates are indeed the 4 products that exist from a customer point of view.

To implement this method, the core network cost model needs to be launched 15 times (see Figure 96):

Figure 96 – Shapley-Shubik scenarios

Scenario	# services	Voice	Broadband	Prioritised	Leased lines
1	1 service	X			
2			X		
3				X	
4					X
5	2 services	X	X		
6		X		X	
7		X			X
8			X	X	
9			X		X
10				X	X
11	3 services	X	X	X	
12		X	X		X
13		X		X	X
14			X	X	X
15	4 services	X	X	X	X

Source: DBA

This enables the determination of the allocation key to apply to each service. The "Shapley-Shubik" spreadsheet is dedicated to the calculation.

9.6 Common costs

In addition to network costs, an operator faces non-network common costs. These costs are potentially material and should be recovered. In line with the methodology traditionally used by NRAs to allocate these costs, the EPMU approach has been implemented.

The LRAIC cost models includes three types of common costs:

- The overhead costs;
- C specific and commercial costs;
- The network management systems (the NMS).

The overhead costs include all the cost (staff and material) related to the non-network teams. Typical costs that are included are the pay costs of the CEO, the CFO, the

COO, the CTO, the finance team, the regulatory team, the legal team, the HR team etc. It would also include the headquarters of the company.

The IC specific and commercial costs include all the costs related to selling wholesale products. This includes the cost of the wholesale billing platforms but also the pay costs of the wholesale team.

The network management systems include all the cost related to IT platforms or IT systems needed to design, plan, operate and maintain the network. There are around 100 IT platforms, each having a specific functionality such as:

- System administrating a fault;
- System allowing wholesale customers to report a fault;
- System used for the access network inventory;
- System to manage the workforce;
- Reporting system.

These costs have been assessed and then allocated using TDC's regulatory accounts.

Mark-ups inputs are located in the spreadhsheet "Non-network costs" and the calculation is performed in the "Non network mark-up" spreadsheet.

9.7 Outputs

9.7.1 Access network cost model

The cost per access line is assessed dividing the yearly network cost by the number of active lines.

The cost of the MDF/ODF and a mark-up for common costs is applied in the LRAIC Core model to determine the total cost of the different access products.

9.7.2 Core network cost model

The determined total annualised cost by asset is mapped to total annualised cost by service using the routing factor table. Mark-ups are then applied.

Unit costs are then determined at the bottom of the "capacity based" and "Shapley-Shubik" worksheets.

10 Model implementation and usage

10.1 LRAIC core network cost model

10.1.1 Structure of the model

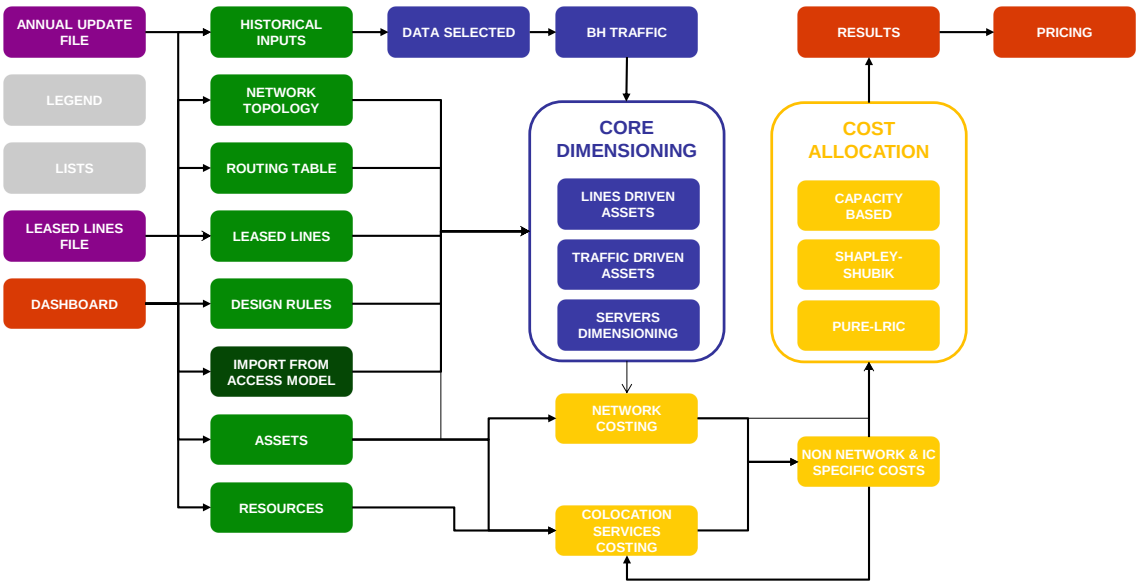
The LRAIC core network cost model is made of three files:

- The annual update file;
- The leased lines file;
- The model.

The annual update file and the leased lines file are two inputs files for the model.

The architecture of the model is presented in the following diagram

Figure 97 – Model architecture



Source: DBA

In order to facilitate the model review, colours are used to mark out the different steps of the modelling:

Figure 98 – Color code

Color	Code
Purple	Input files
Green	Input sheets
Blue	Dimensioning
Yellow	Costing and allocation
Red	Dashboard and results
Grey	Miscellaneous

Source: DBA

As shown in the flow diagram:

- The annual update file fills the “historical inputs” sheet;
- The leased lines file fills the “leased lines” sheet.

A specific input sheet (in dark green) is used to build an interface between the LRAIC core network cost model and the LRAIC access network cost model, as the LRAIC core network cost model uses inputs from the LRAIC access network cost model. This interconnection is described in details in section §10.3.

In addition to the different sheets and calculations, the model uses two macros, one for the pure LRIC calculation and one for the Shapley-Shubik calculation.

The pure LRIC macro is selecting the traffic without the termination traffic increment, then is computing the network cost and finally is saving the results in a dedicated table located in the “Pure LRIC” sheet.

The Shapley-Shubik macro does the exact same thing except that there are much more scenarios as there are 4 different increments which leads to 24 different scenarios of which only 15 are different.

10.1.2 Description of the different sheets of the LRAIC core model

The LRAIC core network cost model is made of 25 spreadsheets described in the following table:

Figure 99 – Description of the spreadsheets of the LRAIC core network cost model

Name	Description
Welcome	Description of the model
Dashboard	Spreadsheet that contains some parameters among which the modelling year
Pricing	Spreadsheet with all the pricing results
Results	Spreadsheet with the results of the core network cost model
Import from the access model	Spreadsheet with the outputs to the access model that are needed in the core model
Historical inputs	Inputs from the yearly update file. It contains all the historical inputs regarding customers and traffic
Network topology	Inputs regarding the topology of the core network and of the DWDM network
Design rules	Technical parameters used to dimension the network
Routing tables	Routing factors for each service and each asset
Leased lines	Inputs from the leased lines files providing the number of ports and the traffic at each Central Office and at each network level (aggregation, edge, distribution, core and intra-core)
Assets	Description of all the assets dimensioned in the model (including core assets but also assets used by the co-location services). The description includes dimensioning rules, allocation drivers, unit costs (CAPEX and OPEX), price trends and asset lives
Resources	Resources required for providing the co-location services
Data selected	Buffer between the network dimensioning and the historical inputs allowing the selection of the inputs corresponding to the year modelled selected by the user in the dashboard
Lines driven asset	Dimensioning of all the assets driven directly or indirectly by the number of lines
BH traffic	Computation of the busy hour traffic, the busy hour call attempts and the aggregated routing matrix
Traffic driven assets	Dimensioning of all assets driven by the traffic
Servers dimensioning	Dimensioning of all the core network servers
Colocation services	Costing of all the co-location services

Name	Description
Network costing	Computation of the network cost
Non-network & IC specific costs	Computation of the costs due to non-network assets such as the network management system and the overhead costs and conversion of these costs into mark-up following the EPMU approach
Capacity based	Allocation of the network cost to all core services based on the capacity based approach
Shapely-Shubik	Allocation of the network cost to all core services based on the Shapley-Shubik approach
Pure LRIC	Allocation of the network cost to the voice termination based on the pure LRIC approach
Legend	Description of the colour codes used in the model
Lists	Miscellaneous: Different lists are registered in this spreadsheet in order to facilitate the model development.

Source: DBA

10.1.3 How to use the LRAIC core network cost model?

The core network cost model contains a dashboard containing several options that can be modified according to the users. The two main parameters are:

- The modelling year which is the year that will be modelled (traffic and unit costs of this year will be considered);
- The scenario as described in section §7.3.1.1

The results of the model are located either in the sheet “Results” or in the sheet “Pricing”.

Two macros are used in the model, one for the computation of the pure LRIC, and one for the computation of the Shapley-Shubik. In order to obtain the up-to-date results for the pure LRIC and for the Shapley-Shubik, it is important to run these two macros. This can be carried out in the “results” sheet by clicking on the buttons that have been added.

10.1.4 How to update the LRAIC core model?

10.1.4.1 Traffic

In order to facilitate the yearly updates of the core model, an update file has been created. The update of the core model is carried out in 3 steps.

Firstly, the update file contains 5 sheets that need to be filled:

- The voice traffic;
- The broadband traffic;
- The bitstream traffic;
- The IPTV traffic;
- The VOD traffic.

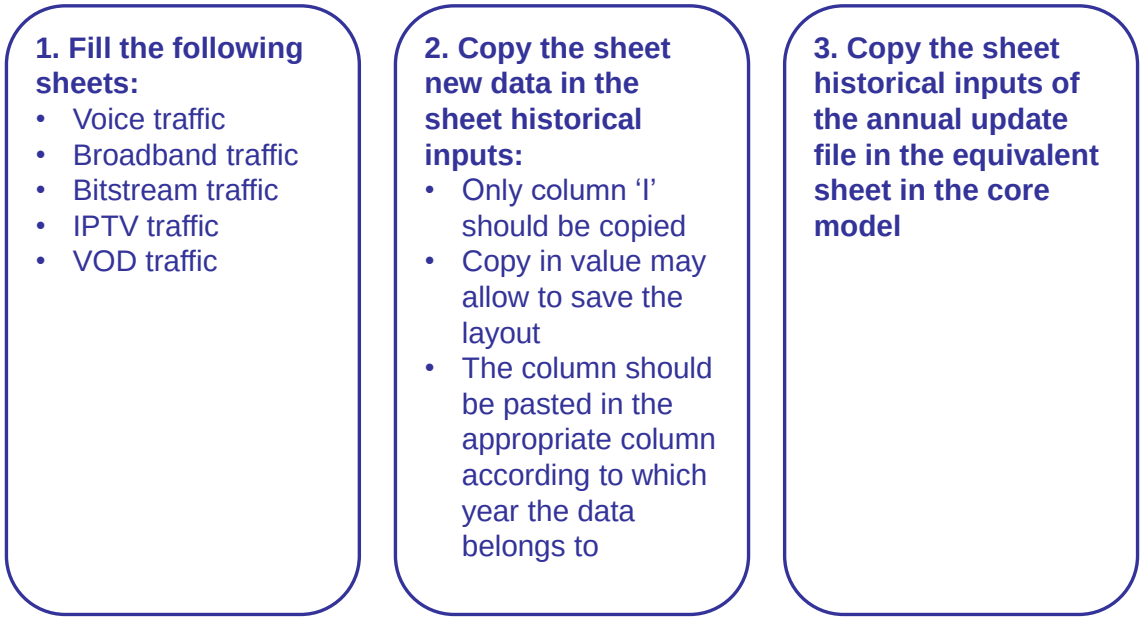
The inputs that need to be updated are almost all the same as in the previous model. The presentation is the most significant change.

The data is then gathered in the sheet “New data” of the annual update file.

Secondly, the whole column ‘I’ can be pasted in the sheet “historical inputs” (a copy in value allows to preserve the sheet formatting).

Thirdly, this “historical inputs” sheet is the exact same sheet as the “historical inputs” sheet from the core model. Once the “historical inputs” sheet from the annual update file contains new data, the sheet can replace its equivalent in the core model.

Figure 100 – Steps of the annual update



Source: DBA

10.1.4.2 Leased lines

The leased lines traffic should be updated on a yearly basis using the "leased lines" file:

- The list of SDH, IP via LL and IP via fibre leased lines should be updated;
- The IP via fibre at the edge should be updated in order to update the contention ratio.

The update of the leased lines file should be done carefully as issues may arise while trying to match the node IDs of the leased lines with the node IDs of the network topology.

10.2 LRAIC access network cost model

10.2.1 Structure of the model

The LRAIC access model is made of three parts:

- An offline calculation for shortest path algorithm, interpretation of the KMS database and addresses analysis. The calculation part is not available, but the detailed result is provided and can be audited;
- The Denmark_Model_V4 SQL model for the dimensioning part of the copper, FTTH-PON, Dong and CATV networks. The inputs used are the offline calculations, the asset list and specifications, and dimensioning rules;
- The Denmark_Model_V5 SQL model dimensions of the FTTH-P2P network capable of simulating rollout of the network in specific areas. This option will

allow computing the cost of the regulated and the non-regulated areas. The SQL model uses same input as the above SQL model;

- A Microsoft Excel model. The input is the dimensioning provided by the SQL calculations. In the model, the costs of services provided by the network are calculated.

It has to be noted that a single Microsoft Excel model calculates costs for all networks.

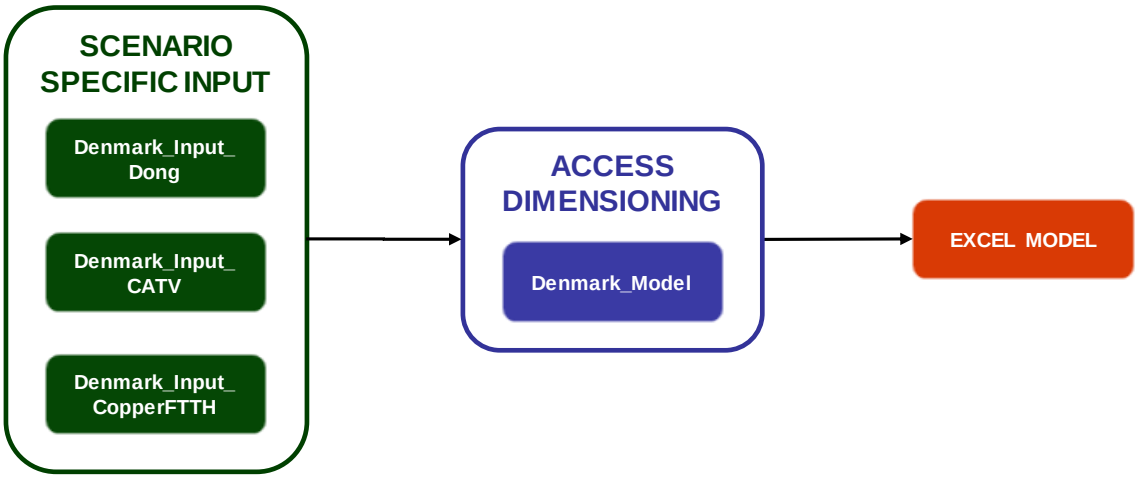
10.2.1.1 Structure of the Denmark_Model_4 SQL file modelling the Copper, Dong, CATV and FTTH-PON networks

This section gives an overview of the Denmark_Model_V4 SQL model, which is further described in a separate document.

