Modification and development of the LRAIC model for fixed networks 2012-2014 in Denmark

MEA ASSESSMENT

Danish Business Authority

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Summary

0 Introduction

The Danish Business Authority ('DBA') has commissioned TERA Consultants to modify and develop the LRAIC model for fixed networks in Denmark for the period 2012-2014. This project is built along 4 main phases[1]: 1) preparation of a Model reference paper, 2) Revision and development of LRAIC model, 3) Model circulation and 4) Setting of maximum prices.

As part of the first phase of this project, the present report aims at identifying the Modern Equivalent Assets (MEA) for fixed access networks. Specifically, the report aims at finding the MEA of copper and cable TV access networks and of PSTN networks. Identifying relevant MEA is key to define the asset and technologies that will be modelled during the project. Indeed, the Price Control Order[2] specifies that, when the LRAIC approach is the preferred approach to assess the costs of regulated products, efficient modern technologies must be used:

> *"(1) Where the LRAIC pricing method is used; the total price for a network access product may not exceed the sum of the long-run average incremental costs associated with the network access product in question.*
>
> *(2) **Only efficiently incurred costs may be included, using efficient modern technologies**."*[3]

This report is a consultation document setting out DBA's preliminary views on the MEA assessment. Industry's responses to this consultation will allow DBA to reach a final view on the MEA assessment. Once the MEA assessment has been conducted and technologies to be modelled have been identified, DBA will be in a position to prepare the Model Reference Paper (phase 1 of the project).

During the kick-off meeting with the industry which took place on DBA premises on the 23rd of January 2013, some operators raised the point that it would be difficult to provide meaningful responses to the issue at stake (MEA assessment) in absence of a detailed context. Therefore, before conducting the MEA assessment, the report first specifies the context and the definition of MEA in section 1. It is also important to keep in mind that the goal of this report is not to determine the methodology to be used to set regulated prices. This will be conducted in phase 4 of the project (which will occur in the 2nd half of 2014), once the model has been developed. Whether the (bottom-up) LRAIC approach will be selected for some or all assets being part of the regulated products, the development of LRAIC models is of high importance for DBA to understand the costs of providing services looking forward and therefore the MEA assessment remains a key prerequisite.

The remainder of this report is laid out as follows:

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

[2] Source: DBA, Executive Order on Price Control Methods, Section 2, dated 27 April 2011

[3] Source: DBA Executive Order on Price Control Methods, Section 3, dated 27 April 2011

- Section 1 will specify the context and the definition of MEA;
- Section 2 will address the question of whether FTTH is the MEA for copper and cable TV;
- Section 3 will address the question of whether VoIP is the modern equivalent technology of PSTN;
- Section 4 is the conclusion of the report.

1 Context and MEA definition

1.1 Legal context

As part of its responsibilities, DBA is in charge of the supervision of the telecommunications companies in the form of price control, regulatory accounts to meet obligations of accounting separation and cost accounting as support for the network access price control. DBA may therefore require providers with Significant Market Power (SMP) to meet certain pricing requirements.

According to the Price Control Order[4], the following price control methods can be used by DBA to set cost-oriented prices:

- The long-run average incremental cost (LRAIC) method;
- Historic cost accounting (HCA);
- Retail minus; and
- Requirements for reasonable prices.

Since 2003 DBA has determined maximum prices for TDC, which has been designated as SMP operator, annually by means of the LRAIC method on a number of fixed network markets, including:

- Wholesale market for fixed network origination (market 2);
- Wholesale market for fixed-network termination (market 3)[5];
- Wholesale market for physical network infrastructure access (market 4);
- Wholesale market for broadband access (market 5).

In the context of setting out a decision on maximum prices to take effect on 1 January 2015, DBA is in the process of revising the LRAIC model that has been used up to now. As an element in preparing for this modelling work DBA analyses which efficient modern technology shall be further considered. Indeed, the Price Control Order states that:

> *"(1) Where the LRAIC pricing method is used; the total price for a network access product may not exceed the sum of the long-run average incremental costs associated with the network access product in question.*
>
> *(2) **Only efficiently incurred costs may be included, using efficient modern technologies**."*[6]

[4] Source: DBA, Executive Order on Price Control Methods, Section 2, dated 27 April 2011

[5] Several other operators are LRAIC-based regulated for market 3

[6] Source: DBA Executive Order on Price Control Methods, Section 3, dated 27 April 2011

In electronic communications, market trends and technologies evolve fast. The definitions of modern technologies and of the MEA therefore need to be updated regularly.

As a consequence, if regulated prices are set on the basis of the (bottom-up) LRAIC method[7], modern equivalent technologies and assets need to be identified. In light of the legal framework in Denmark, the LRAIC and MEA concepts are very closely related.

1.2 Definition of the MEA

According to DBA's model reference paper dated 18 September 2008, the MEA is defined as follows:

> *"The MEA is the asset that can produce the stream of services produced by the existing asset at lowest cost. Where the operating cost or other performance characteristics of the MEA differ from the existing asset, these should be reflected in the asset valuation."*[8]

Considering this definition, two potential interpretations are possible:

- Considering in particular the first sentence, it can be understood that the cheapest assets or technologies should be considered only. That is to say, if coax is cheaper than copper and fibre, then coax is the MEA.
- Considering the full definition in total, it can however be understood that the technology that would be selected to replace an existing technology should be chosen. This technology could have slightly higher investment costs but could have much more capabilities and performances. This is typically the technology which a new operator deploying a network today would choose. Therefore, reflecting this in the asset valuation could lead to the conclusion that this more expensive technology is the MEA.

This latter definition is retained by DBA. This suggests that on top of the analysis of whether the asset produces the same type of services as the existing asset at lowest cost, it is also necessary to look at operating costs and other performance characteristics in order to determine what the MEA is. Such an understanding is in line with other MEA definitions and enables DBA to be consistent with other European countries. Indeed, the ERG (now BEREC) stated in 2005:

> *"Gross MEA value is what it would cost to **replace an old asset with a technically up to date new one with the same service capability, allowing for any differences both in the quality of output and in operating costs**. For the replacement cost valuation to be appropriate it is not necessary to expect that the asset will actually be replaced.*

[7] As explained in the introduction, other methods are available to DBA

[8] Source: NITA, Model reference paper dated 18 September 2008, p.27.

> *The new technologies are usually superior in many aspects to the older technologies in terms of functionality and efficiency. However, since MEA values are required to reflect assets of equivalent capacity and functionality**, it may be necessary to make adjustments to the current purchase price** and also the related operating costs - for example, the new asset may require less maintenance, less energy and less space. Other adjustments may also be required in the calculation of current costs, e.g. surplus capacity."*[9]

The ITU also states that the MEA value shall reflect the cost that a new efficient operator would face.

> *"Modern Equivalent Asset (MEA) should be used whenever it is possible, as it is the most accurate valuation criterion to **reflect the cost of an efficient operator**, since it will **capture the associated costs (and efficiencies) that an entrant/alternative operator would face**, if entering into the market at a specific time.*
>
> *This valuation criterion is accurate when besides a technical change; the asset with the same functionalities is no longer being marketed. Therefore, the aim is to calculate the **cost of an analogous (replacement) asset**."*[10]

In other industries, regulatory authorities[11] define the MEA in the same way.

Therefore, based on these definitions, this report will assess the MEA of a new efficient operator which decides to enter the market and which does not benefit of an infrastructure in place when making its decision. This report will therefore define the MEA as the asset that a new operator taking efficient decisions would take today to deploy a new network.

1.3 Why using the MEA concept?

The MEA concept enables to calculate the cost that a new efficient operator investing today in fixed electronic communications networks would face.

From a regulatory point of view, the MEA concept can be very useful as:

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[9] Source: ERG Common Position: Guidelines for implementing the Commission Recommendation C (2005) 3480 on Accounting Separation & Cost Accounting Systems under the regulatory framework for electronic communication

[10] Source: ITU Regulatory accounting guide, March 2009, p.18

[11] *"The gross MEAV represents the equivalent replacement cost of the asset and should reflect both the most technically up to date new asset and the most technically up-to-date method of constructing that asset."* Source: Water commission-UK, Scottish Water First Draft Business Plan – Guidance, Appendix B, p.10

"The gross capital cost of replacing an existing asset with a technically up-to-date new asset with the same service capability" Source: OFWAT, glossary of terms, p.26

- It enables regulatory authorities to better understand costs looking forward;
- It calculates efficient costs and therefore enables the DBA to make sure that operators buying access to a regulated asset are not paying for the inefficiencies of the regulated operator;
- It enables the DBA to send appropriate "build or buy" signals. Indeed, as the regulated prices to access to the assets are set on the basis of the MEA, it is equivalent for an alternative operator to buy access or to build an equivalent asset which therefore does not deter investment in alternative and promotes infrastructure based competition. This is one of the key aspects of the MEA definition. This aspect would not be achieved if the definition of the MEA was only referring to the lowest cost technology.

One of the potential drawbacks of this concept is that it is not necessarily linked to the costs actually incurred by the regulated operator. Also, in areas where alternative operators are unlikely to deploy alternative infrastructures, the MEA and LRAIC concepts may be less relevant for price setting. However, as noted in the introduction, these comments are mentioned here only to better specify the context but these issues will be discussed in the last phase of the project in more details.

2 Is FTTH the MEA for copper and/or cable TV?

2.1 Context

During the development of the latest LRAIC model for the fixed network in 2010-2011, it was concluded that FTTH was not the MEA for neither copper nor cable TV. The reasons for this included that FTTH was not the cheapest technology for supplying the services requested; that the actual availability of fibre connections was limited; and that the consumers did not to a sufficient degree demand services that required speeds necessitating a fibre network.

Since then, the market has evolved at a quick pace and a new assessment is required. The need for the MEA assessment is all the more necessary as Commissioner Neelie Kroes mentioned on 12 July 2012[12] that fibre is an appropriate MEA for copper. Through the analysis of different criterions, this report will first focus on whether fibre is to be regarded as MEA for copper and/or cable TV for the access network (see section 2.2). Then the report highlights the impact of the MEA choice on prices (see section 2.3).

2.2 MEA assessment

The MEA assessment is carried out through the analysis of the different criterion that enable the DBA to determine what the MEA of copper and cable TV access networks should be and by considering the following issues:

- Can products based on fibre essentially replace similar products based on copper/cable TV (see section 2.2.1, technological criterion)?
- Comparison of the costs for rollout of fibre networks and copper/cable TV networks respectively (see section 2.2.2, cost criterion).
- Does the observed market behaviour support an assumption of fibre as MEA? This issue is handled through the analysis of the subscriber criterion (see section 2.2.3); the operator's strategy criterion (see section 2.2.4) and the retail price criterion (see section 2.2.5).
- What are the best practices in terms of MEA assessment in other European countries (see section 2.2.6)?