The SQL part is made of 4 databases:

- 3 databases specific to the modelled network where the relevant routes are described (one for the copper and national FTTH scenarios, one for the cable-TV scenario and one for the DONG network scenario);
- 1 database used for the modelling, which, upon execution, will calculate the dimensioning for the relevant scenario.

Figure 101 – Model architecture



Source: DBA

The three scenario specific databases are used as a buffer in order to structure the input from offline calculations data into the same format that are used by the model database.

The three input databases are provided with the tables listed Figure 102.

Figure 102 – Description of the tables; scenario-specific

Table name	Description
Output_PDPCOs	Table describing all primary distribution points and Central Offices
Output_Routes_PDPCOs	Table identifying all routes used to link PDPs to Central Offices
Output_Routes_Sections_PDPCOs	Table describing the itinerary of routes used by the PDP to Central Office routes
Output_Routes_Core	Table identifying all routes used to link Central Offices together
Output_Routes_Sections_Core	Table describing the itinerary of routes used by the core routes
Output_Routes_BTO	Table identifying all routes for BTO
Output_Routes_Sections_BTO	Table describing the itinerary of routes used by the BTO routes
Output_Routes	Table identifying all routes used to link end-users to a PDP
Output_Routes_Sections	Table describing the itinerary of routes used by the premises to PDP routes
Output_Addresses_All	Table used to describe all addresses of the country
Output_Sets_Of_DropCables	Table used to describe the part of the network that is in private properties
Output_SectionsUsed	Table used to identify all road sections relevant to the considered scenario

Source: DBA

The model database contains the following input tables:

Figure 103 – Description of the input tables in the model database

Table name	Description
_Source_Sections_All	Table describing all road sections of the country
Parameters	Table containing all parameters scenario-specific. This includes parameters for the current scenario, but also the parameters values specific to each scenario.
Parameters_Technical	Table containing all parameters that are scenario-agnostic, such as trenches engineering rules.
Assets	Table describing all assets used for the modelling. This table is rebuilt each time the model runs (filled by the procedure A01b_FillAssetsTable).

Source: DBA

Figure 104 – Description of the imported tables in the model database

Table name	Description
_Source_Routes	Table identifying all routes used to link end-users to a PDP
_Source_Routes_Sections	Table describing the itinerary in terms of road sections used by the route
_Source_Routes_PDPCOs	Table identifying all routes used to link PDPs to Central Offices
_Source_Routes_Sections_PDPCOs	Table describing the itinerary in terms of road sections used by the route
_Source_Routes_Core	Table identifying all routes used to Central Offices together
_Source_Routes_Sections_Core	Table describing the itinerary in terms of road sections used by the route
_Source_Routes_BTO	Table identifying all routes for BTO
_Source_Routes_Sections_BTO	Table describing the itinerary in terms of road sections used by the route
Addresses_All	This table describes all the addresses of the considered network
PDPCOs	This table describes all Central Offices and PDPs of the considered scenario
Sets_Of_DropCables	Table used to describe the part of the network that is in private properties

Source: DBA

Figure 105 – Description of the calculated tables in the model database

Table name	Description
PDPCOs	This table describes all Central Offices and PDPs of the considered scenario and the dimensioning of PDPs
Sections_Premises	This table contains all road sections related to premises to PDP routes
Sets_Of_DropCables	Table used to describe and dimension the part of the network that is in private properties
Results_Wires_Copper	This table provides calculation results for copper (or coax) wires
Results_Wires_Fibre	This table provides calculation results for fibre wires
Results_Cables_Copper	This table provides calculation results for copper (or coax) cables
Results_Cables_Fibre	This table provides calculation results for fibre cables
Results_Ducts_Copper	This table provides calculation results for copper (or coax) ducts
Results_Ducts_Fibre	This table provides calculation results for fibre ducts
Results_Trenches	This table provides calculation results for trenches
Results_InBuilding	This table provides calculation results for MDU calculation
Results_Aggregated_Assets	This table provides aggregated Central Office results for assets
Results_Aggregated_Trenches	This table provides aggregated per Central Office results for trenches

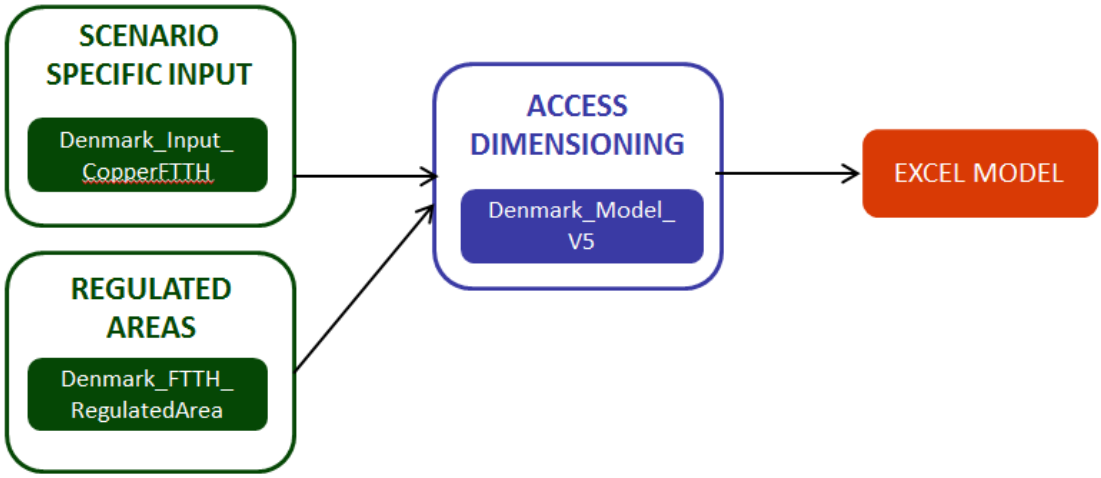
Source: DBA

10.2.1.2 Structure of the Denmark_Model_V5 SQL model for the FTTH-P2P network

This section gives an overview of the Denmark_Model_V5 SQL model. The SQL model consists of 3 databases:

- 2 databases specific to the modelled network containing the addresses and the regulated areas;
- 1 database used for the modelling, which, upon execution, will calculate the dimensioning for the relevant scenario.

Figure 106 – Model architecture (FTTH-P2P)



Source: TERA Consultants

The scenario specific database structures input from offline calculations data into the same format as used by the model database. The input database is provided with the tables listed in the Figure 102.

The regulated areas database is used to select the regulated area. The regulated areas database is provided with the tables listed in Figure 107.

The access dimensioning database contains the input tables described in the Figure 103, Figure 104 and Figure 105.

Figure 107 – Description of the tables (regulated areas)

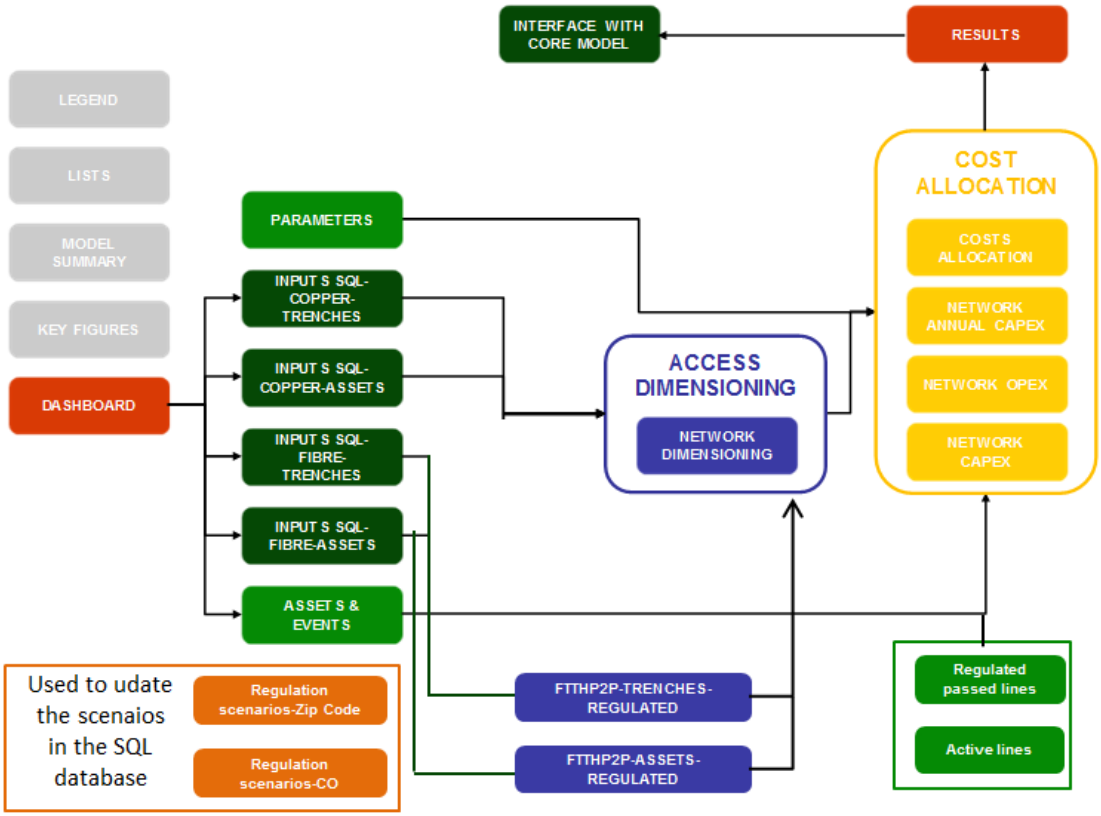
Table name	Description
Output_Addresses_All	Table listing all the Danish addresses with their attributes (city, street, coordinates etc) along with 5 columns to provide 5 different regulation scenarios
Scenarios_COs	Table listing the COs along with 5 columns to provide 5 different regulation scenarios
Scenarios_ZipCodes	Table listing the zip codes along with 5 columns to provide 5 different regulation scenarios

Source: DBA

10.2.1.3 Structure of the Microsoft Excel file

The architecture of the Microsoft Excel part of the access model is shown in the following figure:

Figure 108 – Model architecture



Source: DBA

In order to facilitate the model review, colours are used to mark out the different steps of the modelling:

Figure 109 – Colour code

Colour	Code
Green	Input sheets
Blue	Dimensioning
Yellow	Costing
Red	Dashboard and results
Grey	Miscellaneous
Orange	Used to update the SQL database in order to handle regulation areas

Source: DBA

A specific input sheet (in dark green) is used to build an interface between the core and the access model. This interconnection is described in details in section §10.3.

Four specific input sheets (in dark green) are used to build an interface between the SQL file part of the access network cost model and the excel file part of the access network cost model.

10.2.2 Description of the different parts of the LRAIC access model

10.2.2.1 Description of the Denmark_Model_V4 SQL model for the copper, DONG, CATV and FTTH-PON networks

As described section 10.2.1.1, the SQL model consists of 4 databases. The Denmark_Model_V4 database is used to execute calculations, with the remaining databases are input databases.

The Denmark_Model_V4 database holds the procedures processing the country information to derive a number of assets per CO.

There are 5 user-procedures that can be launched to dimension each one of the 5 scenarios:

- A00_LaunchCopperScenario: The national copper scenario;
- A00_LaunchFTTHP2PScenario: The national FTTH point to point scenario (this procedure is obsolete and should not be used as the FTTH-P2P network is modelled in a separate database);
- A00_LaunchFTTHPONScenario: The national FTTH PON scenario;
- A00_LaunchCATVScenario: The cable-TV scenario; and

- A00_LaunchDongScenario: The Dong coverage FTTH scenario.

Once a procedure has finished running, 2 results tables are provided: one for the asset inventory and one for the trenches inventory. These tables have to be copy-pasted in the Excel model. The procedure to use this model and update the excel file is further detailed in the “SQL Model Documentation” file.

Each scenario has specific parameters that drive the inventory of assets deployed. The parameters used for the SQL procedures can be changed by updating the tables “Parameters” or “Parameters_Technical”.

The “Parameters” table is describing the scenario modelled (copper nationwide network, cable-TV network, FTTH point to point nationwide network, FTTH PON nationwide network, FTTH point to point network with DONG coverage), e.g. the number of wires per premises, the dimensioning rules for SDP, etc.

The table “Parameters_Technical” contains some common parameters such as trenches specifications and MDU dimensioning parameters.

In the “Parameters” table, the NumericValue and StringValue columns are the one used by the current scenario. There are some columns dedicated to each scenario to store the parameters values (e.g. Sc_Copper_Num, Sc_Copper_Str for copper).

The value of the different parameters has been established based on TDC answers regarding their dimensioning rules and on TERA Consultants expertise.