As explained in section 1.2, the question at stake is by which technology an operator today would replace copper or cable TV access network, and especially if FTTH is the MEA of copper and cable TV. For more clarity, the word "FTTH" will be used instead of "fibre" in this report, where relevant, to designate an access network made of fibre from

[12] Source: http://europa.eu/rapid/press-release_MEMO-12-554_en.htm

the end user to the entry point of the core network. Fibre cables can indeed be used in many types of access networks (cable TV, FTTH, FTTC, etc.) and this could generate misinterpretations. The question at stake is therefore: “is FTTH the MEA for copper and/or cable TV?”

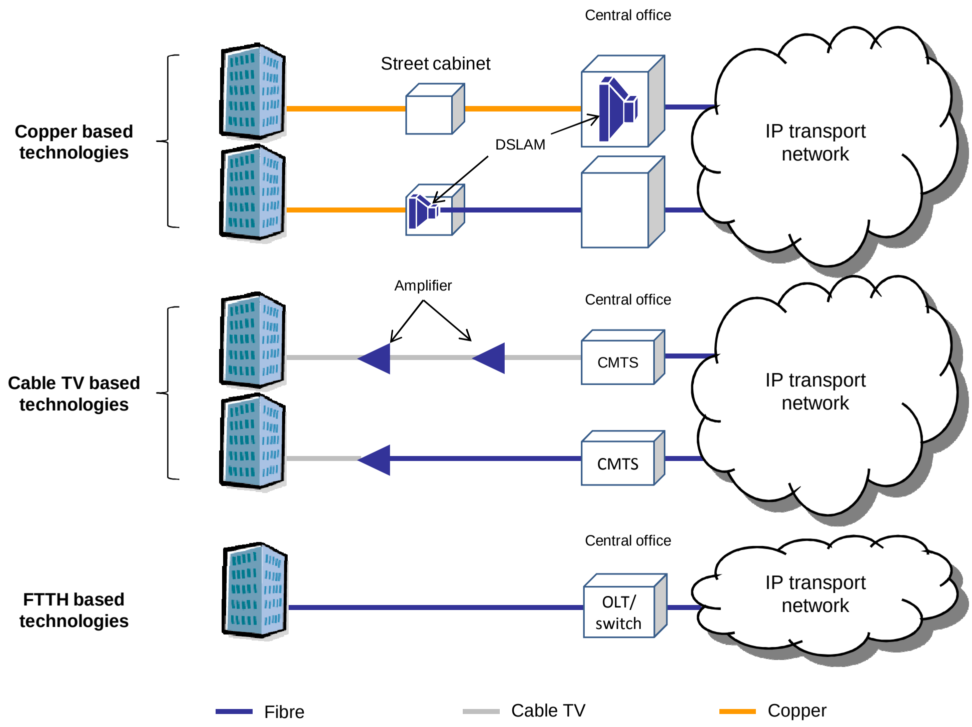
Mobile technologies such as LTE are not considered in this assessment firstly because they are not fixed network technologies, secondly because they are using a medium that is shared to a much more significant extent than fixed networks and thirdly because mobile usage tends to be significantly different than fixed usage.

2.2.1 Technological criterion

Several access network technologies providing fixed electronic communications services (leased lines, voice, broadband, IPTV, etc.) may be present today in the same given geographic area in Denmark:

- **Copper access network** operated by TDC. The copper infrastructure may be used from the access node to the end-user or from the street cabinet to the end-user when fibre has been laid down from the access node to the street cabinet (see section 2.2.1.1).
- **Cable TV access network** operated by TDC through the brand YouSee or by Stofa. The coax technology may be used from the optical node to the end user or from the last amplifier to the end-user when fibre has been laid down from the optical node to the last amplifier (see section 2.2.1.2).
- **FTTH access network** operated by Danish utilities mainly through the brand Waoo! and TDC thanks to the acquisition of DONG’s network. In this situation, fibre is deployed from the central office to the end-user (see section 2.2.1.3).

Figure 1 – Fixed access network technologies



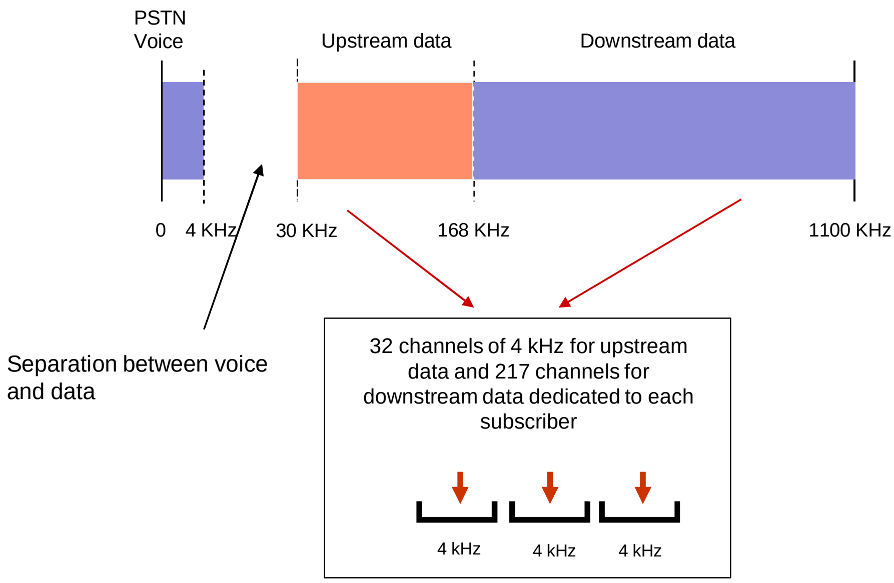
Source: TERA Consultants

The performance of each access network technology is assessed in the next sections. These have been collected thanks to publicly available information but industry may have additional information to complement this (this can be provided as part of the consultation phase).

2.2.1.1 Copper access network

Broadband transmission on the copper access network is achieved through DSL technologies and the sharing of the bandwidth available to the different services, including voice, downstream data and upstream data: from 0 KHz to 1,104 KHz, distributed in 256 channels of 4 KHz.

Figure 2 – Structure of the bandwidth available on copper



Source: TERA Consultants

Mainly two types of DSL technologies are available to operators today:

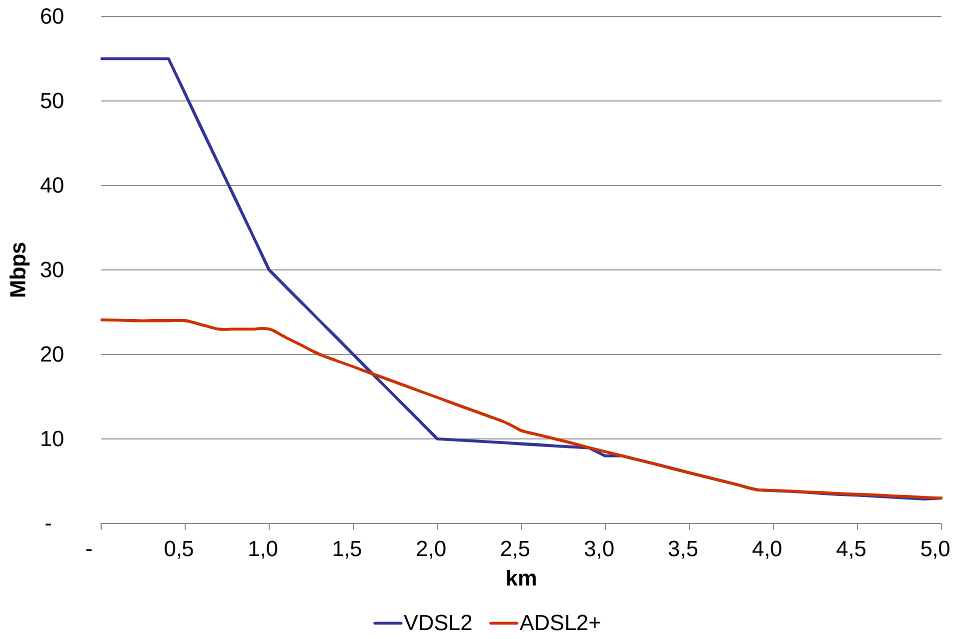
- **ADSL2+** where the DSLAM, which is the active equipment, is generally located at the central office. This technology enables to deliver theoretically up to 24 Mbps downstream and 1.5 Mbps upstream[13].
- **VDSL2** where, in general, fibre is deployed to the street cabinet and the DSLAM is located at the street cabinet (can also be provided from the central office but VDSL2 is more efficient for short distances). This technology enables to deliver theoretically approximately up to 50 Mbps downstream and approximately 5 Mbps upstream[14].

It is to be noted that these downstream and upstream performances are achieved only when the end-user is adjacent to the central office or cabinet where the active equipment is installed. Indeed, for DSL technologies, the higher the line length, the more performances in terms of downstream and upstream capacity are mitigated. In light of the Shannon theorem which specifies the theoretical limit, it appears that it is worth to implement VDSL2 only in areas with short copper loops.

[13] Source: ARCEP, Etude sur le très haut débit: nouveaux services, nouveaux usages et leur effet sur la chaîne de la valeur, February 2012 and FTTH Council Europe, FTTH business guide dated 16th January 2011

[14] Source: ARCEP, Etude sur le très haut débit: nouveaux services, nouveaux usages et leur effet sur la chaîne de la valeur, February 2012

Figure 3 – Line speed mitigation of VDSL2 and ADSL2+



Source: ARCEP[15]

Nevertheless, for both technologies, some techniques enable to substantially increase the downstream and upstream performances:

- **Pair bonding** which consists in combining logically two copper pairs which double capacity available per household. The downstream capacity can then reach up to 100 Mbps and the upstream capacity up to 10 Mbps[16]. One of the main drawbacks of this technique is that it requires two copper pairs and a new Customer-Premises Equipment (CPE).
- **Vectoring** achieved on VDSL2 lines, cancels noise that is created by crosstalk, a phenomenon that occurs in bundles of copper pairs typically deployed in telecommunications access networks. This technique enables to reach up to 100 Mbps downstream and 10 Mbps upstream for loops which length does not exceed 400 meters[17]. This solution has the clear benefit of being an enhancement of the existing VDSL2 technology which is already available.
- **Phantom mode** which combines the benefits of vectoring and bonding multiple pairs on VDSL2 lines. Even though this technology enables up to 300 Mbps

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[15] Source: ARCEP, Etude sur le très haut débit: nouveaux services, nouveaux usages et leur effet sur la chaîne de la valeur, February 2012 and Ericsson, VDSL2 Next important broadband technology, Review No.1, 2006.

[16] Source: Heavy Reading, DSL acceleration: making it work, June 2012

[17] Source: Alcatel Lucent - VDSL2 Vectoring: The Broadband Accelerator http://www.alcatel-lucent.com/solutions/vdsl2-vectoring-broadband-accelerator

downstream capacity[18] in principle, it may be too expensive and too complex to implement for the time being, as this solution has not been standardized yet.

The table below shows the speed achieved by some operators in Europe with VDSL2 during trials.

Table 1 – Minimum downstream achieved on VDSL2 lines with and without vectoring

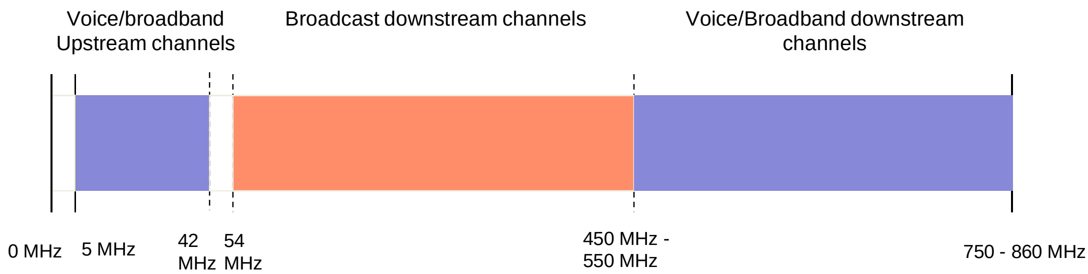
Operator	Trial loop length (Meters)	Downstream minimum speed, no vectoring (Mbps)	Downstream minimum speed, with vectoring (Mbps)
Swisscom	500	24	66
P&T Luxembourg	529 to 613	30	57
Deutsche Telekom	450	53	92
Slovak Telekom	505	52	90
Belgacom	500	20	65

Source: Heavy Reading specifying operators' results of preliminary lab and field test[19]

2.2.1.2 Cable TV access network

Regarding cable TV access network, it is first noted that this type of infrastructure is much less sensitive to electromagnetic disturbances compared to copper infrastructures. This therefore allows much higher distances between the central office, where the main active equipment (CMTS, MPEG station) is located and the end-user. This technology also uses significantly higher bandwidth: from 5 MHz to 750 MHz and sometimes even up to 860 MHz, *i.e.* more than 750 times copper's bandwidth.

Figure 4 – Structure of the bandwidth available on cable TV



Source: TERA Consultants

[18] Source: Alcatel http://www3.alcatel-lucent.com/features/phantom/

[19] Source: [19] Source: Heavy Reading, DSL acceleration: making it work, June 2012

For cable TV access network, transmission is mainly handled through DOCSIS technology that exists through different standards:

- **DOCSIS** itself which has been deployed in the United States and in the UK;
- **EuroDOCSIS** which is the European DOCSIS standard.

Several versions of these standards have been introduced over time:

- DOCSIS 1.0 uses a channel width of 3.2 MHz and enables downstream capacity of 40 Mbps. The associated upstream capacity can reach 10 Mbps.
- DOCSIS 2.0 and 3.0 use a channel width of 6.4 MHz and enables the upstream capacity to increase up to 30 Mbps for DOCSIS 2.0. For DOCSIS 3.0, the downstream and upstream capacities respectively are up to 150 Mbps and 100 Mbps[20].
- EuroDOCSIS standard uses a channel width of 8 MHz. The last version (3.0) enables cable operators to virtually bond multiple downstream and upstream channels together to deliver ultra-high bandwidth to an individual subscriber. The downstream capacity goes up to 200 Mbps whereas the upstream capacity can reach 100 Mbps[21].

In order to further increase the capacity on the cable TV network, three other options are generally identified:

- **Node splitting**. In a typical cable TV network, traffic is sent downstream from the cable head-end to multiple nodes which then distribute the traffic to individual end-users. Nodes generally serve from 500 to 2,000 end users. In order to continually increase the capacity per subscriber, operators are able to split these nodes into several nodes so that it halves the number of subscriber per node (i.e., from 500 to 250). This technique therefore doubles the capacity per subscriber as it has been demonstrated by the cable infrastructure vendor Motorola in the table below.

[20] In this case the number of downstream and upstream channels is equal to 4.

[21] In this case the number of downstream and upstream channels is equal to 4.

Table 2 – Gains enabled by node splitting (column "Mbps")

Today	HHP	Penetration	Concurrency	Mbps	QAMs	MHz
HSD Service - 50 Mbps	500	50%	1%	125	4	24
Single VOD Avg (HD+SD)	1000	50%	6%	300	8	48
					12	QAMs
100 Mbps Window - Entry						
HSD Service	500	50%	1%	250	7	42
IPV 1x SD & 1x HD	500	20%	10%	70	2	12
Single VOD Avg (HD+SD)	1000	50%	10%	500	14	84
					23	QAMs
SPLIT						
100 Mbps Window - Mature						
HSD Service	250	50%	2%	250	7	42
IPV 0.5x SD & 1.5x HD	250	50%	30%	341	9	54
Single VOD HD	500	50%	15%	713	19	114

Source: Current Analysis based on Motorola data[22]

- The use of **Radio Frequency over Glass** (RFoG). This consists in replacing the coax part of the cable operator network with passive optical fibre without changing any of the existing CMTS, head-end and hub equipment or customer premises gear. In addition to the removal of active element such as amplifiers and the use of far less power than cable TV, RFoG enables increased downstream capacity up to 160 Mbps and upstream capacity up to 120 Mbps[23].
- The use of **Ethernet Passive Optical Network Protocol over Coax**, known as EPOC. This technology could provide symmetric speeds up to 10 Gbps or asymmetric speeds up to 10 Gbps downstream and 1Gbps upstream[24]. Nevertheless this technology is still under the process of being standardized.

2.2.1.3 FTTH access network

Regarding FTTH, it is to be noted that there is very low attenuation which enables long distances without the need for repeaters (up to 20km). Also, there are no grounding problems and no cross talk as observed with copper. The technical limit of FTTH is above 50Tbps[25] but it depends on the type of topology that has been rolled out:

- **A point to point (P2P) topology** can be used. With this topology, each end-user is served by a single fibre that runs from the central office to the customer premises. In such a case, the route consists of several sections of fibre joined

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[22] Source: Current Analysis, HFC's Lucky Seven Technologies: How Can Cable Operators Compete with FTTH? March 31, 2011

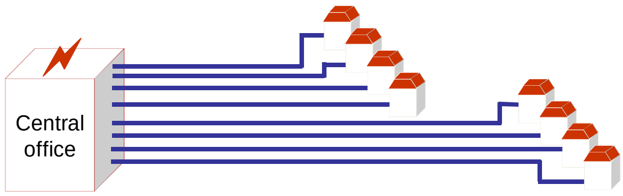
[23] Source: Heavy Reading, Next-Gen Cable Networks: Opportunities for Fiber-Based Technologies, http://www.heavyreading.com/details.asp?sku_id=2346&skuitem_itemid=1166

[24] Source: IEEE 802.3 Ethernet Working Group, Operating the EPON protocol over Coaxial Distribution Networks Call for Interest, 8 November 2011.

[25] Source: FTTH Council America, FTTH Design and Network Basics PC-101-G, Mark Boxer Applications Engineering Manager, OFS Jeff Bush Professional Services Manager, OFS

with splices or connectors, but provides a continuous, uninterrupted optical path from the central office to the home. It is therefore clear that the capacity at the wholesale level is dedicated in such situation. Operators having deployed this solution generally sell offers up to 1Gbps symmetric per subscriber[26].

Figure 5 – P2P FTTH architecture



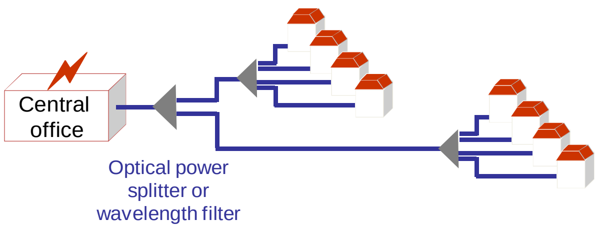
Source: TERA Consultants

- **A point-to-multipoint (GPON) topology** can be preferred. With this topology, traffic is carried on a single, shared fibre from the central office to a branching point, and from there the traffic is routed onto individual, dedicated fibres, one per customer. In a passive optical network technology such as GPON, the downstream signal is broadcasted across multiple fibres with data being encoded so that users only receive data intended for them. This type of solution offers up to 2.4 Gbps downstream in total and 1.2 Gbps upstream in total (not per customer)[27]. A new GPON standard was ratified as G.987 in June 2010 offering up to 10 Gbps downstream and 2.5 Gbps upstream. Contrary to the P2P solution, in such situation, the capacity is shared at the wholesale level. Another option is to route traffic electronically using Ethernet routers, an architecture called Active Ethernet. Although the network has a point-to-multipoint topology, each customer has a logical point-to-point connection. The end-user sends and receives only the data intended for them.

[26] Source: FTTH Council America, FTTH Design and Network Basics PC-101-G, Mark Boxer Applications Engineering Manager, OFS Jeff Bush Professional Services Manager, OFS

[27] Source: FTTH Council America, FTTH Design and Network Basics PC-101-G, Mark Boxer Applications Engineering Manager, OFS Jeff Bush Professional Services Manager, OFS

Figure 6 – GPON FTTH architecture



Source: TERA Consultants

2.2.1.1 Summary of technological performances

When comparing the different access network technologies it appears that FTTH enables to provide the same or higher downstream/upstream capacity compared to copper and cable TV. Capacities of the different access network technologies are summarized in the table below. This table also includes an analysis of whether access network technologies provide dedicated or shared capacity between end-users. Technologies offering dedicated capacities for end-users are considered as superior, all things being equal, to technologies offering shared capacities as they provide greater control of the physical medium (and allow physical unbundling also).