The parameters embedded in the “Parameters” table are the following:

Table 3 – Parameters of the SQL part of the model

Parameter name	Description	Values
CablesRatio_FDP_Cables_Per_Premises	Ratio FDP / Number of premises : Number of cables (copper pairs or fibres) per premises	This parameter has been set to 2 for all networks except for cable TV which has only one termination.
CablesRatio_SDP_To_FDP	Ratio FDP out / FDP in (border of private property)	This parameter has been set to 1 for all scenarios (neutral) except for CATV where it has been set to 1/8 (a cable distribution point can handle up to 8 premises)
CablesRatio_SDP_To_PDP	Ratio SDP out / SDP in	This parameter has been set to 0.75 for copper and Dong, 0.6 for the national FTTH PTP and 1/32 for the national FTTH PON scenario (splitter).
CablesRatio_PDP_CopperOut_To_TotalCopperIn	Ratio at PDP, to calculate the number of outgoing copper pairs based on the number of incoming copper pairs	This parameter has been set to 0.7 for copper, and 0 for all other networks.
CablesRatio_PDP_FibreOut_To_FibreIn	Ratio at PDP, to calculate the number of outgoing fibres based on the number of incoming fibres	This parameter has been set to 0.7 for Dong, 1/32 for the FTTH PON, and 0 for all other networks.
CablesRatio_PDP_FibreOut_To_TotalCopperIn	Ratio at PDP, to calculate the number of outgoing fibres based on the number of incoming copper pairs (in case of VDSL modelling)	This parameter has been set to 0 for all scenarios.
MinSectionLengthForJoint_CoreBTO	Minimal length of a section to get a joint at the end: if a road section is used by a Core or BTO route, and its length is greater than the parameter, a joint will be installed	The value of this parameter has been set after calibration of the model in order to be consistent with the maximal length of a cable drum and maps provided by TDC. This parameter has been set to 50m.
MinSectionLengthForJoint_PDP	Minimal length of the section to get a joint at the end	The value of this parameter has been set after calibration of the model in order to be consistent with the maximal length of a cable

Parameter name	Description	Values
		drum and maps provided by TDC. This parameter has been set to 50m.
MinSectionLengthForJoint_SDP	Minimal length of a section to get a joint at the end	This parameter has been set after calibration to 15m to avoid jointing on very small sections, however the update of the model introduced a change in the SDP modelling and now a joint is used every time two cables have to be aggregated instead of installing a joint automatically at each cross road as detailed in section 3.4.8.
Scenario	Indicates to the algorithm the scenario modelled	This is a technical parameter.
SDP_TriggerPerAddress_NbPremises	A new SDP is installed every time this number is overstepped. This parameter impacts on the number of SDP per section in denses areas	This value has been set to 12 for the FTTH PTP and Dong scenarios according to engineering rules provided by TDC. 32 is used for the FTTH PON scenario (size of the splitter), 80 for the CATV scenario (capacity of the FTTN node). 20 has been used for the copper scenario after optimisation of the model.
SDP_TriggerPerSection_Premises	Minimal number of premises that triggers the installation of SDPs on a section (0 or 1 means at least 1 SDP per section that has premises). This parameter mainly impacts the number of SDPs in non-denses areas	This value is used in the copper, FTTH PTP and Dong scenarios (a SDP is installed on each section if a building is present). It has been set to 16 for the FTTH PON scenario and 50 for the CATV scenario (a FTTN node is installed if the number of premises aggregated on the section is above 50, otherwise the cable is transferred to the next section).
Source_Database	The database used as a source for the scenario	This is a technical parameter
Technology_Aggr	FDP to SDP cables type	This parameter has been set to

Parameter name	Description	Values
egation	(copper, fibre or coax)	copper for the copper scenario, fibre for FTTH and Dong scenarios, coax for the CATV scenario.
Technology_SDP_PDP	SDP to PDP cables type (copper, fibre or coax)	This parameter has been set to copper for the copper scenario, fibre for FTTH, Dong and CATV scenarios.
Technology_PDP_CO	PDP to Central Office cables type (copper, fibre or coax)	This parameter has been set to copper for the copper scenario, fibre for FTTH, Dong and CATV scenarios.

Source: DBA

The value of the parameters CablesRatio_FDP_Cables_Per_Premises, CablesRatio_SDP_To_FDP, CablesRatio_SDP_To_PDP, CablesRatio_PDP_CopperOut_To_TotalCopperIn, CablesRatio_PDP_FibreOut_To_FibreIn and CablesRatio_PDP_FibreOut_To_TotalCopperIn result in the following cable network dimensioning:

Table 4 - Network dimensioning - Number of cables deployed at each network level for one premise

Scenario	Premises	FDP in	FDP out	SDP in	SDP out	PDP in	PDP out
Copper	2	2	2	2	2x0.75	1.5	1.5x0.7 = 1.05
Dong	2	2	2	2	2x0.75	1.5	1.5x0.7 = 1.05
FTTH PTP	2	2	2	2	2x0.6	1.2	1.2
FTTH PON	2	2	2	2	Roundup(1/32) = a	a	Roundup(a/32)
CATV	1	1	Roundup(1 / 8) = b	b	b / 80	b / 80	b / 80

Source: DBA

10.2.2.2 Description of the Denmark_Model_V5 SQL model

As described in section 10.2.1.2, the SQL model consists of 3 databases. The Denmark_Model_V5 database to execute the calculations, the input database that calculates the dimensioning for the relevant scenario, and the regulated areas database to select the regulated premises;

The Denmark_Model_V5 database contains the procedures needed to derive the number of assets per CO and per regulation area.

There are 2 user-procedures that can be executed to dimension each one of the FTTH-P2P scenarios:

- A00_LaunchFTTHP2PScenario: The procedure that launches all the computations happening before selecting the regulated and non-regulated areas;
- A00_LaunchRegulationUpdate: The procedure that launches all the computations happening after selecting the regulated and non-regulated areas;

Once the procedures are finished running, 4 results tables are provided: one for the asset inventory, one for the trenches inventory, one for list of assets used and the last for the split between regulated and non-regulated premises per zip code. The first, second and the last of these tables have to be copy-pasted to the Excel access model. The procedure to use in this model and the update in the excel file is further detailed in the documentation of the SQL model.

10.2.2.3 Description of the Microsoft Excel file

The Microsoft Excel file uses input from the SQL models and the user.

From the dashboard, it is possible to select the year of the modelling and the scenario. Once the scenario has been selected, the model provides all service costs in the “Results” spreadsheet.

For the FTTH-P2P scenario, it is possible to calculate costs for: Regulated areas, non-regulated areas or full national coverage.

The Microsoft Excel file part of the access network cost model is made of 31 main spreadsheets of which 1 is used to interact with the core network cost model described in the following table:

Figure 110 – Description of the spreadsheets

Name	Description
Welcome	This sheet describes the model
Dashboard	This sheet contains the main parameters of the model
Assets in the network	This sheet provides a mapping between the assets modelled and labels used for each level of the network
Results	This sheet contains the results of the model
Assets	This sheet regroups all the data about the network assets
Parameters	This sheet regroups various parameters about the network assets
Historical input – Access	This sheet contains historical inputs for the access model
Interface with core model	This sheet contains all the data calculated by the access model
Key figures	This sheet gives the main figures of the model
Network inventory	This sheet contains the entire inventory calculated by the access network model for the selected scenario
Network capex	This sheet calculates the total investment cost of the access network
Network opex	This sheet calculates the OPEX of the access network
Network annual capex	This sheet calculates the total investment cost of the access network
Costs allocation	This sheet allocates the costs to the different services
Costs allocation – CATV	This sheet allocates the costs to the different services for the CATV scenario
Inputs SQL -->	This sheet separates the input sheet fed by the SQL model
Copper-assets	This sheet takes as input the inventory required of each asset for each level of the network
Copper-trenches	This sheet takes as input the lengths of trenches in meter for each level of the network
FTTHP2P-assets	This sheet takes as input the inventory required of each asset for each level of the network
FTTHP2P-	This sheet takes as input the lengths of trenches in meter for each

Name	Description
trenches	level of the network
FTTHPON-assets	This sheet takes as input the inventory required of each asset for each level of the network
FTTHPON-trenches	This sheet takes as input the lengths of trenches in meter for each level of the network
CATV-assets	This sheet takes as input the inventory required of each asset for each level of the network
CATV-trenches	This sheet takes as input the lengths of trenches in meter for each level of the network
Other-assets	This sheet takes as input the inventory required of each asset for each level of the network
Other-trenches	This sheet takes as input the lengths of trenches in meter for each level of the network
Annexes -->	
Lists	This list regroups all the lists and names used in this file
Legend	This is the description of the sheet
Model Summary	This sheet summarizes all sheets descriptions

Source: DBA

7 new sheets are added for the splitting the cost of the FTTH-P2P network between regulated and non-regulated areas as described in the following table:

Name	Description
FTTHP2P-assets-Regulation	This sheet is used to calculate the inventory required of each asset for each level of the network for the chosen regulated area
FTTHP2P-trenches-Regulation	This sheet is used to select the lengths of trenches in meters for each level of the network for the chosen regulation area
Network opex - Regulation	This sheet is used to compute the allocation key used to split the OPEX into regulated and non-regulated areas
Active lines	This sheet takes as input the number of active lines per zip code
Regulation scenarios-ZipCode	This sheet is used to generate the SQL code used to update the regulation scenarios
Regulation	This sheet is used to generate the SQL code used to update

Name	Description
scenarios-CO	the regulation scenarios
Regulated passed lines	This sheet takes as input the number of passed lines and regulated passed lines per zip code

10.2.2.4 Specific assets of the COAX network

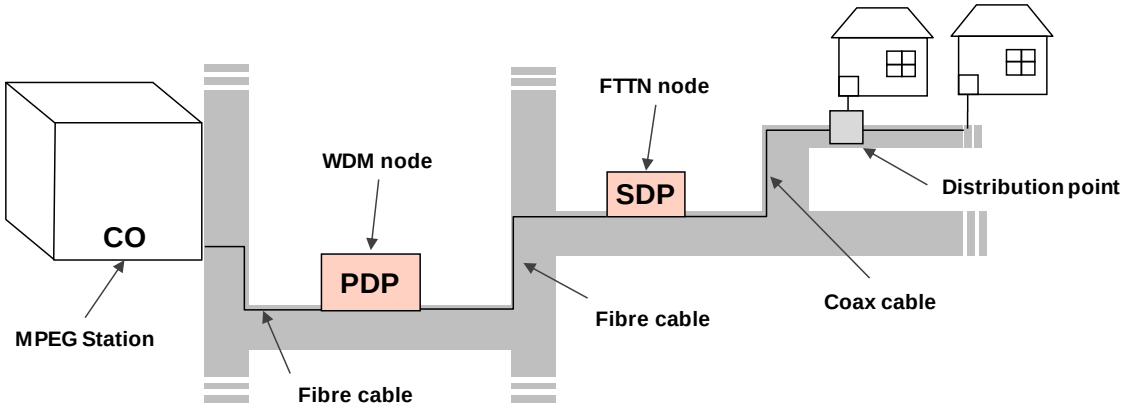
In order to keep a standard modelling, the cable equipment have been matched to the names used for the copper and fibre networks. The table below shows the mapping between the two nomenclatures.

Tableau 1 - CATV assets mapping

Network level	Type of equipment					
	cable	joint	dp	duct	Chamber	trench
Private	Single cable per MDU	N/A	Passive cable splitter	Duct	N/A	Private property trench
Aggregation	Single cable from SDP to the last distribution point	N/A	N/A	Duct	N/A	Roadside trench
SDP	Fibre cable to PDP	Fibre joint between SDP and PDP	FTTN node	Duct	Chamber	Roadside trench
PDP	Fibre cable to the MPEG station	Fibre joint between PDP and the MPEG station	N/A	Duct	Chamber	Roadside trench
BTO	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Core	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

Source: DBA

Figure 111 – Cable-TV network rolled out



Source: DBA

10.2.3 How to update the LRAIC access model?

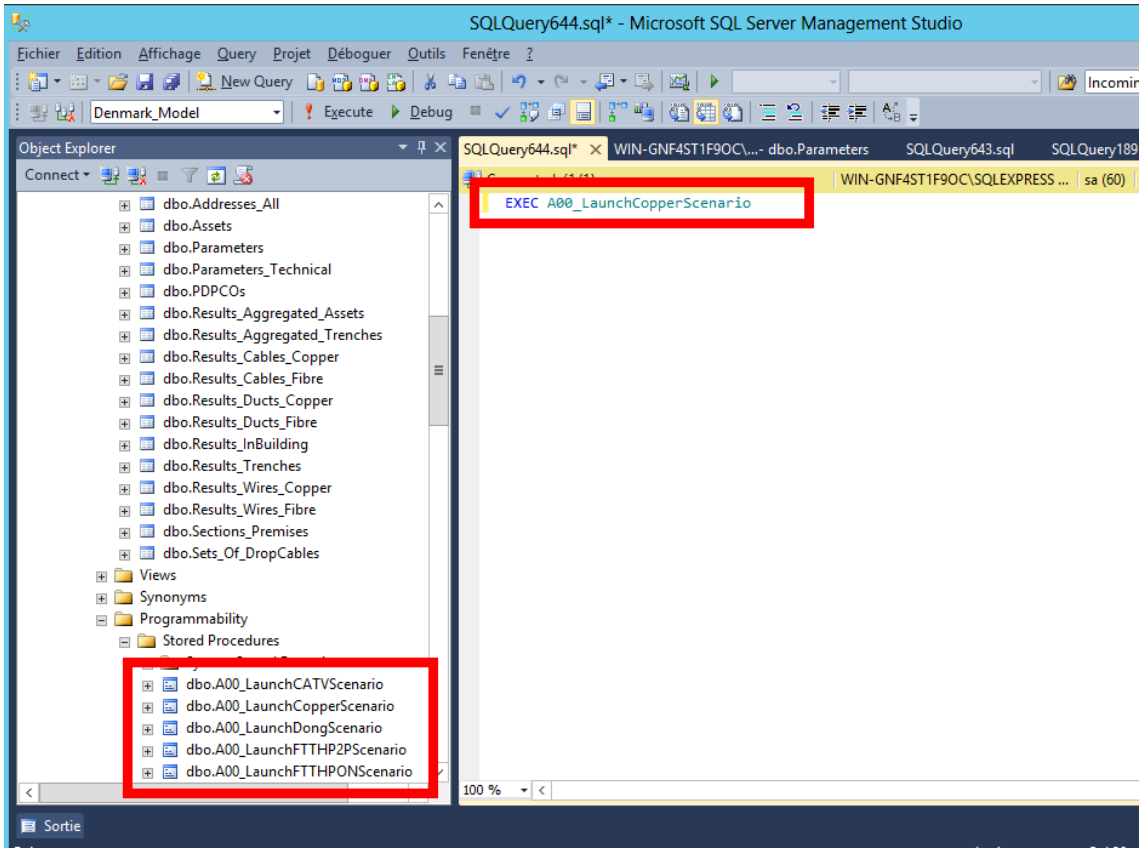
Updating the results of the LRAIC access model can be done by using the control panel of the Microsoft Excel file.

10.2.3.1 Updating the SQL parts of the networks other than FTTH-P2P

Updating the results including the SQL part for the networks other than FTTH-P2P requires the following tasks:

- Run one of the 4 “Denmark_Model_V4” SQL procedures (Figure 112), cf. section 10.2.2.1 (the FTTH-P2P network is simulated in the Denmark_Model_V5 SQL database). The procedures can take up to one hour depending on the scenario. This will provide two result tables; Select the first one from the top-left cell, right click on this cell and click on “Copy with headers” in the context menu;

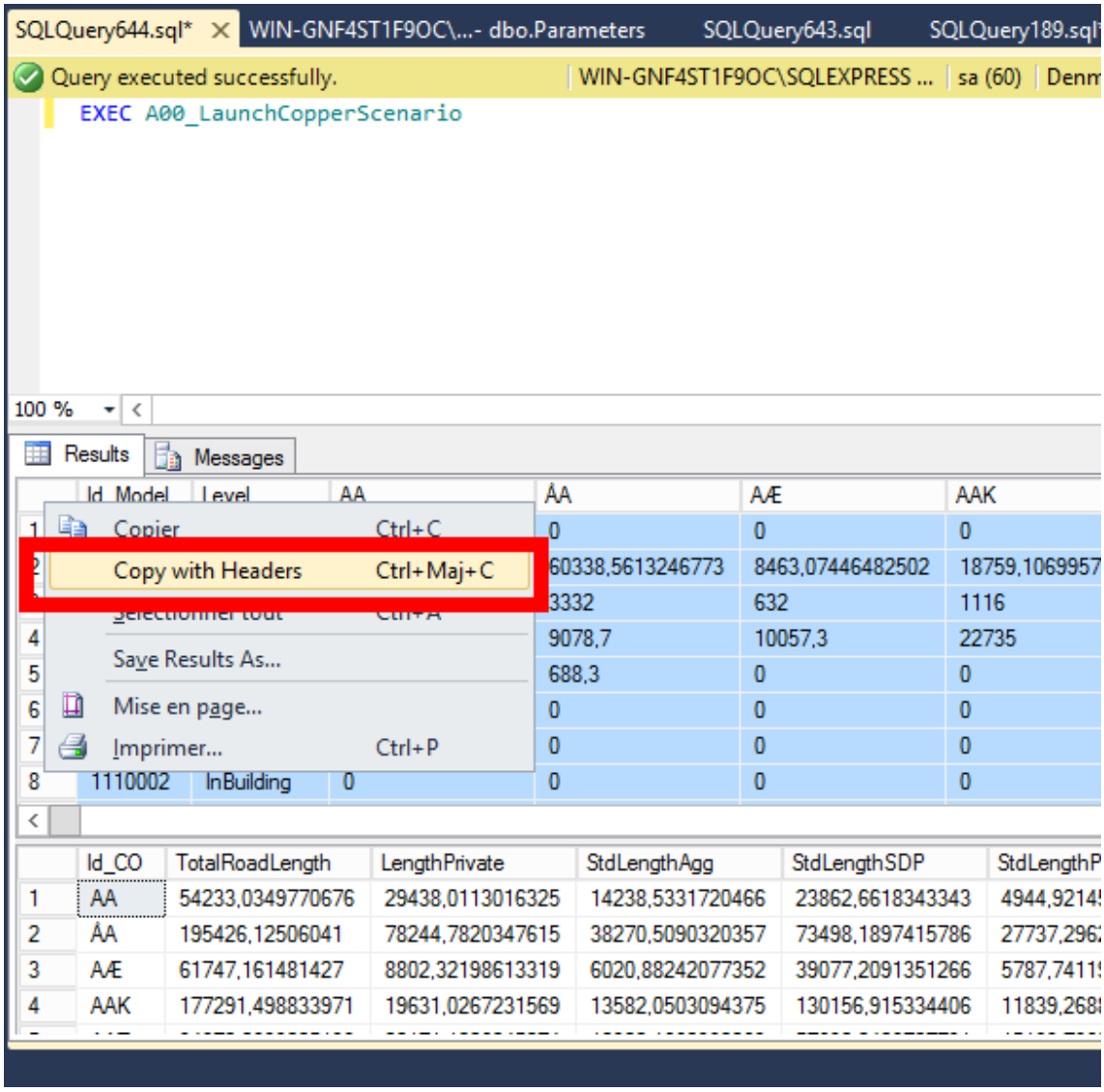
Figure 112 – Run "Denmark_Model_V4" SQL procedures



Source: DBA

- In the SQL database, select the first table and copy all the data (Figure 113);

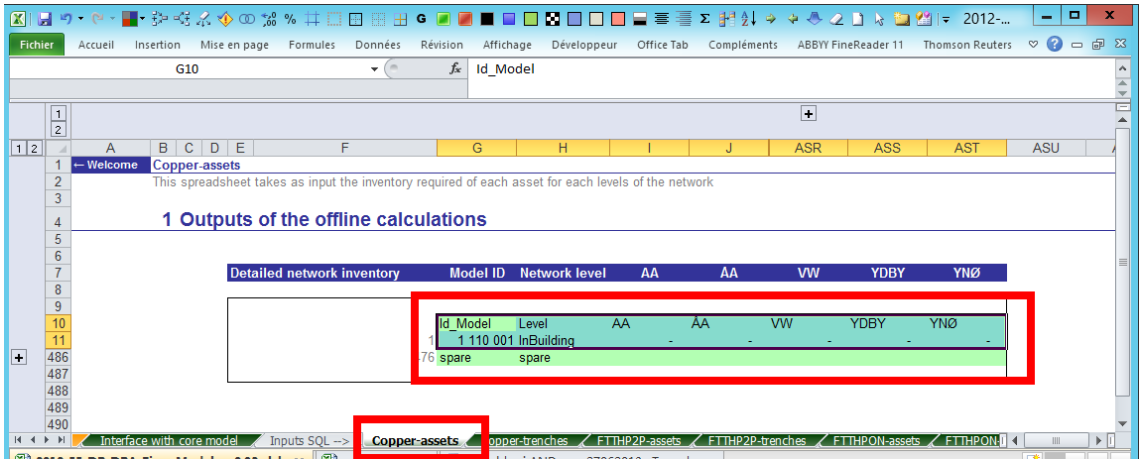
Figure 113 – Copy the table "Copper-Assets"



Source: DBA

- Paste in the Microsoft Excel spreadsheet "Copper-Assets" (or the relevant scenario's spreadsheet) in the green area (Figure 114);

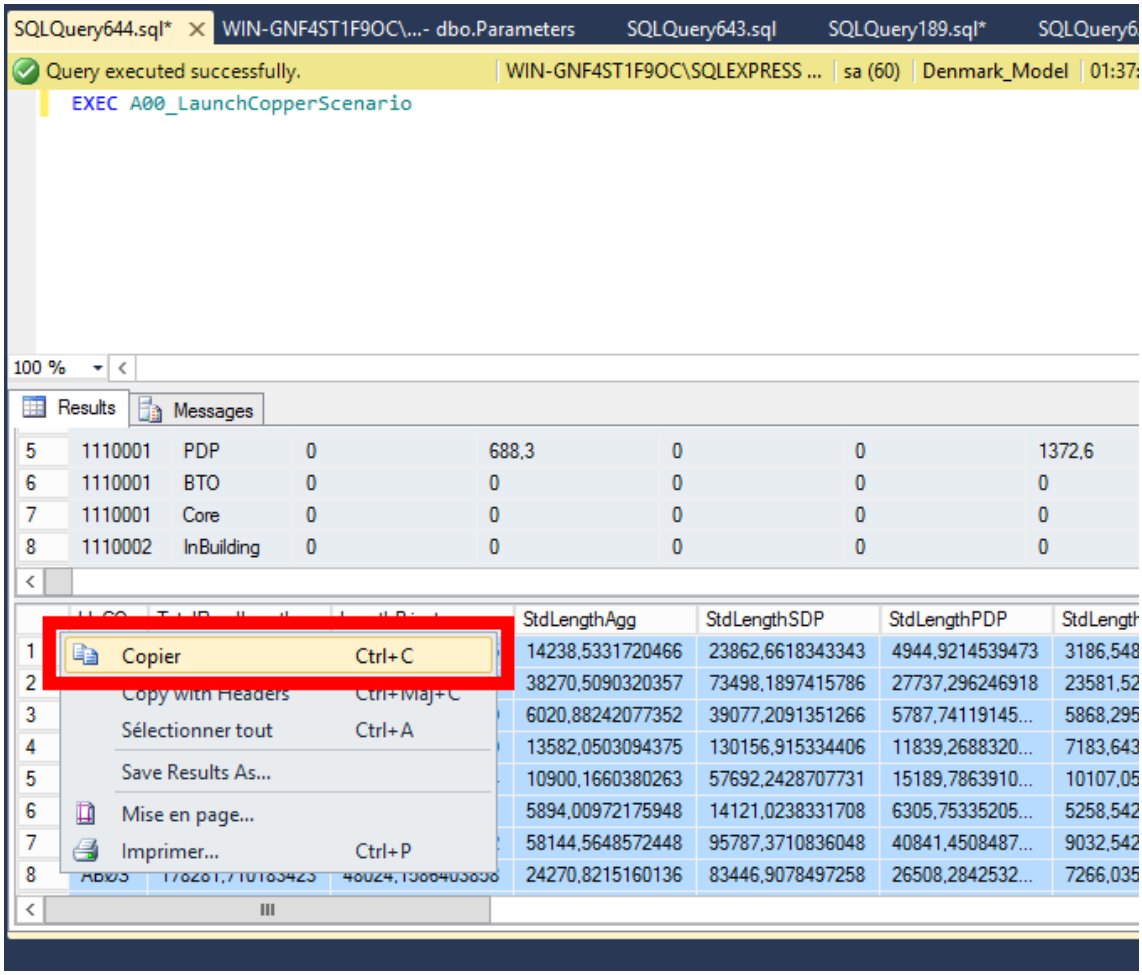
Figure 114 – Paste in the Microsoft Excel spreadsheet "Copper-Assets"



Source: DBA

- Back in the SQL database, select the second table copy all the data (Figure 115);

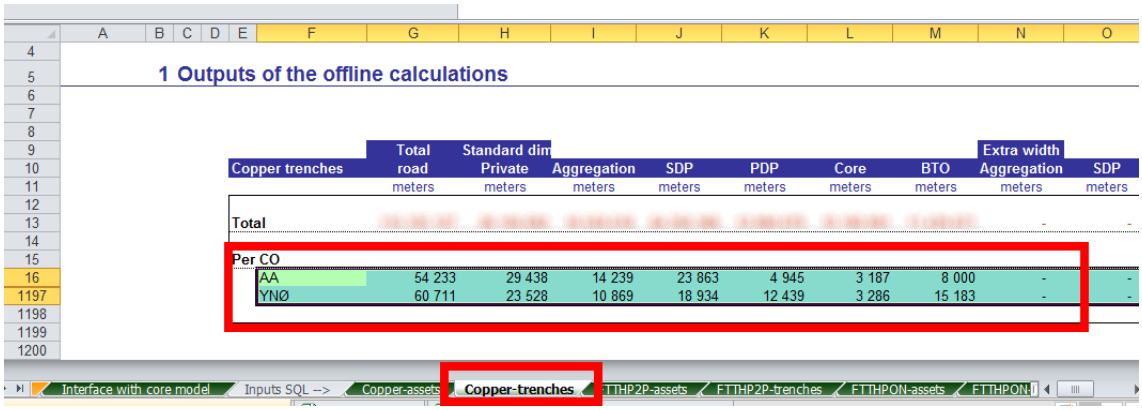
Figure 115 – Copy the table "Copper-Trenches"



Source: DBA

- Paste the data into the Microsoft Excel spreadsheet "Copper-trenches" (or the relevant scenario's spreadsheet) in the green area (Figure 114);

Figure 116 – Paste in the Microsoft Excel spreadsheet "Copper-Trenches"



Source: DBA

10.2.3.2 Updating the FTTH-P2P SQL parts the network

To update SQL part of the FTTH-P2P Network requires the following steps:

Step 1: Execute the A00_LaunchFTTHP2PScenario procedure. The "Message" tab displays the progress and the "Result" tab displays the results at the end of the calculation. This calculation can take from 1h to several hours (8h) depending on the machine executing the procedure. To split the regulated and non-regulated areas, a separate database "Denmark_FTTH_RegulatedArea" has been added in order conduct this split. This database is composed of 3 tables:

- *Output_Addresses_All*
  - Similar to the other addresses tables of the model. Each address is indexed by a global id "Id_Address" common among all tables of the model.
  - Contains some detailed geographic information regarding each address
  - Contains a "IsRegulated" field which is the current scenario which will be used to calculate the results of the model
  - Contains 5 scenario columns (ScC1-ScC5) which can be used to test different geographical pre-defined scenarios.
- *Scenarios_ZipCodes*
  - Contains a ZipCode column and 5 scenario columns (ScA1-ScA5) which can be used to test different scenarios
- *Scenarios_Cos*
  - Contains a Id_CO column and 5 scenario columns (ScB1-ScB5)

Step 2 (Zip codes): Using the Excel model to update the regulation scenarios in the SQL model based on zip codes.

To do so, using the section 1 "scenario – zip area" of the sheet "Regulation scenarios-ZipCode", update the regulation status for each Zip Area of each scenario (Figure 117).

Figure 117 – Scenarios - Zip Area input

Zip area	Name	Nb active lines	ScA1	ScA2	ScA3	ScA4	ScA5
other	Other		1	1	1	1	1
0877-0999	København C		1	1	1	1	1
1050-1473	København K		1	1	1	1	1
9990	Skagen		1	1	1	1	1

Source: DBA

Using the section 2 “SQL code for database update” of the sheet “Regulation scenarios-ZipCode”, copy the SQL code generated in the section 2 column “SQL Code” (Figure 118).

Figure 118 – Scenarios - Zip Area SQL code

COs	ScB1	ScB2	ScB3	ScB4	ScB5	SQL Code
AA	1	1	1	1	1	UPDATE [D
ÅA	1	1	1	1	1	UPDATE [D
YNØ	1	1	1	1	1	UPDATE [D

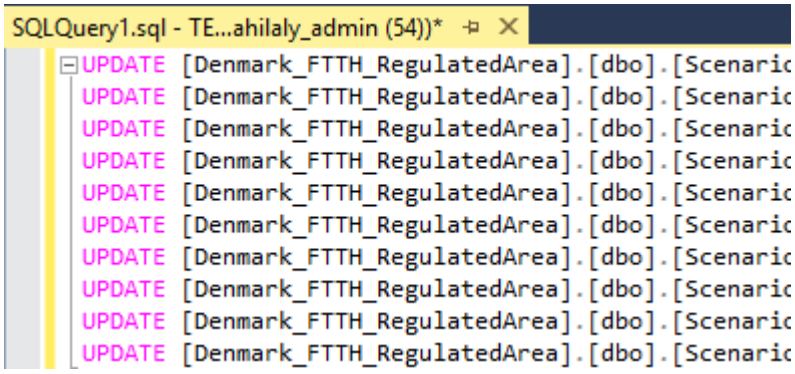
Source: DBA

Update the scenarios in the SQL database:

- Right click on the ”Denmark_FTTH_RegulatedArea” database to create a new query.
- Paste the code copied from the Excel file in the new query-window
- Press F5 to run the query.

The number of lines of the SQL code should be equal to the number of zip codes (Figure 119).

Figure 119 –Zip codes SQL code



Source: DBA

Step 2 (CO): The step 2 can be completed using the COs instead of the zip code areas.

To do so, the same steps as the step 2 have to be performed using the sheet ”Regulation scenarios-CO” of the Excel file.

Step 3: Right click on the Denmark_Model_V5 database and open a new Query window. Type: EXEC A00_LaunchRegulationUpdate ‘ScA1’

- *This will execute the scenario “ScA1”.*
- *The available scenarios are :*
  - ScA1, ScA2, ScA3, ScA4, ScA5 for zip codes
  - ScB1, ScB2, ScB3, ScB4, ScB5 for COs

- ScC1, ScC2, ScC3, ScC4, ScC5 for addresses

Below, the ”Message” tab displays the progress; the ”Result” tab displays the results. The calculation can take from 10 minutes to 1h depending on the machine capacity

Step 4:

The calculation output 4 tables:

- An Assets inventory table
- A Trenches inventory table
- A list of assets used
- A split of Regulated/non-regulated premises per zip code

The two first tables need to be pasted in the Excel model.