Table 3 – Comparison of downstream/upstream between different technologies

	Technology	Maximum downstream capacity (Mbps/user)	Maximum upstream capacity (Mbps/user)	Line length	Capacity shared or dedicated between users
Copper	ADSL2+	24	1.5	up to 1.5 km	Dedicated capacity
	VDSL2	50	5	up to 400 meters	Dedicated capacity [28]
	Pair bonding	Capacity doubled	Capacity doubled	As above	Depends on where the active equipment is installed
	Vectoring	100	10	up to 400 meters	Shared capacity
	Phantom mode	300	N/A	up to 400 meters	
Cable TV	DOCSIS 1.0/2.0/3.0	40/40/150	10/30/100	up to 10 km	Shared capacity
	EuroDOCSIS 1.0/2.0/3.0	50/50/200	10/30/100	up to 10 km	
	Node split	Capacity doubled	Capacity doubled	up to 20 km	
	RFoG	160	120	up to 20 km	
	EPOC	10,000 (not standardized)	10,000 (not standardized)	up to 20 km	
Fibre	P2P	100-1,000 (theoretically up to 50 Tbps)	100-1000 (theoretically up to 50 Tbps)	up to 20 km	Dedicated capacity
	GPON	10,000	2,500	up to 20 km	Shared capacity

Source: TERA Consultants

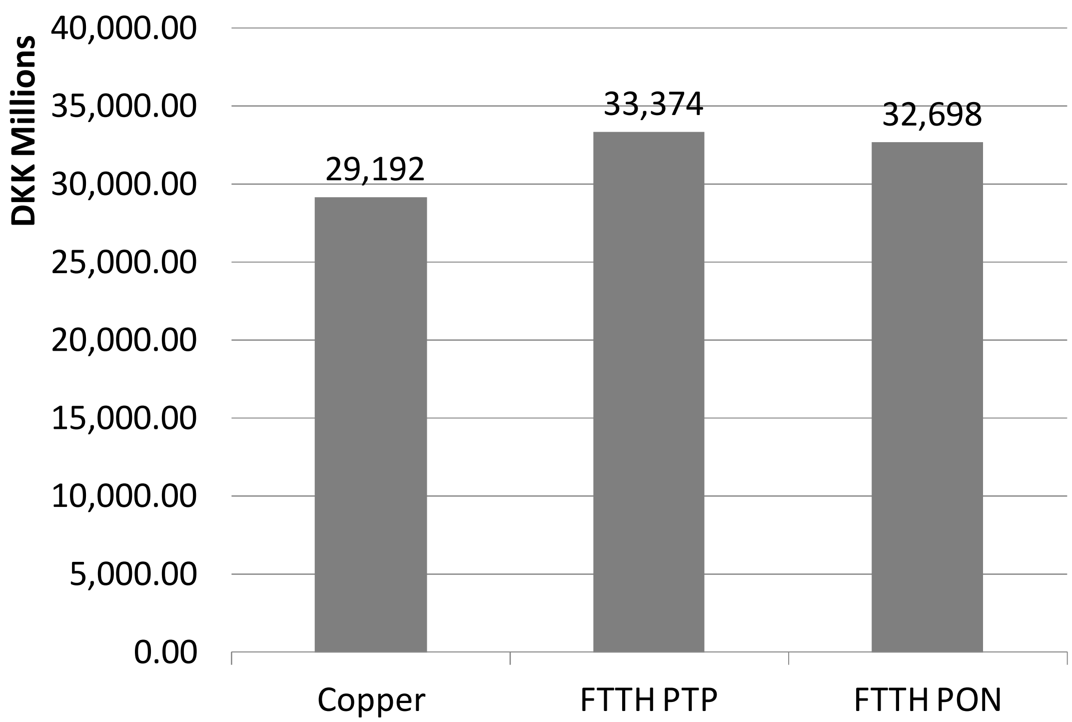
The analysis of the technological criterion suggests that FTTH may be the MEA of both copper and cable TV since it offers greater capabilities (higher and symmetric speeds) among the standardized technologies. Cable TV could provide similar performances as FTTH in the long term but this is mainly due to the fact that more and more fibre is deployed in cable TV networks. Finally, FTTH can provide dedicated capacity for end-users in a point-to-point configuration which is not the case for cable TV.

[28] Because of the fact that alternative operators rarely unbundle street cabinets (due to lack of economies of scale) and because of the fact that VDSL2 technology is aimed at being deployed at the street cabinet, in the future, wholesale access to this type of technology is likely to be mainly provided at higher level in the network where capacity is shared between end-users

2.2.2 Cost criterion

As stated in MEA definition quoted in section 1.2, it is necessary to compare the cost of the different fixed access network technologies in the MEA assessment. To conduct this comparison, existing LRAIC models can be used but as it is important to compare technologies on a like with like basis, adjustments have been made to make sure copper and FTTH are compared with similar geographical scope and similar network scope[29]. As cable TV coverage is significantly different from copper and FTTH, it is not possible to compare FTTH with cable TV costs with the current model on a like with like basis. To avoid differences in economies of scale, only the total investment to reach a given coverage is compared. Results show that the investment required for a FTTH network would be around 12% higher than the investment in a copper network[30] today. This excludes CPE and active equipments since costs of copper active equipments and CPE can vary significantly depending on the technology chosen (vectoring, pair bonding, etc.). However, the passive part of the copper and FTTH networks should represent the very large part of costs[31].

Figure 7 – Comparison of the investment required for a standalone FTTH Point to Point, a standalone FTTH GPON, for a standalone copper access network (excluding CPE and active equipment)



[29] See appendices for detailed explanations of how calculations have been carried out.

[30] Excluding CPE and active equipments since costs of copper active equipments and CPE can vary significantly depending on the technology chosen (vectoring, pair bonding, etc.)

[31] In the GPON scenario, CPE and OLT represent 3% of total costs only.

Source: TERA Consultants based on DBA's LRAIC model – see appendices

It is to be noted that the gap between the cost of the copper and FTTH networks will probably narrow in the coming years due to the combination of the steadily decrease of fibre prices and of the increase of copper cost. Indeed, the price trend for fibre is in average -5% whereas for copper it is around 3%.

Table 4 – Benchmark of fibre cable and of copper cable price trends in bottom-up models[32]

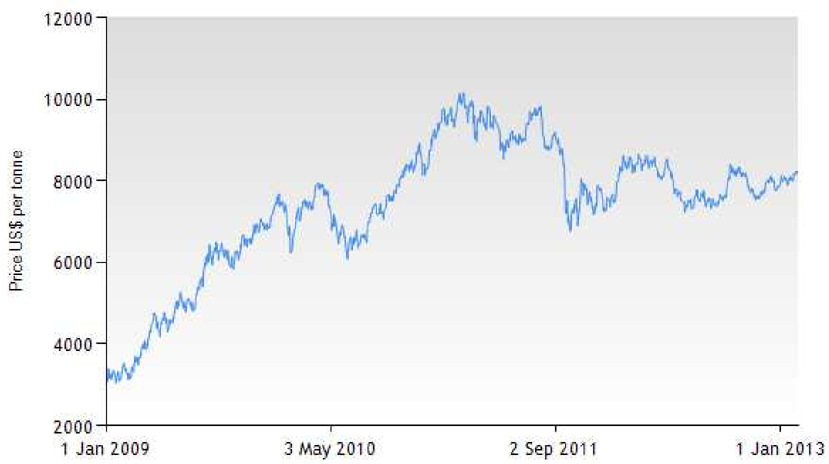
Country	Fibre cable price trend
Australia	-9.2%
Sweden	-2.0%
Denmark	-5.0%
France	-4.0%
AVERAGE	**-5.0%**

Country	Copper cable price trend
Australia	-0.7%
Sweden	-2.0%
Denmark	6.0%
Country A	4.7%
Country B	7.4%
AVERAGE	**3.1%**

Source: NRAs' core and access models

The average copper price trend implemented in models is confirmed by the evolution of copper that has been observed the last years. LME copper price represent indeed a significant share of copper cable prices.

Figure 8 – Evolution of the copper price in US$/ton on LME between 2009 and today

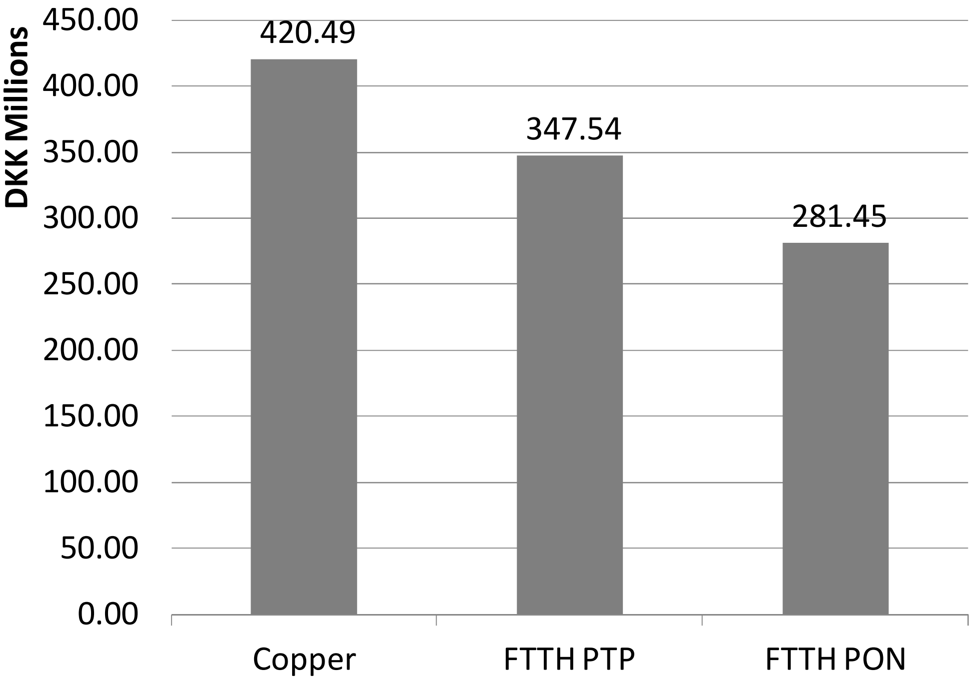


[32] Country A and B are countries for which TERA Consultants built models but which are not publicly available

Source: LME

Besides, the comparison of the level of fully allocated operating costs (OPEX) between the different technologies as calculated in DBA's existing LRAIC model stresses out that FTTH is a much more efficient technology compared to copper.

Figure 9 – Comparison of the annual OPEX of a FTTH Point to Point network, of a FTTH GPON network and of a copper network



Source: TERA Consultants based on DBA's 2010 LRAIC model

Ericsson underlines to that the absence of active equipment in a fibre network would lead to lower a level of OPEX:

> *"Compared to copper and hybrid fibre-coax (HFC) networks, OPEX will be considerably lower as P2P fibre provides the best distance-bandwidth solution with fewer number of active elements required in the network. This reduction in active elements in the OSP also results in a lower OPEX."*[33]

The Industry organization FTTH Council Europe also explains that the level of OPEX for FTTH should be lower than for copper networks and lists the potential saving opportunities:

[33] Source: Ericsson, Point-to-point deep fiber access, 2010

> *"An additional motivator for service providers is that FTTH networks have lower operating costs (OPEX) than existing copper or coaxial cable networks. FTTH networks consume less electricity with some reports putting the figure at 20 times less than HFC or VDSL. Network operation and maintenance is simplified using full automation and software control, requiring fewer staff. Maintenance costs are also reduced as there is no active equipment in the field to maintain, and optical components are extremely reliable. Optical fibre is not affected by electromagnetic interference, which is a source of downtime in copper networks."*[34]

Finally, in a presentation on next generation networks, the Italian NRA AGCOM quotes that the OPEX saving as compared to copper is circa 50%:

> *"NTT / Verizon: 40-60% OpEx decrease with FTTH networks w.r.t. copper local loop"*[35].