- The Assets inventory table needs to be pasted into the sheet “FTTHP2P-assets”.
- The Trenches inventory table need to be pasted into the sheet “FTTHP2P-trenches”

The last output table should be pasted in the “Regulated passed lines” sheet. This output is used to compute the percentage of active lines in the regulated and non-regulated areas.

10.2.3.3 Updating the other parts of the Excel model

The number of active lines in each zip code area has to be pasted in order to split the number of active lines into the regulated and non-regulated areas. These should be updated in the spreadsheet “Active lines“, section “Active lines computation”, column “Active lines” as shown in Figure 120.

Figure 120 – Active lines

Zip area	Name	Active lines
0877-0999	København C	140
1050-1473	København K	28.229
1550-1799	København V	21.532
1800-1974	Frederiksberg C	15.755
2000	Frederiksberg	36.536

Source: DBA

The updated model allows for the FTTH-P2P scenario to calculate the cost per line for:

- The regulated area
- The non-regulated area;
- and a national coverage

The relevant scenario can be chosen using the dashboard, cell G12.

➢ **Go to the dashboard, select the relevant scenario and recalculate the model.**

10.3 Interactions between the Excel cost models

10.3.1 Description of the interactions

The access cost model contains some parameters and computes some results needed in the core cost model. E.g.: the cost of the trench infrastructure is computed in the access network cost model and then is allocated between the access and the core networks. The cost borne by the core network is therefore an output of the access network cost model and is used as an input for the core network cost model.

In each model, there is a sheet dedicated to the interaction between the models:

- In the core model, the sheet “Import from the access model” is used to gather all the data from the access model;
- In the access model, in the excel part, the sheet “Export to the core model” is used to gather the data needed by the core cost model

Figure 121 – Extract of the interface sheet located in the core model

Network assets	Quantity	Year of input	CAPEX trend	OPEX trend	Asset life	Unit CAPEX	Unit OPEX
	2013		%	%	year	DKK per km	DKK per km
Trenches	10,191	2,013	4%		40	115,873	-
Ducts	11,909	2,013	2%		40	24,248	-
Cables	14,410	2,013	4%		20	9,363	234
Chambers	-	2,013	4%		40	-	-
Joints	105,019	2,013	4%		20	25	-

Source: DBA

10.3.2 Outputs of the access model used as inputs by the core model

The list of the outputs of the access model used as inputs by the core model is given in the following table:

Figure 122 - Outputs of the access model used as inputs by the core model

Category	Outputs	Data
Civil engineering	Trenches	Asset quantity, year of data, price trend, asset life, unit CAPEX and unit OPEX
Civil engineering	Ducts	Asset quantity, year of data, price trend, asset life, unit CAPEX and unit OPEX
Civil engineering	Cables	Asset quantity, year of data, price trend, asset life, unit CAPEX and unit OPEX
Civil engineering	Chambers	Asset quantity, year of data, price trend, asset life, unit CAPEX and unit OPEX
Civil engineering	Joints	Asset quantity, year of data, price trend, asset life,

Category	Outputs	Data
		unit CAPEX and unit OPEX
CATV	Topology	Share of lines per Central Office, share of active lines per Central Office and number of PDP per Central Office
Active lines	Overlap active lines reduction factor	Share of active cable-TV customers being passed by a copper line
Active lines	Active lines per technology	Number of active lines per year for PSTN, broadband without PSTN, BSA without PSTN, ISDN2, ISDN30, copper leased lines, fibre leased lines, raw copper, sub-loop, cable-TV and FTTH
Fibre PON	Topology	Number of splitters
Access network	Annual cost	Annual cost (total yearly cost = depreciated CAPEX + OPEX)
Results of the access network	Annual cost	Annual cost per line of the local loop, the sub loop, the local loop with pair bonding and without co-production, the local loop with pair bonding ad with co-production, the sub loop with pair bonding and without co-production, the sub loop with pair bonding ad with co-production Annual cost of the BTO The share of the civil engineering in the BTO
Number of lines rolled-out	Number per year	Total number of lines Number of lines rolled-out for copper, fibre PTP (dong network), fibre PON and cable-TV
General parameters	Hourly wage	Wage of technician
General parameters	WACC	Value of the WACC
General parameters	Payment term	Number of months to be used in the payment term

Source: DBA

10.4 The different scenarios

10.4.1 The copper scenario

In order to obtain the copper results, the following steps have to be followed:

- The scenario of access network cost model has to set to “Copper”;
- The model has to be run;

- The whole spreadsheet “Export to Core Model” of the access network cost model has to be copied and pasted in the spreadsheet “Import from Access model” of the core network cost model;
- The scenario of core network cost model has to set to “Copper”;
- The model has to be run.

10.4.2 The fibre point-to-point scenario

In order to obtain the fibre point-to-point results, the following steps have to be followed:

- The scenario of access network cost model has to set to “FTTHP2P” and relevant geographical scenario chosen;
- The model has to be run;
- The whole spreadsheet “Export to Core Model” of the access network cost model has to be copied and pasted in the spreadsheet “Import from Access model” of the core network cost model;
- The scenario of core network cost model has to set to “Fibre - PTP”;
- The model has to be run.

10.4.3 The fibre GPON scenario

In order to obtain the fibre GPON results, the following steps have to be followed:

- The scenario of access network cost model has to set to “FTTHPON”;
- The model has to be run;
- The whole spreadsheet “Export to Core Model” of the access network cost model has to be copied and pasted in the spreadsheet “Import from Access model” of the core network cost model;
- The scenario of core network cost model has to set to “Fibre - PON”;
- The model has to be run.

10.4.4 The CATV scenario

In order to obtain the CATV results, the following steps have to be followed:

- The scenario of access network cost model has to set to “Copper”;
- The model has to be run;
- The whole spreadsheet “Export to Core Model” of the access network cost model has to be copied and pasted in the spreadsheet “Import from Access model” of the core network cost model;
- The scenario of access network cost model has to set to “CATV”;
- The model has to be run;

- Solely the table 10 in the spreadsheet “Export to Core Model” of the access network cost model has to copied and then pasted in the spreadsheet “Import from Access model” of the core network cost model;
- The scenario of core network cost model has to set to “TDC actual network”;
- The model has to be run.

11 Validating the cost models

Validating the LRAIC cost models is an important step in order to derive reasonable prices. For both the core and the access network cost models, analyses have been carried out to ensure that:

- The technical inputs of the model reflect the MEA technology and the choices that an efficient operator would make if rebuilding entirely its network today;
- The cost of the different assets in the model are the market costs;
- The OPEX are those of an efficient and modern network;
- The outcomes are consistent with reality;
- The scope of the models is consistent: no cost should be forgotten but also no unnecessary cost should be included.

The different analyses carried out for each of the LRAIC cost models are presented in the next sections.

11.1 Validating the core model

The different analyses carried out to validate the core model are:

- Comparison with the former core network cost model;
- Analysis of TDC’s regulatory accounts to ensure consistent level of opex is taken into account;
- Analysis of the characteristics of each assets modelled: vendors documentation analysis, comparison of the different answers provided by the industry, benchmark with other countries and analysis of the relevance to the model;
- Analysis of the core network traffic: comparison between the figures in the model and the real world figures;
- Building a bridge between the former routing matrix and the new routing matrix to ensure the same services are modelled;
- Analysis of the technology choices;
- Analysis of the network topology to understand the local peculiarities, the local of the different servers and the point of interconnection;

- Sensitivity analysis to ensure the model is reacting as expected;
- Formula checks have been directly built in the model;
- Sensitivity analyses to ensure that the efficient solution is selected when several possibilities exist;
- Analysis of the cost allocation in order to ensure that all costs are recovered.

11.2 Validating the access model

The different analyses carried out to validate the access model are:

- Comparison with the former access network cost model;
- Analysis of the characteristics of each assets modelled: comparison of the different answers provided by the industry, comparison of the consistency with the former model, benchmark with other countries and analysis of the relevance to the model;
- Comparison with the inventory provided by TDC for sample zones;
- Cross check algorithms, map representation of modelled data in order to identify potential modelling issues;
- Sensitivity analysis to ensure the model is reacting as expected;
- Summary tables in order to track the order of magnitude for each step of the calculation;
- Sensitivity analysis to ensure that the efficient solution is selected when several possibilities exist;
- Analysis of the cost allocation in order to ensure that all costs are recovered.

12 Appendix

12.1 Access network graph algorithm

The paths of the access network are designed in order to follow the architecture of the road network in Denmark.

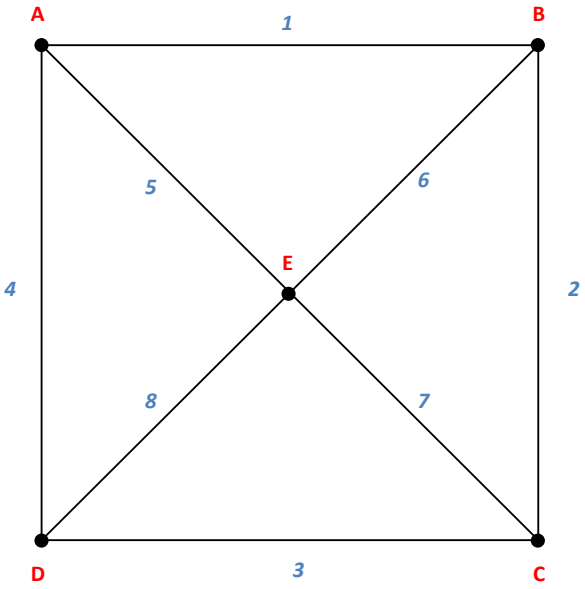
The aim of the graph algorithm is to create all the possible routes between the network node (e.g. a PDP) and all the constructions within the corresponding coverage area. The algorithm is iterative. It selects, at each iteration, all the sections that have a common node (a node is the extremity of a section) with already selected sections (see the following example).

The following rules are used to select the path from one section to another:

- A section is a portion of a street located between two intersections called nodes. As a consequence, a street might be composed of several sections.
- Each section is defined by two nodes that are located at each extremity of the section.
- Sections are linked together by nodes.
- Sections are doubled in order to give an orientation to each section (section AB can be crossed from A to B or from B to A).
- The departing point of the graph is the closest section to the distribution frame.
- All possible routes are tested and only the shortest one is kept.

The following graph is a simplified example. It represents 8 sections and the 5 associated nodes (see Figure 123 and Figure 124). In the reality, the number of possible routes is exponential:

Figure 123 - Example with a 8-section area



Source: Geocible

Figure 124 - List of sections within the example

ID_SECTION	Nodes	Reverse orientation
1	AB	BA
2	BC	CB
3	CD	DC
4	DA	AD
5	AE	EA
6	EB	BE
7	EC	CE
8	DE	ED

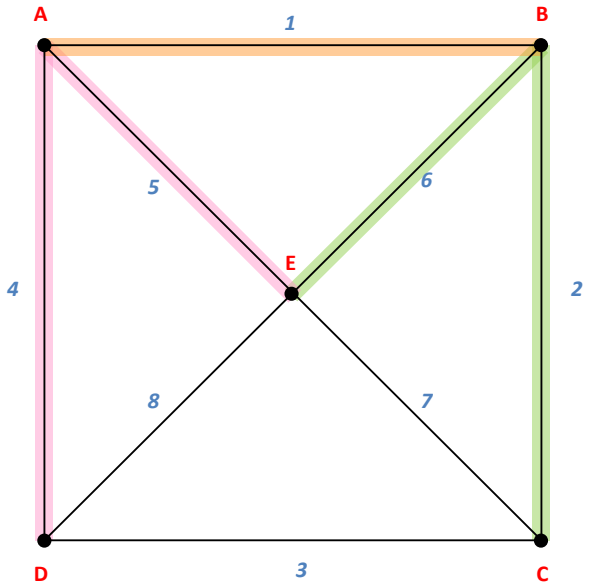
Source: Geocible

The first step is to identify the departing section: in this example, it is the section with ID 1 (in orange in the following figure).

The second step is to identify every section directly linked to the departing section, i.e. all the sections that have a common node with section 1 (node A or node B). In our example, section 1 is linked to the four following sections (see Figure 125):

- Sections 4 and 5 that have in common the node A with the departing section (in pink in Figure 125).
- Section 2 and 6 that have in common the node B with the departing section (in green in Figure 125).

Figure 125 - Sections linked to section 1

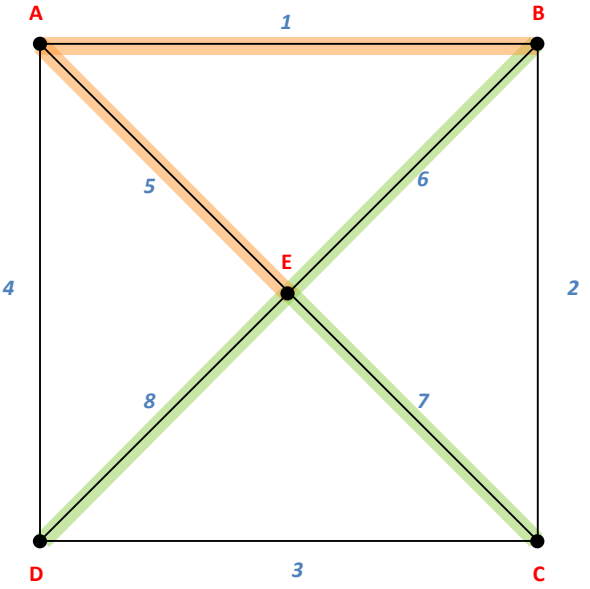


Source: Geocible

The graph algorithm then looks at the route starting from section 1 (AB) and going to section 5 (AE) (in orange in Figure 126). The next step is to select all the sections that have the node E in common (in green in Figure 126):

- Section 6 (EB).
- Section 7 (EC).
- Section 8 (ED).

Figure 126 - Sections that have node E in common (in green)



Source: Geocible

Once all possible routes have been tested by the algorithm, the shortest route is selected.

12.2 Access network graph results

For each graph, a database comprising of three tables has been produced:

- a table describing each section;
- a table describing the nodes location;
- a table describing every route; and
- a table describing the path taken by each route.

A database on addresses is also required.

12.2.1 The sections table

This table (see Figure 127) describes all the 1,962,964 sections of the road network:

- Real section or virtual section (e.g. to connect an island);
- Length;
- Addresses within the section;
- etc.

For each section (identified by a unique ID number called 'ID_section'), the table contains the two end nodes (ID_Node_1 and ID_Node_2).