Currently, the cost of an FTTH access network seems to remain slightly higher compared to a copper access network. However, it should be taken into account both the fact that an FTTH network offers higher capacity and that cable prices tend to indicate that the cost of FTTH will decrease in comparison to copper. Hence, assuming that end-users will demand higher broadband speeds over the next couple of years, it is unclear whether the FTTH network will remain the more expensive. Also, FTTH seems to provide significant OPEX savings compared to copper. It is not possible to compare FTTH and cable TV costs but it is noted that more and more, cable TV networks are made of fibre which should make the cost of a new cable TV network close to the cost of a new FTTH network while FTTH OPEX appear to be lower than cable TV according to Ericsson.

2.2.3 Subscriber criterion

The market behaviour and more specifically the demand for each access network technology can also support the MEA assessment and provide relevant indicators. For this reason it is appropriate to look at the evolution of the number of connections for each type of technology.

To that extent, since the model expansion in 2010-2011, the demand for FTTH connections has risen: at the overall level, FTTH subscriptions have been multiplied by 3 in volumes and in market share since 2008 whereas in the same period DSL subscriptions decreased and cable TV subscriptions stagnated (see Figure 10).

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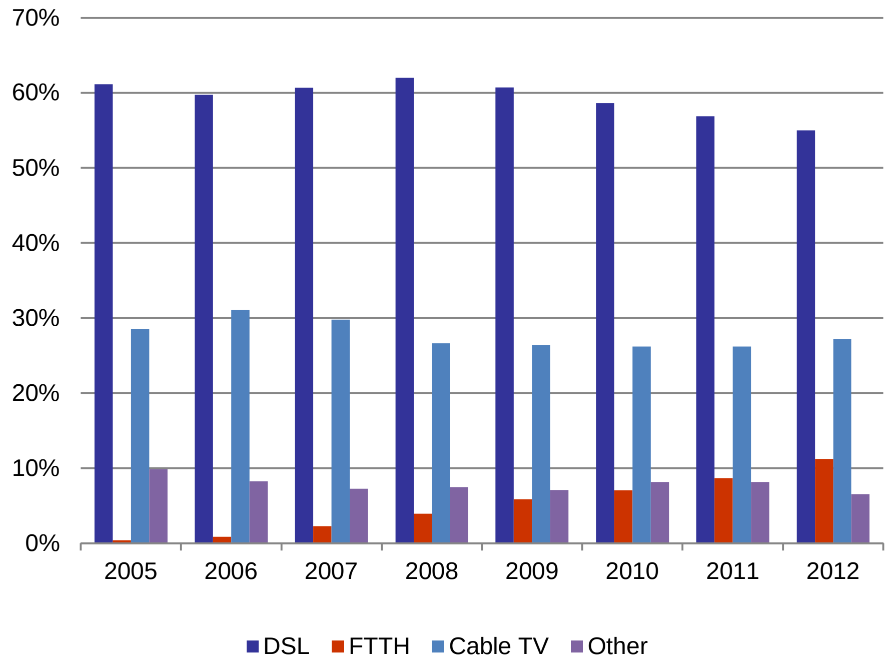
[34] Source: FTTH Council web site

[35] Source: AGCOM (Italian NRA), Challenges in moving towards the Next Generation of Fixed and Mobile Networks, January 2010

Figure 10 – Broadband market share by technology 2005-2012 in Denmark



Source: TERA Consultants' analysis based on DBA's data

One of the reasons of this growth in the number of FTTH customers is the increased roll out of FTTH networks by the utility companies which are focusing on FTTH broadband.

All these indicators relative to the market suggest that FTTH is currently being preferred by customers buying new broadband connections. But in order to assess if FTTH is the MEA of copper and cable TV, it is necessary to have a look at a more local level on how subscribers react to the presence of FTTH offers. An analysis on different areas is therefore conducted below[36]:

- **Area 1** which corresponds to DONG's network footprint: this area represents 25% of active lines in Denmark. As TDC owns DONG's network but also copper and cable TV infrastructures, it is necessary to analyse this part of the country separately.
- **Area 2** where the coverage of FTTH is relatively important[37] excluding DONG area: this area represents approximately 38% of active lines in Denmark;

[36] NB1: the different areas selected are not complementary.

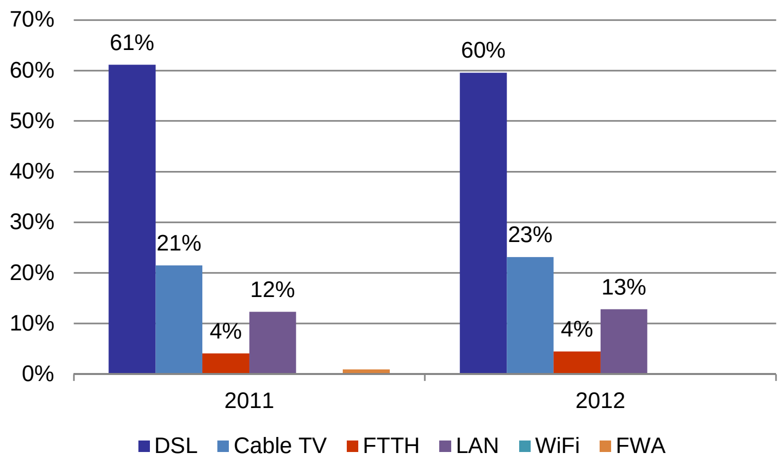
NB2: As specified above, the critical factor when setting the 3 areas is the technology coverage observed in areas corresponding to different postal codes in Denmark. However as this coverage is a range of coverage and not a specific percentage, it has been therefore considered the average between the two extremities of the range specified for the postal code. For example if for fibre the coverage is in the range [20-40%] the coverage level considered is 30%.

[37] A postal area is included in this area where FTTH covers more than 50% of the households of the area in 2012

- **Area 3** where the coverage of FTTH is relatively important excluding DONG's area and where the coverage of cable TV is relatively low[38]: this area represents 16% of the total number of active lines in Denmark. As cable TV offers much greater capabilities than copper, it is interesting to analyse this type of area.

The analysis of area 1 outlines that there is no significant take-up of TDC's FTTH offers in the DONG area. The proportion of FTTH subscriptions remains stable from 2011 to 2012 whereas cable TV subscriptions increase (see Figure 11). However, as TDC operates a FTTH, a copper and a cable TV infrastructure in this area, these 3 platforms are not purely competing with each other. Also, it is noted that FTTH support a price premium of 99 DKK/month. Therefore, it is difficult to draw conclusions on customers' willingness to get FTTH for this area.

Figure 11 – Area 1: Broadband market share by technology 2011-2012

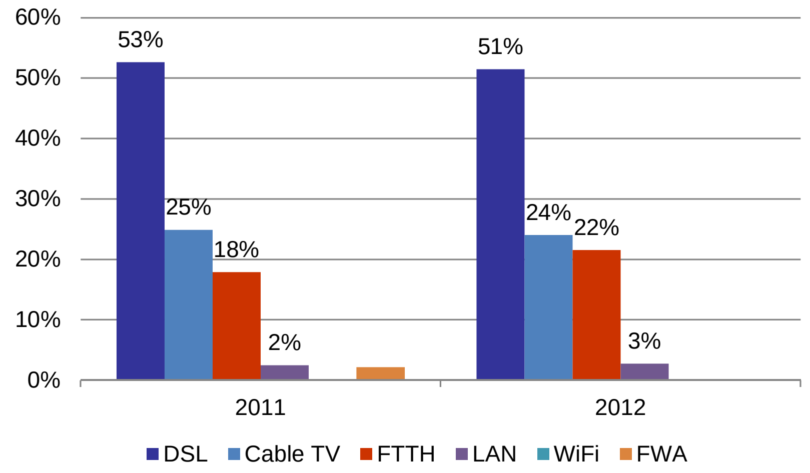


Source: TERA Consultants' analysis based on DBA's data

Results of the analysis of area 2 suggest that end users tend to migrate on FTTH offers. Indeed the FTTH market share in this area significantly increases from 18% to 22% between 2011 and 2012 whereas copper and cable TV market shares both decrease (see Figure 12).

[38] A postal area is included in this area where cable TV covers less than 50% of households in the area considered in 2012

Figure 12 – Area 2: Broadband market share by technology 2011-2012

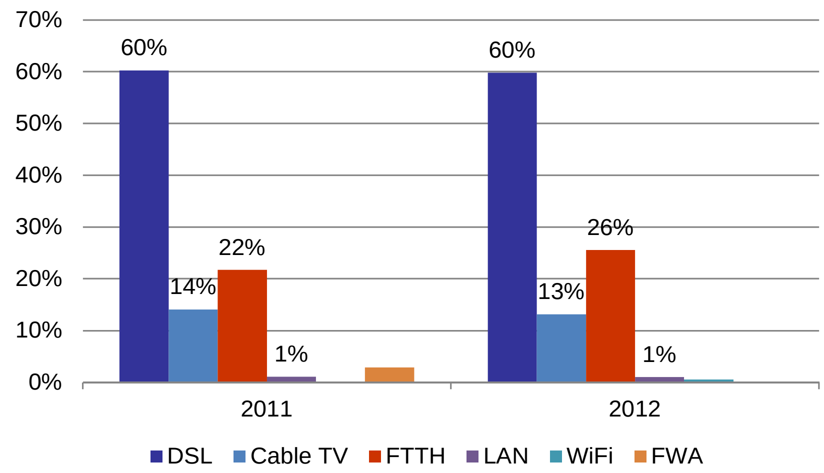


Source: TERA Consultants' analysis based on DBA's data

To that extent, DBA notices that Waoo!'s coverage increased from 23.9% of the total number of households beginning 2011 to 28.9% beginning 2012. At the same time, the proportion of active lines out of installed lines increased from 25.8% to 29.5% which outlines also that customers are more and more migrating toward FTTH[39].

The same conclusion can be set in area 3 where cable TV access network is less significant than in the other analysed areas. This suggests therefore that end-users tend to migrate from copper offers to FTTH offers (see Figure 13).