Figure 127 - Section table used as an input of the access BU model

Id_Section	Id_PDPCO	Section_Category	Section_Length	Id_Node_1	Id_Node_2	Adresses_Id_Section	Affected_Tc
1	100578920	Virtual	841	585911	593368	0	-1
2	102412163	Virtual	27054,4	1146565	1185724	0	-1
3		Virtual	2983,3	1530237	1530235	0	0
4	FEJØ	Virtual	8597,8	1086945	1095651	0	-1
5	LÆK	Virtual	1627,8	1288249	1289946	0	-1
6		Virtual	3515,3	1353857	1357095	0	0
7	102917133	Virtual	1818,1	1108206	1108031	0	-1

Source: DBA

12.2.2 Node location table

The node location table provides details on where TDC's network nodes (PDP, Central Offices, etc.) are located:

- Node ID;
- Corresponding Central Office ID;
- Type of node (PDP, Central Office…);
- ID of the section where the node is located;
- Building / Road section distance;
- XY of the road section's closest point to the address;

- Position as compared to the end of the section;
- Side of the street (left/right).

Figure 128: Node location table

Id_PDPCO	Id_CO	PDPCO_Typ	Id_Section	Distance_To_Section	Projection_X	Projection_	Projection_	Projection_
100000668	FJU	PDP	90525226	5,89	597 767	6 264 133	42,89%	L
100000669	FJU	PDP	91628504	4,97	594 455	6 263 816	58,57%	L
100000670	FJU	PDP	87235522	8,00	601 312	6 262 484	93,28%	L
100000672	FJU	PDP	90539332	5,77	594 490	6 262 284	6,28%	L
100000675	FJU	PDP	91636257	5,35	596 358	6 264 210	97,97%	L
100000676	FJU	PDP	91619572	8,65	597 066	6 264 250	1,13%	L

Source: DBA

12.2.3 The routes tables

Route tables describe all types of routes required to design the network.

In the case of the copper access, it corresponds to:

- Central Office to PDP;
- PDP to door.

For each route (e.g. from a PDP to the doors of a given section), the corresponding route table provides the total length (Length) and the number of sections crossed (Section_Count) (see Figure 129).

Each line of the table (identified by a unique ID number called 'Id_Route') corresponds to a route linking a PDP (defined by 'Id_PDPCO') to the corresponding Central Office. The two end sections of the route are also provided (Id_Section_End and Id_Section_Start).

Figure 129: copper routes table used as an input of the access model

Id_PDPCO	Id_Route	Section_Count	Id_Section_End	Id_Section_Start	Length
100000668	2	1	90525226	90525226	95,3
100000668	3	2	87208559	90525226	143,4
100000668	4	2	90539545	90525226	106,6
100000668	5	2	90540830	90525226	109,3
100000668	6	2	91630276	90525226	100
100000668	7	2	91650824	90525226	190,7
100000668	8	3	87215171	90525226	187,2

Source: DBA

12.2.4 The detailed routes table

This table describes the path of every route identified in the previous table (see example in Figure 130).

As a consequence, a route that has a “Section count” of 4 in the table Figure 129 will be split into 4 lines in the table Figure 130.

Figure 130: Detailed route table

Id_PDPCO	Id_Route	Section_Nui	Id_Section	Id_Node	Cliquer pour ajouter
100000668	2	1	90525226		
100000668	3	1	90525226		
100000668	3	2	87208559	973853	
100000668	4	1	90525226		
100000668	4	2	90539545	973781	

Source: DBA

12.2.5 The addresses table

The addresses table (see Figure 131) provides the list of all addresses within TDC’s databases with the following details:

- Localisation in kvh;
- Address:
  - Zipcode;
  - City;
  - Street name;
  - House number;
  - House letter;
- Type of access line:
  - Copper (Yes / No)
  - CA-TV YouSee (Yes / No)
  - CA-TV Private (Yes / No)
  - FTTH under 30m (Yes / No)
  - FTTH above 30m (Yes / No)
- Coordinates XY;
- Building ID;
- ID of the building’s road section;

- Building / Road section distance;
- XY of the road section closest point;
- Size of the street;
- …

Figure 131: Addresses table

ZipCode	City	StreetName	HouseNumber	HouseLetter	Copper	CATV_Yousee	CATV_Private	FTTH_Inf30	FTTH_Sup30	X	Y
4760		ALGADE	2		-1	0	0	0	0	685481,71	6100045,73
4760		ALGADE	3		-1	0	0	0	0	685508,64	6100068,17
4760		ALGADE	3	B	-1	0	0	0	0	685508,64	6100068,17
4760		ALGADE	4		-1	0	0	0	0	685489,35	6100042,06
4760		ALGADE	5	A	-1	0	-1	0	0	685532,59	6100056,33
4760		ALGADE	5	B	-1	0	-1	0	0	685539,84	6100052,42

Source: DBA

12.3 Access networks model inputs

Main inputs of the access network cost modelling are addresses and geo-marketing inputs which have been described in the body of the document.

12.4 Core networks model inputs

12.4.1 List of network assets

In the spreadsheet named “Network assets and costs” of the core model are listed the core network assets;

The model includes 147 assets without counting the trenches, ducts and cables that are modelled in the access network model. The list of assets is the following:

Figure 132 – List of the assets

Network level	Category	Asset
SC	Small SC	SC - 200 ports
SC	Medium SC	SC - 400 ports
SC	Large SC	SC - 600 ports
SC	Very Large SC	SC - 800 ports
CO	MDF 250	MDF - 250 ports
CO	MDF 500	MDF - 500 ports
CO	MDF 2000	MDF - 2000 ports
CO	MDF 10000	MDF - 10000 ports
CO	MDF 50000	MDF - 50000 ports
SC/CO	ODF 500	ODF - 500 ports
SC/CO	ODF 1000	ODF - 1000 ports
SC/CO	ODF 2000	ODF - 2000 ports
SC/CO	ODF 5000	ODF - 5000 ports
SC/CO	ODF 10000	ODF - 10000 ports
SC/CO	ODF 20000	ODF - 20000 ports
SC/CO	MSAN - PON	Rack

Network level	Category	Asset
SC/CO	MSAN - PON	Card
SC/CO	MSAN - PON	Port
SC/CO	MSAN - PTP	Rack
SC/CO	MSAN - PTP	Card
SC/CO	MSAN - PTP	Patchcables
SC	MSAN - xDSL - REMOTE	Rack
SC	MSAN - xDSL - REMOTE	MDF cable
SC	MSAN - xDSL - REMOTE	SFP
SC	MSAN - xDSL - REMOTE	xDSL card
SC	MSAN - xDSL - REMOTE	VECTORING processor card
SC	MSAN - xDSL - REMOTE	VECTORING card (small)
SC	MSAN - xDSL - REMOTE	Vectoring card (large)
CO	MSAN - xDSL	Rack
CO	MSAN - xDSL	Subrack
CO	MSAN - xDSL	MDF cable
CO	MSAN - xDSL	SFP
CO	MSAN - xDSL	xdsl card
CO	MSAN - xDSL	SDSL card
CO	MSAN - xDSL	Vectoring processor card
CO	MSAN - xDSL	Vectoring card (small)
CO	MSAN - xDSL	Vectoring card (large)
CO	Site	Power supply unit
CO	Site	Backup site power
CO	Site	Air conditioning unit
CO	Site	Security system
CO	Site	Site preparation
CO	Site	Site maintenance
CO	Site	Security guard
CO	Site	Backdoor setup
SC	Site	Power supply unit
SC	Site	Backup site power
SC	Site	Air conditioning unit
SC	Site	Security system
SC	Site	Site preparation
SC	Site	Site maintenance
SC	Site	Security guard
Aggregation site	Aggregation switch	Rack with 2 10Gbps ports
Aggregation site	Aggregation switch	Rack with 4 10 Gbps ports
Aggregation site	Aggregation switch	Card 10Gbps
Aggregation site	Aggregation switch	Card 1Gbps
Aggregation site	Aggregation switch	SFP 10Gbps
Aggregation site	Aggregation switch	SFP 1Gbps
Aggregation site	Site	Power supply unit
Aggregation site	Site	Backup site power
Aggregation site	Site	Air conditioning unit
Aggregation site	Site	Security system
Aggregation site	Site	Site preparation
Aggregation site	Site	Site maintenance
Aggregation site	Site	Security guard
Aggregation site	Site	Backdoor setup
Edge site	Edge router	Rack
Edge site	Edge router	Card 10Gbps
Edge site	Edge router	Card 1Gbps

Network level	Category	Asset
Edge site	Edge router	SFP 10Gbps
Edge site	Edge router	SFP 1Gbps
Edge site	Site	Power supply unit
Edge site	Site	Backup site power
Edge site	Site	Air conditioning unit
Edge site	Site	Security system
Edge site	Site	Site preparation
Edge site	Site	Site maintenance
Edge site	Site	Security guard
Edge site	Site	Backdoor setup
Distribution site	Distribution Router	Rack
Distribution site	Distribution Router	Card 10Gbps
Distribution site	Distribution Router	SFP
Distribution site	Site	Power supply unit
Distribution site	Site	Backup site power
Distribution site	Site	Air conditioning unit
Distribution site	Site	Security system
Distribution site	Site	Site preparation
Distribution site	Site	Site maintenance
Distribution site	Site	Security guard
Distribution site	Site	Backdoor setup
Core site	Core Router	Rack
Core site	Core Router	Card 10G
Core site	Core Router	SFP
Core site	Site	Power supply unit
Core site	Site	Backup site power
Core site	Site	Air conditioning unit
Core site	Site	Security system
Core site	Site	Site preparation
Core site	Site	Site maintenance
Core site	Site	Security guard
Core site	Site	Backdoor setup
IMS platform	IMS	IMS Core
IMS platform	IMS	IMS Core licences for residential customers
IMS platform	IMS	IMS Core licences for business customers
IMS platform	IMS	IMS Services
IMS platform	IMS	IMS Services licences for residential customers
IMS platform	IMS	IMS Services licences for business customers
IMS platform	IMS	OSS/BSS
IMS platform	IMS	OSS/BSS licences
IMS platform	IMS	SBC – small
IMS platform	IMS	SBC – large
IMS platform	IMS	Monitoring setup
Intelligent network	IN	Platform1
Intelligent network	IN	Platform2
Intelligent network	IN	Platform3
PSTN GW	PSTN GW	Platform
PSTN GW	PSTN GW	Licences
PLMN GW	PLMN GW	Server
PLMN GW	PLMN GW	licence based on traffic

Network level	Category	Asset
PLMN GW	PLMN GW	licence based on traffic
PLMN GW	PLMN GW	licence based on traffic
International GW	International GW	Platform
CATV servers	CATV servers	DHCP server
CATV servers	CATV servers	ToD server
CATV servers	CATV servers	TFTP server
CATV servers	CATV servers	DNS
CATV	MPEG station	L3 routers
CATV	MPEG station	VoD server
CATV	MPEG station	Transcoder for analogue TV/radio and digital TV
CATV	MPEG station	Transcoder for VoD
CATV	MPEG station	Transcoder for broadband
CATV	MPEG station	CMTS rack
CATV	MPEG station	Card
CATV	Other CATV assets	Narrowcast transmitters
DWDM	DWDM platform	2 direction branch node
DWDM	DWDM platform	3 direction branch node
DWDM	DWDM platform	4 direction branch node
DWDM	DWDM platform	5 direction branch node
DWDM	DWDM platform	Line module
DWDM	DWDM platform	Mux/demux
DWDM	DWDM platform	40G Line side
DWDM	DWDM platform	20G Line side
DWDM	Amplifier for DWDM	Amplifier
Transmission	Civil engineering	Trench
Transmission	Civil engineering	Duct
Transmission	Civil engineering	Cables

Source: DBA

The different assets are grouped into categories which are then grouped into network levels.

In order to fully dimension a category, all the assets belonging to the same category have to be dimensioned. E.g.: in order to dimension the core router, the following assets have to be dimensioned:

- Rack;
- 10Gbps card;
- SFP.

To dimension a node of the network, all the categories belonging to the same network level should be dimensioned. E.g.: to dimension a street cabinet (SC), the following categories should be dimensioned:

- Small SC;
- Medium SC;
- Large SC;
- Very Large SC;

- ODF 500;
- ODF 1000;
- ODF 2000;
- ODF 5000;
- ODF 10000;
- ODF 20000;
- MSAN – PON;
- MSAN – PTP;
- MSAN - xDSL – REMOTE;
- Site.

Therefore a street cabinet includes 14 different types of categories which each include several assets.

A particular attention should be given to the “xDSL card” category: this card is a mix of an ADSL card and of a VDSL card. Its cost is the weighted average cost of an ADSL card and a VDSL card, the weights being the number of cards rolled-out in TDC’s network.

For each asset, the following elements are provided:

- An ID;
- A cost allocation driver;
- The network level to which it belongs to (Central Office, Aggregation, Transmission, …);
- A dimensioning driver and a capacity;
- The CAPEX associated (cost of the asset, cost of installation, planning cost);
- The OPEX associated (maintenance, cost of power, yearly rental cost);
- Asset life;
- Price trends.

Figure 133 – Extract of the core network assets description

Network assets	Cost allocation driver	Network level	ID	Equipment	Dimensioning driver unit	Dimensioning driver capacity	Throughput	Spare
						#	Gbps	%
MDF/SC	Copper	CO						
Small SC			Asset1	SC - 200 ports	Subs	200		0%
Medium SC			Asset2	SC - 400 ports	Subs	400		0%
Large SC			Asset3	SC - 600 ports	Subs	600		0%
Very Large SC			Asset4	SC - 800 ports	Subs	800		0%
MDF/SC	Copper	CO						
MDF 250			Asset5	MDF - 250 ports	Subs	250		0%
MDF 500			Asset6	MDF - 500 ports	Subs	500		0%
MDF 2000			Asset7	MDF - 2000 ports	Subs	2,000		0%
MDF 10000			Asset8	MDF - 10000 ports	Subs	10,000		0%
MDF 50000			Asset9	MDF - 50000 ports	Subs	50,000		0%
ODF	Fibre	CO						
ODF 500			Asset10	ODF - 500 ports	Subs	500		0%
ODF 1000			Asset11	ODF - 1000 ports	Subs	1,000		0%
ODF 2000			Asset12	ODF - 2000 ports	Subs	2,000		0%
ODF 5000			Asset13	ODF - 5000 ports	Subs	5,000		0%
ODF 10000			Asset14	ODF - 10000 ports	Subs	10,000		0%
ODF 20000			Asset15	ODF - 20000 ports	Subs	20,000		0%
MSAN								
MSAN - PON	Fibre	CO	Asset16	Rack	Cards	16		1%
			Asset17	Card	Port	8		5%
			Asset18	Port	Splitters	1		5%
MSAN - PTP	Fibre	CO	Asset19	Rack	Cards	18		1%
			Asset20	Card	Port	36		5%
			Asset21	Patchcables	Port	1		5%
MSAN - xDSL - REMOTE	Copper	CO	Asset22	Rack	Cards	4		1%
			Asset23	MDF cable	Port	96		5%
			Asset24	SFP	Rack	1		5%
			Asset25	xDSL card	Port	48		5%
			Asset26	VECTORING processor card	Port	48		5%
			Asset27	VECTORING card (small)	Port	192		5%
			Asset28	Vectoring card (large)	Port	384		5%
MSAN - xDSL	Copper	CO	Asset29	Rack	Subrack	2		1%
			Asset30	Subrack	Cards	16		5%
			Asset31	MDF cable	Subs	96		5%
			Asset32	SFP	Rack	1		5%
			Asset33	xdsl card	Port	48		5%
			Asset34	SDSL card	Port	48		5%
			Asset35	Vectoring processor card	Port	48		5%
			Asset36	Vectoring card (small)	Port	192		5%
			Asset37	Vectoring card (large)	Port	384		5%
SWITCH - LEASED LINES	Leased Lines	CO	Asset38	Rack	Cards	4		1%
			Asset39	Card 10G	Port 10G	2		5%
			Asset40	Card 1G	Port 1G	20		5%
			Asset41	SFP 10G	Port 10G	1		5%
			Asset42	SFP 1G	Port 1G	1		5%

Source: DBA

12.4.2 General costs

The LRAIC model includes 8 general costs:

- Cost of power;
- Cost of cooling;
- Annual wages for technicians, administrative workers and academics;
- Yearly rental cost (building and land).

Figure 134 – General costs

General costs		Value	Unit
Power & cooling			
	Power	0.86	DKK per kWh
	Cooling	11.23	DKK per W
Wage			
	Technician	514,180	DKK per year
	Administrative	386,266	DKK per year
	Academic	635,924	DKK per year
Rental costs			
	Building incl. technical houses	481.51	DKK per m² per year
	Building excl. technical houses	482.79	DKK per m² per year
	Land	31.21	DKK per m² per year

Source: DBA

The general costs are located in the spreadsheet named “Dashboard”.

12.4.3 Historical inputs

The LRAIC core network cost model includes all the historical inputs of all relevant data such as:

- The yearly traffic of the different services;
- The number of subscribers of the different services;
- The peak to mean ratio of the different services.

Figure 135 – Extract of the historical inputs

Traffic per service	Unit	2010	2011	2012
PSTN				
Voice - On-net	minutes			1,110,226,201
Voice - IN	minutes			359,818,755
Voice - International - Incoming	minutes			301,632,080
Voice - International - Outgoing	minutes			98,572,812
Voice - International - Transit	minutes			468,792,317
Voice - Incoming fixed off-net	minutes			2,058,355,693
Voice - Transit - Local interconnection	minutes			905,102,749
Voice - Transit - National interconnection	minutes			91,291,032
Voice - Outgoing off-net	minutes			976,102,631
Voice - Incoming Mobile to fixed	minutes			931,438,040
Voice - Incoming Mobile to Outgoing International	minutes			365,630,998
VoIP				
Voice - On-net	minutes			127,090,601
Voice - IN	minutes			41,189,428
Voice - International - Incoming	minutes			34,528,641
Voice - International - Outgoing	minutes			11,283,897
Voice - International - Transit	minutes			53,663,926

Source: DBA

12.4.4 Network topology

In line with the MRP and with the previous model, the updated cost model follows the scorched node approach. Therefore, the topology of the network modelled is TDC's topology. There are two topologies that are included in the model:

- The nodes topology;
- The DWDM network topology.

12.4.4.1 Nodes topology

For each node of the core, the following elements have been provided:

- An ID
- The Central Office ID;
- The aggregation ring;
- The edge ring;
- The parent edge nodes;
- The parent distribution nodes;
- The parent core nodes.

This set of data makes it possible to dimension the network as it provides the relationship between all the nodes of the network.

The location of the network servers and of the MPEG stations is also provided.

Figure 136 – Extract of the network topology

Network nodes	Node name	Are IDs unique?	CO-ID	CO name	Aggregation ring	Edge ring	rent Edge sit	rent Edge site	Parent distribution site 1
Total		VRAI	1183						
per CO									
Ab11	Ålborg 11	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab12	Ålborg 12	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab14	Ålborg 14	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab15	Ålborg 15	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab16	Ålborg 16	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab27	Ålborg 27	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab35	Ålborg 35	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab36	Ålborg 36	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab37	Ålborg 37	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab38	Ålborg 38	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab46	Ålborg 46	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab47	Ålborg 47	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab7	Ålborg 7	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab8	Ålborg 8	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab9	Ålborg 9	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Ab	Ålborg Centrum	VRAI	Ab	Ålborg Centrum	MM2-107-108	MM3-107	ab	sr	ab
Abr	Åbybro	VRAI	Abr	Åbybro	MM2-106-105	MM3-106	bl	hj	ab
Abr2	Åbybro 2	VRAI	Abr	Åbybro	MM2-106-105	MM3-106	bl	hj	ab
Abr3	Åbybro 3	VRAI	Abr	Åbybro	MM2-106-105	MM3-106	bl	hj	ab

Source: DBA

12.4.4.2 DWDM network topology

The DWDM network topology has been provided by TDC.

Figure 137 – DWDM network topology

DWDM link	CO-ID 1	CO-ID 2	Network level	Jse of optical amplifie	CO-ID
DWDM1	Boa	Kj	Edge to Distribution	FAUX	
DWDM2	Kj	Næ	Edge to Distribution	FAUX	
DWDM3	Næ	Alb2	Distribution to Core	FAUX	
DWDM4	Alb2	Boa	Intra Core	FAUX	
DWDM5	Boa	Arc	Intra Core	VRAI	Vig
DWDM6	Arc	Ab	Distribution to Core	VRAI	Hb
DWDM7	Ab	Vg	Edge to Distribution	VRAI	Års
DWDM8	Vg	Arc	Distribution to Core	FAUX	
DWDM9	Arc	Slt	Distribution to Core	FAUX	
DWDM10	Slt	Hr	Edge to Distribution	FAUX	
DWDM11	Hr	Vg	Edge to Distribution	FAUX	
DWDM12	Hr	Es	Edge to Distribution	FAUX	
DWDM13	Hr	Nbl	Edge to Distribution	FAUX	
DWDM14	Es	Nbl	Edge to Distribution	FAUX	
DWDM15	Es	Kd4	Distribution to Core	FAUX	
DWDM16	Kd4	Arc	Intra Core	FAUX	
DWDM17	Kd4	Od	Distribution to Core	FAUX	
DWDM18	Od	Alb2	Distribution to Core	VRAI	Kø

Source: DBA

12.4.5 Design rules

The design rules are the engineering rules or parameters used to dimension the network. They are located in the spreadsheet called “Network dimensioning rules”.

Figure 138 – Design rules parameters

Design rules	Description
Traffic parameters	Parameters used to dimension the traffic
Allowance for growth	Parameters used to taken into account for use
Redundancy parameters	List of the elements that are subject to geographic redundancy
Rack parameters	Size of the racks
CATV parameters	Parameters used to dimension the MPEG stations
Colocation parameters	Size of the racks for colocation
Port capacity	Parameters used to determine the effective port capacity
Power consumption	Parameter to convert the maximum consumption into an effective consumption

Source: DBA

12.4.6 Routing table

The individual values in the routing table specify how much a given service uses a given network asset.

Figure 139 – routing table

Routing matrix	Service category	Aggregation node equipment	Edge node equipment	Distribution node equipment	Core node equipment	Tx path: aggregation ring	Tx path: aggregation to Edge	Tx path: edge ring	Tx path: edge to Distribution	Tx path: distribution to Core	Tx path: intra Core	IMS platform	Inteligent network	PSTN GW	PLMN GW	International GW
Voice																
Voice - On-net	Voice	2.0	2.0	4.0	2.2	2.0	2.0	2.0	2.0	4.0	0.2	1.1	-	-	-	-
Voice - IN	Voice	2.0	2.0	4.0	4.0	2.0	2.0	2.0	2.0	4.0	2.0	1.0	2.0	-	-	-
Voice - International - Incoming	Voice	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	-	1.0	-	-	-	1.0
Voice - International - Outgoing	Voice	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	-	1.0	-	-	-	1.0
Voice - International - Transit	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	2.0
Voice - Incoming fixed off-net - Local interconnection	Voice	1.0	2.0	4.0	1.0	1.0	1.0	1.0	2.0	4.0	-	1.0	-	1.0	-	-
Voice - Incoming fixed off-net - National interconnection	Voice	1.0	2.0	4.0	2.0	1.0	1.0	1.0	2.0	4.0	1.0	2.0	-	1.0	-	-
Voice - Transit - Local interconnection	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	2.0	-	-
Voice - Transit - National interconnection	Voice	-	-	4.0	2.0	-	-	-	2.0	4.0	-	2.0	-	2.0	-	-
Voice - Outgoing off-net	Voice	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	1.0	-	0.7	0.3	-
Voice - Incoming Mobile to fixed	Voice	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	1.1	-	-	1.0	-
Voice - Incoming Mobile to Outgoing International	Voice	-	-	-	-	-	-	-	-	-	-	1.0	-	-	1.0	1.0
Broadband																
Broadband - Internal VULA/BSA	Broadband	1.0	2.0	2.0	1.5	1.0	2.0	1.0	2.0	2.0	0.5	-	-	-	-	-
Broadband - External VULA/BSA - Cabinet	Bitstream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Broadband - External VULA/BSA - Layer 2	Bitstream	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Broadband - External VULA/BSA - Layer 3	Bitstream	1.0	1.0	-	-	1.0	2.0	-	-	-	-	-	-	-	-	-
Broadband - Ethernet Transport - National	Bitstream	-	1.0	2.0	2.0	-	1.0	2.0	2.0	2.0	1.0	-	-	-	-	-
Prioritised																
Prioritised - Unicast - Layer 2	Unicast	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prioritised - Unicast - Layer 3	Unicast	1.0	-	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Unicast - National	Unicast	1.0	1.0	2.0	2.0	1.0	1.0	1.0	2.0	4.0	2.0	-	-	-	-	-
Prioritised - Multicast - uplink - Distr-Edge	Multicast	-	-	1.0	-	-	-	-	1.0	-	-	-	-	-	-	-
Prioritised - Multicast - uplink - POI2-POI1	Multicast	-	1.0	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - Core-Core	Multicast	-	-	-	1.0	-	-	-	-	-	1.0	-	-	-	-	-
Prioritised - Multicast - Core-Distr	Multicast	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-
Prioritised - Multicast - Distr-Edge	Multicast	-	-	1.0	-	-	-	1.0	1.0	-	-	-	-	-	-	-
Prioritised - Multicast - POI2-POI1	Multicast	-	1.0	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - POI1-DSLAM	Multicast	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prioritised - Multicast - DSLAM-End user	Multicast	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leased lines																
LL <= 2 Mbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-
LL <= 1 Gbps & > 2 Mbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-
LL > 1 Gbps	Leased lines	1.0	1.0	1.0	1.0	0.5	1.0	0.5	1.0	1.0	1.0	-	-	-	-	-

Source: DBA

12.4.7 Leased lines

The leased lines input is the results of the leased lines analysis carried out in the file "2012-55-DB-DBA-Fixed LRAIC-Leased Lines".

For each Central Office, this spreadsheet provides for the following data:

- The number of leased lines (split between leased lines with a capacity below 2 Mbps, leased lines with a capacity between 2 Mbps and 1 Gbps and leased lines with a capacity above 1 Gbps);
- The traffic generated by the leased lines at each level (aggregation, edge, distribution, core and intra-core).

Figure 140 – Extract of the leased lines table

Leased lines		Aggregation ring	Edge ring	er of LL <= 2umber of LL <= 1 Gbps & > 2 Mb		Number of LL > 1 Gbps	Traffic at aggregation	Traffic at edge
				#		#	Mbps	Mbps
Total				14,742	34,376	312	273,611	236,137
per CO								
	Ab	MM2-107-108	MM3-107	4	3	-	2,4	2,0
	Abr	MM2-106-105	MM3-106	3	28	-	180	-
	Abs	MM2-107-108	MM3-107	8	48	-	317	-
	Abv	MM2-107-108	MM3-107	49	188	-	1,093	-
	Aby	MM2-304-105	MM3-304	3	4	-	27	-
	Abøs	MM2-107-109	MM3-107	32	137	-	953	-
	Ac	MM2-201-105	MM3-201	4	48	-	166	-
	Ad	MM2-107-104	MM3-107	3	4	-	8	-
	Adp	MM2-103-108	MM3-103	2	2	-	11	-
	Ag	MM2-109-102	MM3-109	3	18	-	37	-
	Ags	MM2-107-101	MM3-107	-	-	-	-	-
	Agt	MM2-106-109	MM3-106	-	-	-	-	-
	Agø	MM2-303-104	MM3-303	-	-	-	-	-
	Ahj	MM2-106-102	MM3-106	-	-	-	-	-
	Aiu	MM2-106-112	MM3-106	2	4	-	22	-
	Al	MM2-109-101	MM3-109	2	12	-	55	931
	Alb2	MM2-308-101	MM3-308	653	300	16	4,615	15,089
	Ald	MM2-201-112	MM3-201	1	2	-	4	-
	Ali	MM2-303-107	MM3-303	1	-	-	2	-
	All	MM2-302-101	MM3-302	10	4	-	88	-
	Alr	MM2-303-109	MM3-303	1	4	-	20	-
	Als	MM2-107-107	MM3-107	2	6	-	26	-
	Alv	MM2-102-104	MM3-102	1	4	-	10	-
	Alø	MM2-201-106	MM3-201	1	2	-	6	-
	Am	MM2-104-104	MM3-104	11	62	-	331	-
	Amb	MM2-310-102	MM3-310	144	502	2	4,201	0

Source: DBA

12.4.8 Colo and other services

The “colo and other services” spreadsheet contains the:

- The resources needed for each regulated service in terms of man-work;
- The assets needed for each regulated service;
- The unit costs of the assets for the regulated services.

12.4.8.1 Resources

The resources table lists for each colocation and other services:

- the man-work required by technicians, administrative workers and academics;
- the quantity of assets needed.

Figure 141 – Extract of the colocation and other services resources table

Resources per service	Administrative	Administrative	Administrative	Administrative
	Processing of order	Customer service	Installation	Testing and monitoring/supervision
LLU				
New Installation- Unassisted	6	-	-	-
New Installation- Ingineer assisted	6	-	-	-
Inquiry	-	-	-	-
New setup	-	-	-	-
Physical rearrangement	-	-	-	-
Change to trunk number	10	-	-	-
Visit by technician	-	-	-	-
Cancellation-fee II	11	-	-	-
Calculation of attenuation on the line	3	-	-	-
Unproductive fault handling	5	-	-	-
Raw copper -full loop: migration to full loop from BSA	6	-	-	-
Raw copper -full loop: migration to full loop from Shared Raw	6	-	-	-

Source: DBA

12.4.8.2 Yearly costs for regulated services

The co-location and other services use assets for which the yearly costs are based on TDC's regulatory accounts. The model includes 61 assets:

Figure 142 – Extract of the regulated assets description

Regulated assets	Unit	ID
IT		
IT Cost (Columbus)		Asset146
IT Cost (Columbine)		Asset147
Other		
Unproductive interconnection in distributor		Asset148
Unproductive interconnection in socket		Asset149
New equipment		Asset150
Equipment for closets		Asset151
Visit at E-customer		Asset152
Visit at E-customer (extraordinary visit)		Asset153
Cables PDS 2*cat per 10 meter	per 10 meters of cable	Asset154
Cables PDS 10*cat per 10 meter	per 10 meters of cable	Asset155
Cables 12 fibre pairs (SM) per 10 meter	per 10 meters of cable	Asset156
Cables 12 fibre pairs (SM) per 10 meter (Internal)	per 10 meters of cable	Asset157
Cables 8 coax pairs per 10 meter	per 10 meters of cable	Asset158
Cables 24 coax pairs per 10 meter	per 10 meters of cable	Asset159
Cables 100 copper pairs per 10 meter	per 10 meters of cable	Asset160

Source: DBA

12.4.9 Non-network costs

The LRAIC core network cost model includes non-network costs such as the network management system, the overheads and the interconnection and commercial specific costs. These costs are used to compute a mark-up following the EPMU approach.