Figure 13 – Area 3: Broadband market share by technology 2011-2012

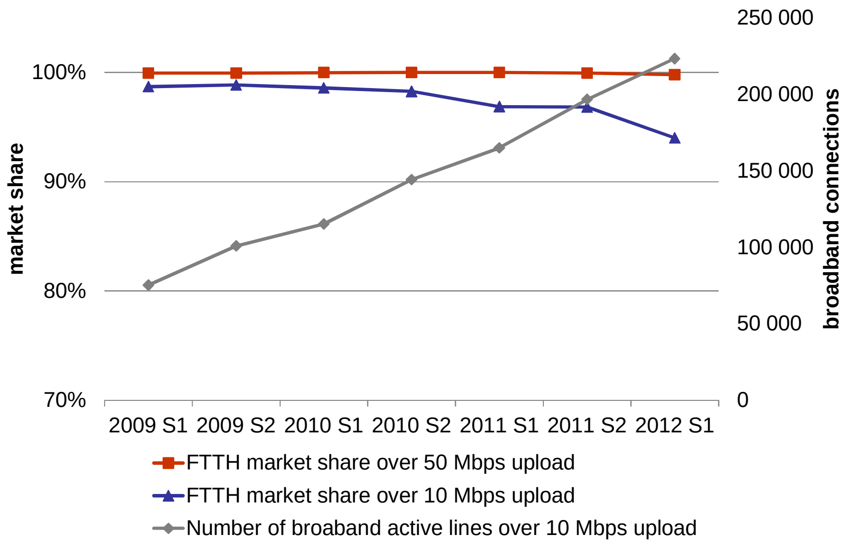


Source: TERA Consultants' analysis based on DBA's data

[39] http://www.ftthcouncil.eu/documents/CaseStudies/WAOO_Update1.pdf

The outcome of the analysis of these different areas is therefore that FTTH offers with higher speeds are more and more subscribed, even if in the DONG area it is not the situation. However, this may be explained by aggressive pricing strategies rather than real demand from customers. To assess customers' needs, the evolution of broadband connections per type of technology and per range of capacity provides interesting views. In particular, looking at upstream capacity is particularly relevant in the present analysis since FTTH mainly differentiate from cable TV and copper from the fact that it is capable of offering symmetric speeds and therefore higher upstream speeds as described in Table 3. Even if cable TV has provided higher speeds since 2009, its market share on broadband connections over 10 Mbps upstream capacity or over 50 Mbps upstream capacity is still very limited compared to FTTH. The very large majority of high upstream connections (above 10 Mbps or above 50 Mbps) are based on FTTH which tends to show that end-users demanding high upstream connections prefer using FTTH (even if it is not available on the whole country). At the same time the number of broadband connections over 10 Mbps upstream tripled between 2009 and 2012 which also shows that the number of end-users demanding high upstream connections is growing fast.

Figure 14 – Evolution of FTTH market share on broadband connections with high upstream speeds and of the number of broadband active lines with high upstream speeds (2009-2012)



Source: TERA Consultants' analysis based on DBA's data

In the context of rapid increase in speeds requested by end-users as outlined by the figure above, it is observed that FTTH concentrates the vast majority of broadband lines of more than 10 Mbps upload. Also, in areas where FTTH is deployed by alternative operators, FTTH market share has increased by 4 points in one year. The analysis of the subscriber criterion suggests that FTTH may be the MEA of both copper and cable TV as subscribers are more and more requiring the capabilities offered by FTTH.

2.2.4 Operator's strategy criterion

When assessing the MEA it may be also appropriate to observe the strategy followed by operators, as it provides a good indicator of what is expected to be the long term access network technology. This is very relevant in light of the MEA definition (see section 1.2).

For a company not owning copper infrastructure, FTTH seems to be the preferred technology. On the Danish market, this is supported by the deployment strategy of the utility companies who have established fibre networks to a great extent. This strategy has also been adopted in similar countries such as Sweden and Switzerland by new operators ready to enter the broadband market.

- **In Sweden** a large part of the deployment of FTTH access networks is due to the incumbent Telia but also to the so called *"Stadsnäts"* which corresponds to PPP partnerships mainly between utility companies and municipalities. Since 2000[40], several cities have decided to build their own municipal FTTH network in order to develop a communications infrastructure for their own use, and to attract new businesses to the city. According to the FTTH Council:

  "*Despite the relatively high upfront cost, subscribers are attracted by the fact that they are adding value to their property, and gaining lifetime access to a wide range of services (including telephony, broadband, television, community services such as healthcare and communication for the elderly, etc.) at lower prices than those on other networks"*[41]

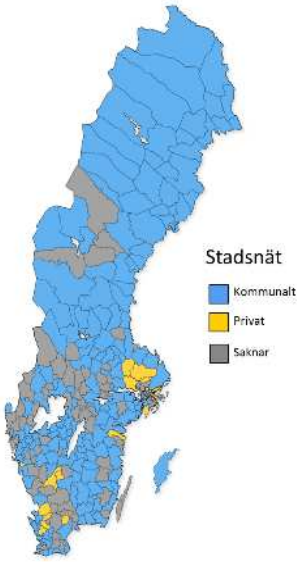
  Today up to 70% of the municipalities in Sweden have deployed such type of network[42].

[40] The municipality of Västerås was the first in Sweden, and probably in Europe, to build an open access fibre network in July 2000.

[41] Source: FTTH Council business case, MälarEnergi Stadsnät

[42] Source: Swedish Association of urban networks http://www.ssnf.org/Stadsnat/Var-finns-stadsnat/

Figure 15 – Coverage of utilities' FTTH access networks in 2012



Source: Swedish Association of urban networks

NB**:** areas in blue are covered by municipalities. Areas in yellow are covered by private operators and areas in grey are still not covered

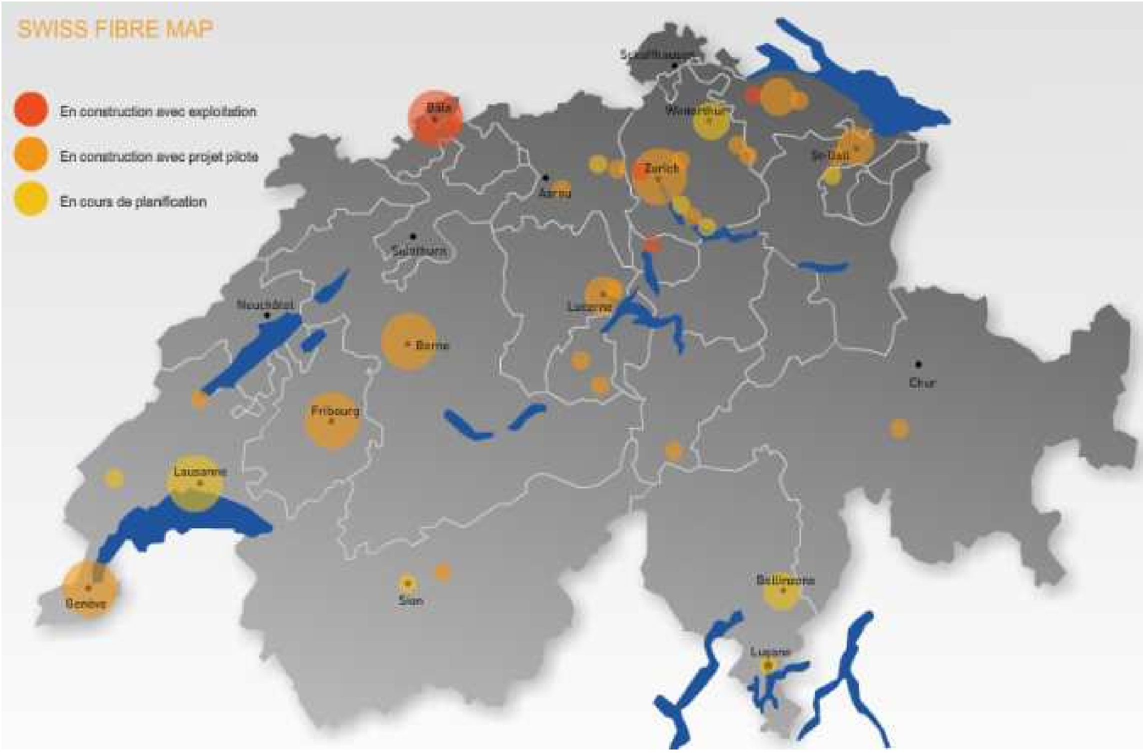
- **In Switzerland,** the situation has some similarities with Denmark, as several power utilities deployed their own FTTH network in parallel to the cable TV access network owned by UPC Cablecom (70% coverage in terms of territory[43]) and to the copper access network owned by Swisscom which uses VDSL technology (98% ADSL coverage and 75% VDSL coverage[44]). In order not to be put aside on the ultra-fast broadband market, the incumbent Swisscom decided to participate to numerous projects initiated by these municipalities[45].

[43] Source: UPC Cablecom http://www.upc-cablecom.ch/fr/b2c/about/ueberuns/unternehmen.htm

[44] Source: Swisscom, Position paper, Next Generation Access Networks (NGA), July 2009

[45] Including Genève, Lausanne, Fribourg, Berne, Bâle, Lucerne, Zürich, Winterthur, St-Gall, Sion, Bellinzona, Aarau.

Figure 16 – Coverage of utilities' FTTH networks in 2012



Source: Openaxs[46]

In general, new access network deployments in Europe have been almost only focused on FTTH. According to Idate, the number of FTTH end-users connections has been multiplied by almost 3 between start 2011 and start 2013, shifting from 1.4M to 3.9M[47] which clearly indicates that FTTH is the technology that is the most prevalent according to operators.

For companies already owning access network infrastructure, FTTH also seems to be regarded as the long term technology. However, the deployment strategy differs from that of new operators.

With regards to Denmark, the strategy followed by TDC for the coming years is multiple. Regarding its copper and cable TV access network, TDC intends to upgrade both of them by deploying fibre closer to the end-users.

[The following text has been redacted due to confidentiality].

[46] Source: http://www.openaxs.ch/fr/index.php. The map is in French. "En construction avec exploitation" means "Being built and being operated" "En construction avec projet pilote" means "Being built with pilot project" and "En cours de planification" means "being planned"

[47] Source: Idate, FTTH Council-EU, "G20 need to speed up on Fibre to the Home", Press Release, February 26, 2010, and FTTH Council, December 2012 European Ranking, February 2013

In light of the strategy followed by new operators in similar countries but also in Denmark with utility companies, the “operator strategy” criterion suggests that FTTH is the MEA for cable TV and copper. We are not aware of any new large scale copper or cable TV deployment in Europe, contrary to FTTH.