Figure 143 – Extract of the Network Management System description

Non-network resource	Unit
NMS for DSL	DKK
NMS for copper	DKK
NMS for IP	DKK
NMS for CATV	DKK
NMS for fibre	DKK
NMS for switches	DKK

Source: DBA

12.5 List of services

12.5.1 List of colocation services

Figure 144 – List of co-location services

Group	Service	Resource category	Description
LLU	Re-establising trunks	Processing of order	Registration in CU
		Installation	Connection on central
		IT-cost	Columbus IT-cost
	Cancellation fee II	Processing of order	
		Installation	Coupling in exchange
	Calculation of attenuation on the line	Processing of order	
		Installation	Coupling in exchange
	Migration of 30 or more connections in an project	Processing of order	Allocation of conduction path in DOK
		Installation	Connection of local loop or BSA
		Transport and installation	Driving to central
		Customer service	
		IT-cost	Columbus IT-cost
LLU backhaul	Interconnection of fibre pairs in optic distributor	Interconnection of fibre in optic distributor	

Group	Service	Resource category	Description
	between points of termination	Other material	
	Interconnection of fibre pairs in socket (splicing) between points of termination	Splicing	
		Other material	
		Splicing hole (contractor)	
		Opening and closing of socket	
	Cancellation fee pr. fibre pair or tube	Customer service	
		IT-cost	Columbus IT-cost
		Unproductive interconnection in distributor	
		Unproductive interconnection in socket	
	Debugging per hour	Testing and monitoring/supervision	
	Measurement report for fibre pairs	Projecting and planning	Measurement and delivering
Common for LLU and BSA	Fall back Express on GDS	Customer service	
		Transport, installation and Testing and monitoring	
		IT-cost	Columbus IT-cost
		IT-cost	Columbine IT-cost
Raw fibre BTO	Tender pr. end customer	Customer service	
		Processing of order	Operations receives order and gives offer
		IT-cost	Columbus IT-cost
Leased lines	Upgrade and speed change - both services (remote)	Customer service	
		Processing of order	Operations receives order, perform upgrade and registrer in inventory system
		IT-cost	Columbus IT-cost
	Change of interface	Customer service	
		Installation	Driving to customer

Group	Service	Resource category	Description
	without change of modem		and central including work at customer and at central
		Projecting and planning	Projection receives order, performs projection and registrer in inventory system
		IT-cost	Columbus IT-cost
	Change of interface + change of modem	Customer service	
		Installation	Driving to customer and central including work at customer and at central
		Projecting and planning	Projection receives order, performs projection and register in inventory system
		IT-cost	Columbus IT-cost
	Acquisition. 1. line	Customer service	
		Processing of order	Operations receives order and re-registrer in inventory system
		IT-cost	Columbus IT-cost
	Acquisition. 2. and consecutive lines	Processing of order	Operations receives order and re-registrer in inventory system
		Processing of order	Registration in CU
		IT-cost	Columbus IT-cost
Common for capacity (raw fibre BTO, leased lines and Ethernet transport)	Extra inspection between 07 AM and 6 PM	Processing of order	Registration in CU
		IT-cost	Columbus IT-cost
		Installation	Visit at E-customer
	Additional fee for inspection between 6 PM abd 7 AM	Processing of order	Registration in CU
		IT-cost	Columbus IT-cost
		Installation	Visit at E-customer (extraordinary visit)
	Cancellation fee, order received	Customer service	Processing in customer service
		Annulment fee	

Group	Service	Resource category	Description
		Customer service	Customers signup is deleted in inventory system
		Projecting and planning	
		IT-cost	Columbus IT-cost
	Postponement fee, order received	Customer service	Processing in customer service
		Processing of order	Operations receives postponement and replans the execution
		IT-cost	Columbus IT-cost
	Postponement fee, later than one week before confirmed delivery	Customer service	Processing in customer service
		Processing of order	Operations receives postponement and replans the execution
		IT-cost	Columbus IT-cost
	Postponement fee, at point of delivery	Customer service	Processing in customer service
		Processing of order	Operations receives postponement and replans the execution
		IT-cost	Columbus IT-cost
		Installation	Unproductive visit by technician
	Unwarranted claim for debugging, transmission	Testing and monitoring/supervision	Debugging: Receives invoice and documentation from technician regarding unjustified debugging. Is then processed and checked in FAS and subsequently inputted in Columbus before send to operator
		Transport	Driving to end customer and unproductive debugging
		IT-cost	Columbus IT-cost

Group	Service	Resource category	Description
Ethernet transmission (eBSA)	Establishment of relation between 2 layer 2 rings (from POI2 to POI3), with 1000Mbit/s capacity	Processing of order	Manual processing of order and
		Processing of order	Operations receives order, process the order and registrer in inventory system
		IT-cost	Columbus IT-cost
	Establishment of national solution relation BE, AF and EF. EF is established to also support single channel solutions (802.1P)	Processing of order	Manual processing of order
		IT-cost	Columbus IT-cost
		Processing of order	Operations receives order, perform planning and solution and register in inventory system
	Change of capacity	Processing of order	Manual processing of order
		Processing of order	Operations receives order, perform the changes and process the registration in inventory system
		IT-cost	Columbus IT-cost
Bit Stream Access (eBSA and common for eBSA, VULA and Fibre BSA)	Change of speed	Processing of order	
		Testing and monitoring/supervision	Provisioning/calculation of attenuation on the line
	Move	Processing of order	
		Installation	Physical coupling in exchange and visit at end user
		Transport	Transport time to exchange and transport time to end user
	Change GDS between PSTN and ISDN	Processing of order	
		Installation	Physical coupling in exchange and visit at end user
		Transport	Transport time to

Group	Service	Resource category	Description
			exchange and transport time to end user
	Unproductive visit (Technician)	Installation	Unproductive visit by technician
	Cancellation	Customer service	Customer service receives the order electronically and types into Columbus. Project centre receives annulment via Columbus (customer calls the retailer who types in the annulment order)
		Annulment fee	
		IT-cost	Columbus IT-cost
		IT-cost	Columbine IT-cost
	Mac addresses 32/64	Processing of order	Provisioning in Operations, i.e. receiving the mail, provisioning a number of MAC addresses, answering mail
		Customer service	Customer service redirect mail to operations and invoice manually
		IT-cost	Columbus IT-cost
	Convertion between eBSA and ATM BSA	Processing of order	
		Installation	Physical coupling in exchange, Switching in DSLAM and ATM network
		Transport	Transport time to Exchange and ATM network
Bit Stream Access specifically for Multicast	Specification of parameters in multicast setup in relation to the establishing	Processing of order	Specification of parameters and in typing in inventory system

Group	Service	Resource category	Description
	a customer		
	Implementation of specific customer.	Projecting and planning	Implementation of solution and inputting in inventory system and planning of solution
Co-location	Inquiry	Processing of order	
	Offer	Processing of order	
	Trunk cables PDS 2*cat.5 Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Trunk cables PDS 2*cat.5 per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Trunk cables PDS 10*cat.5 Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Trunk cables PDS 10*cat.5 per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Trunk cables 12 fibre pair (sm) Installation	Processing of order	Receiving and visitations of order. The order is executed is the

Group	Service	Resource category	Description
			relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
		Pathpanel material	
	Trunk cables 12 fibre pair (sm) per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm PDS 2*cat.5 Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm PDS 2*cat.5 per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm PDS 10*cat.5 Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm PDS	Installation	Measuring and cable installation

Group	Service	Resource category	Description
	10*cat.5 per 10 m	Cable	
		installation of cable tray	
	Internal cabling mm 12 fibre pair (sm) Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm 12 fibre pair (sm) per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm 8 Coax pair Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm 8 Coax pair per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm 24 coax pair Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration

Group	Service	Resource category	Description
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm 24 coax pair per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm 100 copper pair Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm 100 copper pair per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Internal cabling mm 3*100 copper pair Installation	Processing of order	Receiving and visitations of order. The order is executed is the relevant section and is registered and invoiced in Columbus.
		Projecting and planning	Projecting and registration
		Transport	
		IT-cost	Columbus IT-cost
	Internal cabling mm 3*100 copper pair per 10 m	Installation	Measuring and cable installation
		Cable	
		installation of cable tray	
	Technical house led/cover - delivery of	Cover/led per section	

Group	Service	Resource category	Description
	led/cover		
	Technical closet in technical house - installation	Projecting and planning	Projecting and planning, including digging request and documentation
		Testing and monitoring/supervision	
		Purchase and delivery of DSL cabinet	
		Installation of DSL closet	
	Technical closet in technical house - Monitoring and battery check	Testing and monitoring/supervision	Check of batteries, repair of graffiti etc.
		New equipment	
	Technical closet in technical house - 48 VDC 100W. Installation of point outlet with cable and fuse	Transport	
		Installation	Technician and installation
	Technical closet in technical house 48 VDC 100W - Each year inclu. Utilities	Utilities (power, depreciation, debugging)	
Co-location, specifically for closets	Delivery and installation of DSL closet without co-production	Projecting and planning	Projecting and planning, including digging request and documentation
		Testing and monitoring/supervision	
		Purchase and delivery of DSL cabinet	
		Installation of DSL closet	
	Delivery and installation of	Purchase and delivery of DSL cabinet	

Group	Service	Resource category	Description
	DSL closet with co-production	Installation of DSL closet	
		Projecting and planning	Projecting and planning, including digging request and documentation
		Testing and monitoring/supervision	
	230 VAC, 4A supply incl. Fuse og monitoring device	Installation	
		230 VAC interconnection cable, contractor fee	
		Earthing and cable	
		Interconnection fee to utility company	
		Monitoring device	
		Monitoring device incl. UG frame	
	1x100 pair cables and fibre trunk incl. Digging and termination of 1x100 copper pairs and 4 fibres	Installation	Cobber trunk, 1x100 pair, hours á
		Copper trunk, 1x100 pair 10m. , materials	
		Fibre trunk, cable+tube 10m. + connector	
		Fibre trunk, termination of 4 fibres in the end (TDC)	
		Fibre splicing	
		Cost of digging pr. Meter	
	1x100 pair cable with termination at TDC	Installation	Cobber trunk, 1x100 pair, hours á
		Copper trunk, 1x100 pair 10m. , materials	
		Cost of digging pr. Meter	
	Fibre trunk with termination of 4 fibres i	Copper trunk, 1x100 pair 10m. , materials	
		Fibre trunk,	

Group	Service	Resource category	Description
	distributor at TDC	cable+tube 10m. + connector	
		Fibre splicing	
		Cost of digging pr. Meter	
	Fibre trunk with termination of 4 fibres in socket (splicing) at TDC	Fiber trunk, cable+tube 10m.	
		Splicing hole	
		Handling of socket	
		Fibre splicing	
		Other material	
		Cost of digging pr. meter	
Common for LLU and BSA	Manual order	Customer service	Customer service receives the order electronically and types into Columbus
Exchange of traffic	Pre fix for switched interconnection, basic fee, implementation	Customer service	Customer service process the order and typed into Columbus and send to Net Planning. Customer service invoice the order in Columbus after ending the implementation
		Projecting and planning	
		Processing of order	Sales division performs the order at prefix implementation
		IT-cost	Columbus IT-cost
	Pre fix for switched interconnection, per central, implementation	Customer	Customer service invoices the order in Columbus after ending the implementation. Customer service moreover process the order and typed into Columbus and send to Net Planning
		Projecting and	Net planning

Group	Service	Resource category	Description
		planning	investigate the amount of relevant centrals and performs operator status
		Processing of order	Sales division performs the order of prefix implementation
		IT-cost	Columbus IT-cost
	Pre fix with same routing as established pre fix from same operator for switched interconnection, per central , implementation	Projecting and planning	Net planning process order and plan prefix implementation per Central Office. Moreover, Station data performs central data for prefix per central
	Pre fix for switched interconnection, per central, change	Projecting and planning	Net planning process order and plan prefix implementation per Central Office. Moreover, Station data performs central data for prefix per central
	Pre fix with same routing as established pre fix from same operator for switched interconnection, per central, change	Projecting and planning	Net planning process order and plan prefix implementation per Central Office. Moreover, Station data performs central data for prefix per central
	Pre fix for local interconnection, per central, change	Projecting and planning	Net planning process order and plan prefix implementation per Central Office. Moreover, Station data performs central data for prefix per central
Colocation	Hourly rate for re-registration of co-location, e.g. from quarterly to	Processing of order	

Group	Service	Resource category	Description
	monthly payment of rent		
Cables	Processing of inquiry on cables, per hour	Processing of order	Processing of a request of for cable tube, per hour
Fibre BSA	Digging/blowing per meter, above 30 meters, per meter	Processing of order	
		IT-cost	Columbus IT-cost
		IT-cost	Columbine IT-cost
Resources Co-location specific site cost	Room fit-out	Testing and monitoring/supervision	Fire alarm - installation

Source: DBA

12.5.2 Mapping between the core voice services of the previous model and the actual model

The mapping between the voice services of the two models is done in the following table. As the network modelled is an “all-IP” core network, only VoIP services have been kept.

Figure 145 – Mapping of voice services

New model	Previous model
Voice - On-net	Local call + National call + Duet to fixed + Duet to VMS
Voice - IN	IN Basic @ Internet + IN Basic other + IN advanced + Dir enq & emerg calls (operator services)
Voice - International - Incoming	International in
Voice - International - Outgoing	International out
Voice - International - Transit	International transit
Voice - Incoming fixed off-net - Local interconnection	Local IC + IC own area + IC other area : the voip local call notion is different than in the PSTN one
Voice - Incoming fixed off-net - National interconnection	Local IC + IC own area + IC other area : the voip local call notion is different than in the PSTN one
Voice - Transit - Local interconnection	IC transit within area
Voice - Transit - National interconnection	IC transit between areas
Voice - Outgoing off-net	Fixed to other network + Duet to fixed
Voice - Incoming Mobile to fixed	Mobile to fixed
Voice - Incoming Mobile to Outgoing International	Mobile to International

Source: DBA