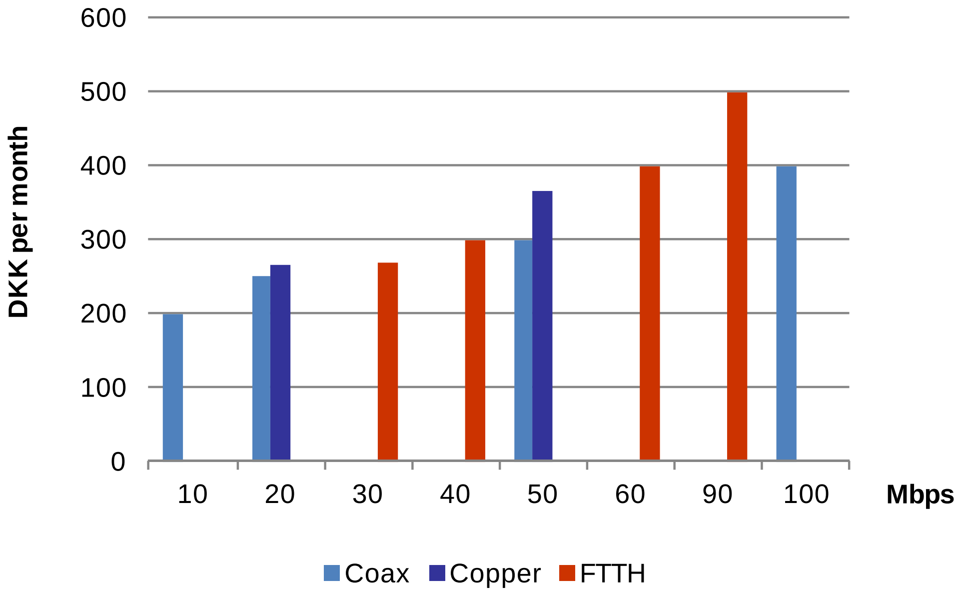
2.2.5 Retail price criterion

The analysis of retail prices between the different technologies may be more controversial. First of all, it is different to assess end-user’s actual willingness to pay for different products. Further, retail prices depend on the pricing strategy that operators may have at a given point in time. Such an analysis should be complemented by an analysis of profitability over a long period of time and has less significance than the analyses carried out in the previous sections.

The analysis below is confined to the comparison of retail offers with the same downstream capacity and does not take into account the short term commercial strategy of the operator which tries to enlarge its subscriber base.

The analysis suggests that FTTH offers at the retail level are at a similar level as copper and cable TV offers, i.e. end-users are not paying a premium to get FTTH. However, comparing monthly retail prices does not reflect the fact that many end-users already have a copper or cable TV broadband connection and in most cases switching to FTTH includes significant setup charges as well as the inconvenience of switching supplier and having FTTH installed.

Figure 17 – Monthly retail price of broadband access versus download speed



Source: operators' web pages 22nd of February 2013

Hence, this comparison is not sufficient to clearly measure the willingness of end-users to pay a premium for fibre offers. To give further insight, TDC made DBA aware that:

> *"YouSee has established cable-TV over FTTH in a number of areas in North Zealand (former DONG-network). The offering to these customers is identical to YouSee's standard cable-TV offering over coax – apart from a price premium of 99 DKK/month. After more than 2 years the penetration in these areas is around [XX] % - whereas the normal penetration in comparable coax-based areas after 2 years would be around [XX] %."*[48]

This indicates that end-users are not willing to pay around 30 to 50 % extra (besides additional setup charges etc.) to get the same product using FTTH instead of cable TV. Further, the example does not show whether end-users are willing to pay a premium if the FTTH upstream speed was increased compared to the upstream speed on their existing cable TV connection.

As a consequence, while FTTH retail prices are similar to copper and cable TV prices, it is not clear whether customers are willing to pay extra to get FTTH. It must however be reminded that as observed in section 2.2.3, subscribers are more and more migrating to FTTH and that for speeds above 10 Mbps upstream, the market share of FTTH is very significant in Denmark.

[48] Source: TDC's answers to ERST/TERAs questions, Ref: KBP 1. feb. 2013

2.2.6 Best practices

According to a quick overview on how wholesale prices are set in Europe for access to copper and FTTH networks[49], it appears that prices of wholesale services based on copper are generally set on the basis of a cost model (bottom-up or top-down) which calculates the cost of the copper access network (this is the case in France, in Ireland, in Belgium, in Croatia, in Romania, in Denmark, etc.). Contrary to copper, when FTTH has been deployed in a given country, NRAs have not always decided to set cost oriented prices for FTTH. For example, in France, only an obligation to set reasonable prices is imposed. When a cost orientation obligation is imposed, it seems that NRAs build up a NGA model that is used to set regulated access prices, as it is the case in Denmark until now. However, as the obligation to set cost oriented prices for FTTH does not apply in all countries yet and as FTTH is not deployed in all European countries, it does not appear that such a debate on the MEA for copper has been discussed, except in Sweden.

In Sweden, the situation is similar to Denmark at the exception that Telia is deploying FTTH. PTS published two documents in 2010 which addressed in particular the question of whether FTTH is the MEA of copper. As it is the case in Denmark, PTS observed that FTTH was more expensive to deploy than copper but that in the long term, it would be more efficient to deploy FTTH. Therefore, PTS decided that FTTH was the MEA of copper. Today, FTTH and copper regulated prices are set on the basis of FTTH costs. It is however noted that one of the main differences between Denmark and Sweden is that Telia is significantly deploying FTTH while TDC is not.

According to best practices, the assumption of FTTH as the MEA of copper is therefore consistent and appropriate.

2.2.7 Overall findings

For the vast majority of criterions, the analyses support the assumption that FTTH is the MEA of copper and cable TV (see summary in Table 5).

Table 5 – Overall findings

Criterion	Is FTTH the MEA of copper?	Is FTTH is the MEA of cable TV?
Technological criterion	++	+
Cost criterion	- for CAPEX but + for OPEX	/
Subscriber criterion	++	+

[49] Cable TV networks are rarely regulated

Operator's strategy criterion	++	++
Retail price criterion	/	/
Best practices	+	/

Source: TERA Consultants

2.3 Impact of the MEA choice on prices

As suggested by DBA and BEREC, if FTTH is accepted as the MEA of copper and cable TV, the key question is how to adjust fibre prices to set copper and cable TV prices.

> *"The MEA is the asset that can produce the stream of services produced by the existing asset at lowest cost. Where the operating cost or other performance characteristics of the MEA differ from the existing asset, **these should be reflected in the asset valuation**."*[50]

> *"Modern Equivalent Asset (MEA) should be used whenever it is possible, as it is the most accurate valuation criterion to reflect the cost of an efficient operator, since it will capture the associated costs (and efficiencies) that an entrant/alternative operator would face, if entering into the market at a specific time.*

> *This valuation criterion is accurate when besides a technical change; the asset with the same functionalities is no longer being marketed. Therefore, **the aim is to calculate the cost of an analogous (replacement) asset**."*[51]

In such a case, three possible adjustments have been identified at this stage to set price of copper (VULA, pair-bonding, etc.) and cable TV:

- Adjustment based on consumer preference (see section 2.3.1);
- Adjustment based on technologies and performances (see section 2.3.2);
- Adjustment based on costs (see section 2.3.3).

The aim of these adjustments is to compute a discount that will be applied on the FTTH price in order to set the regulated price of copper and cable TV. All these adjustments will be analysed thereafter in light of DBA's objectives with regards to price control obligations which consists in *"promot[ing] efficiency and sustainable competition and maximise consumer benefits"*[52], *i.e.* in:

- Allowing efficient costs to be recovered;

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[50] Source: NITA, Model reference paper dated 18 September 2008, p.27.

[51] Source: ITU Regulatory accounting guide, March 2009, p.18

[52] Directive 2002/19/EC of the European Parliament and of the Council of 7 March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive)

- Ensuring that rates are not excessive;
- Also, in the specific case of migration from copper toward NGA and considering the EU 2020 agenda[53], it is also important to make sure that migration to NGA is not slowed down.

2.3.1 Adjustment based on consumer preference

The adjustment based on consumer preference is an adjustment based on customers' point of view. Once customers' willingness to pay extra for FTTH is known, it is possible to establish copper and cable TV prices by applying a discount on FTTH prices.

For illustrative purpose, if customers are willing to pay DKK 20 per month to change their copper subscriptions into a FTTH subscription (because FTTH offers greater capabilities), and if FTTH price is DKK 120 per month, then copper price would be DKK 100 per month. A key issue is here the definition of the methodology to assess this willingness to pay. Appropriate questions need to be asked to consumers to assess such a level.

It is to be noted that this adjustment methodology does not disadvantage the migration towards FTTH from a customer point of view. As end-users accept to pay more for FTTH and since the differential between copper or cable TV and FTTH prices reflects this extra they are willing to pay, then end-users will neither be encouraged nor prevented to migrate to FTTH. Besides, as prices are based on FTTH, it could be argued that long-term efficient costs are properly recovered and incentives to invest in FTTH are present. In that sense, this adjustment methodology complies with DBA's objectives listed above. However, this methodology has drawbacks and especially the fact that it might be difficult to calculate consumer willingness precisely and that the willingness to pay extra for FTTH is likely to change over time. Also, it may not encourage investing in the most cost-efficient technology since the differential of prices between copper or cable TV and FTTH does not represent the differential of costs.

For all these reasons, it appears that this type of adjustment should not be used in the specific context of Denmark.

2.3.2 Adjustment based on technological performances

The adjustment based on technologies is an adjustment based on the different capabilities of the different technologies. In that sense, price of copper and cable TV is set as a proportion of FTTH price, the proportion being the ratio of capacity of copper or cable TV on FTTH capacity.

For illustrative purpose, let us consider the following capacities:

[53] http://ec.europa.eu/europe2020/index_en.htm

- Capacity of copper is 50 Mbps (see section 2.2.1.1 for more details);
- Capacity of cable TV is 100 Mbps (see section 2.2.1.2 for more details);
- Capacity of FTTH is 1 Gbps (see section 2.2.1.3 for more details).

The ratio to be applied on FTTH prices for copper and cable TV prices would be therefore respectively 5% (= 50Mbps/1Gbps) and 10% (= 100 Mbps/1Gbps). If FTTH price is set to DKK 120 per month then copper price would be set at DKK 6 per month and cable TV price would be set at DKK 12 per month.

The main drawback of this methodology is that current price of copper and cable TV would be completely uncorrelated from their associated cost. Indeed, the cost of copper is not 100 times lower than FTTH which provides ultra-fast broadband whereas copper capacity is limited. The use of this methodology would therefore lead to regulatory inconsistencies as it contradicts one of DBA's objectives which is to incentive efficient investment infrastructure, i.e. allow efficient costs to be recovered.

From a dynamic point of view, capacities improvement can also occur faster than price changes. On top of that, copper and cable TV capacities may still increase due to improvements and lead to price increase which would be inconsistent. For all these reasons, this adjustment methodology has never been used by any NRA and is not proposed to be used in the context of Denmark.

2.3.3 Adjustment based on costs

The adjustment based on costs is an objective adjustment based on the cost of the different networks. This means that it is first necessary to compute on one side the FTTH price and on the other side the cost of copper and cable TV networks. The differential in level of costs enables the DBA to calculate the differential in level of regulated prices. All things being equal (depreciation, asset lives, penetration rate, cost of capital, etc.), the technology having the best cost / performance trade-off will then be preferred by end-users, depending on their willingness to pay. This therefore enables the DBA to make migration towards NGA neutral from a technological point of view. This also enables the DBA to make sure that efficient investment in infrastructure is incentivised.

2.3.4 Conclusion

In light of DBA's statutory objectives, it is more relevant to use the adjustment methodology based on costs as detailed in section 2.3.3.

Copper and cable TV prices are then determined by applying on FTTH cost the difference with the FTTH cost. It is to be noted that this methodology appears to be in line with the draft Recommendation of the European Commission[54] published December 2012 which specifies that:

> *"NRAs should adopt a BU LRIC+ costing methodology that estimates the current cost that a hypothetically efficient operator would incur to build a modern efficient network, which is in principle an NGA network."*
>
> *"When estimating the cost of wholesale access services that are based entirely on copper, NRAs should adjust the cost calculated for the NGA network to reflect the less performant features of a copper network.* ***For this purpose, the NRAs should consider an FttC network to be the modern efficient NGA network and should estimate the cost difference between an access product based on FttC and an access product based entirely on copper by making the relevant adjustments in the FttC engineering model, e.g. replacing the optical elements with efficiently priced copper elements, where appropriate****." (highlighted by the author).*

While the European Commission states that FTTC is the modern efficient NGA network and not FTTH, it is important to highlight that the European Commission requires computing the costs of a copper access network: a FTTC network with optical elements replaced by copper elements is a copper access network. As a consequence, the proposed approach is in line with the European Commission draft recommendation.

2.4 Next steps

The conclusions stated in sections 2.2.7 and 2.3.4 raise the question of how to model the different types of network equipment. This issue will be handled in detail in the Model Reference Paper. At this stage, DBA finds it relevant to consider looking at passive and active equipments separately.

The passive and active equipment of the copper network are different compared to the other technologies.

It does not appear necessary to develop a LRAIC model calculating the costs of a coax network as the passive part of cable TV access network is already significantly based on fibre and fibre will be more and more deployed in the coming years. This should make the passive part of the networks very similar: both include trenches, fibre and splitters (see Table 6).

Table 6 – Overview of passive and active equipment by technology

Technology	Passive components-	Active components -	Active and passive

[54] Source: COMMISSION RECOMMENDATION on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment

<table>
<tr><th></th><th>Access</th><th>Access</th><th>components - core</th></tr>
<tr><td>Copper</td><td>Trenches, copper and sometimes fibre (FTTC)</td><td>DSLAM, Aggregation nodes</td><td rowspan="3">TDC IP core infrastructure</td></tr>
<tr><td>Cable TV</td><td>Trenches, coax, fibre, splitters</td><td>MPEG station, CMTS, Amplifiers, Optical nodes</td></tr>
<tr><td>Fibre</td><td>Trenches, fibre, splitters</td><td>OLT</td></tr>
</table>

Source: TERA Consultants

In order to simplify the modelling process for the industry, it appears therefore appropriate to model passive components specific to copper on the basis of copper cost model and passive components specific to FTTH and cable TV on the basis of a FTTH cost model. However for each technology, each active equipment component shall be modelled specifically[55].

Table 7 – Over view of passive and active equipment to be modelled

<table>
<tr><th>Technology</th><th>Passive components-Access</th><th>Active components - Access</th><th>Active and passive components - core</th></tr>
<tr><td>Copper</td><td>Trenches, copper and sometimes fibre (FTTC)</td><td>DSLAM, Aggregation nodes</td><td rowspan="3">TDC IP core infrastructure</td></tr>
<tr><td>Cable TV</td><td rowspan="2">Trenches, fibre, splitters</td><td>MPEG station, CMTS, Amplifiers, Optical nodes</td></tr>
<tr><td>Fibre</td><td>OLT</td></tr>
</table>

Source: TERA Consultants

It is noted that this is a different approach than the one used for example in Sweden. However, as TDC is not planning to deploy a large scale FTTH network and intends to rely on its copper and cable TV infrastructure to provide services, the context is different than in Sweden and it appears necessary to assess the costs of copper and cable TV.

[55] It is noted that even if FTTH and cable TV may have different coverage areas, the bottom-up LRAIC model that will be developed will be able to calculate in different areas.

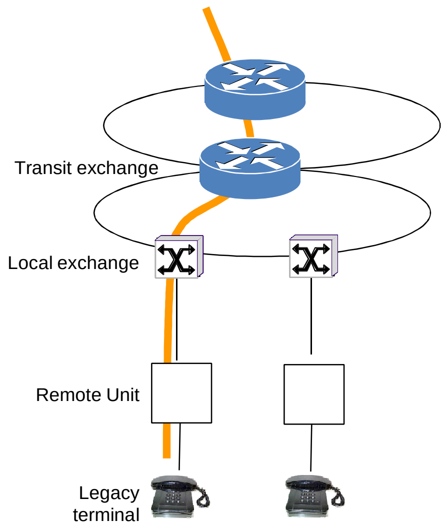
3 Is VoIP the modern equivalent technology for PSTN?

3.1 Context

Today, voice services can be supported in several ways by electronic communications network:

- **PSTN legacy** which corresponds to the old technology installed many years ago. This platform uses switching equipment such as local exchange, transit exchange, etc.

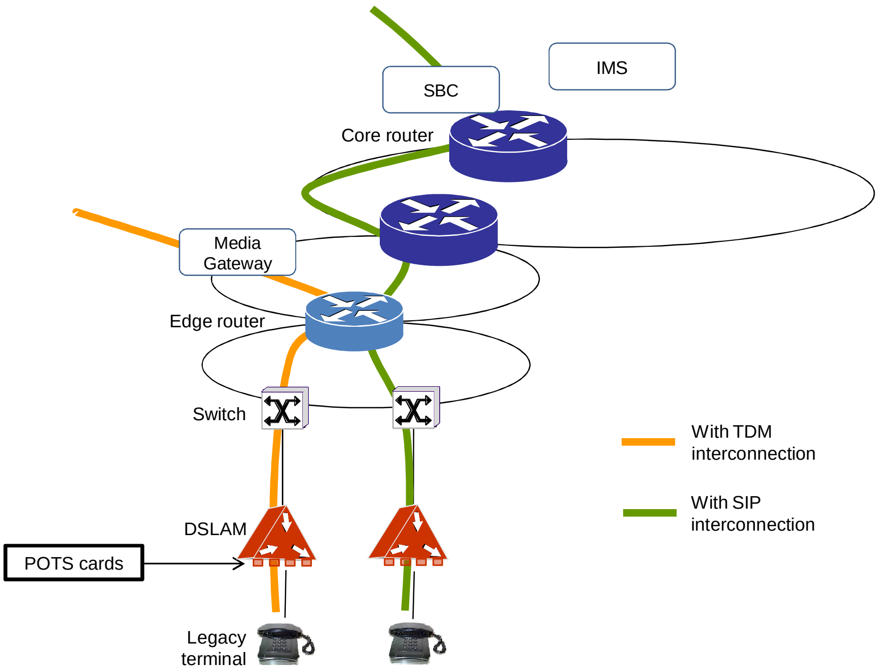
Figure 18 – PSTN platform and typical route for an "off-net" call (in orange)



Source: TERA Consultants

- **PSTN emulated over NGN.** This technology can be described as the migration of PSTN towards the NGN infrastructure. All PSTN features remain available but the voice traffic transit on the IP-MPLS platform through the use of POTS cards installed in MSAN/DSLAM. This is a VoIP technology but end-users are not aware of any change in the service in comparison to a PSTN legacy platform. Interconnection with other operators can either be a TDM interconnection which requires a MediaGateWay (MGW) or IP-IP/SIP interconnection handled by a Session Border Controler (SBC). The IP Multimedia Subsystem (IMS) manages the quality of such type of service (priority needed for the voice service).

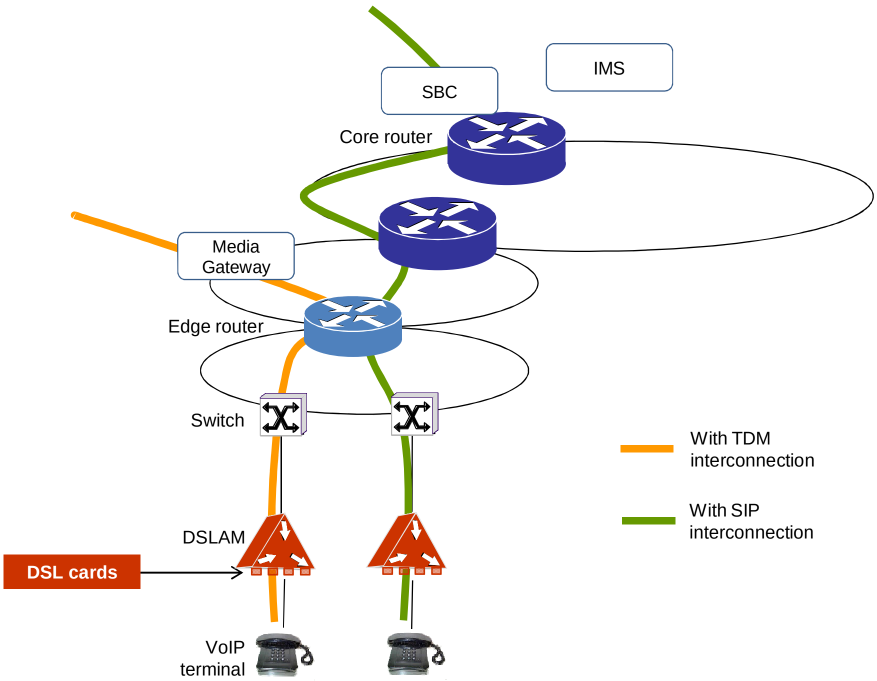
Figure 19 – PSTN emulated over NGN platform and typical route for an "off-net" call (in orange for TDM interconnection, in green for IP-IP interconnection)



Source: TERA Consultants

- **PSTN simulated over NGN.** This technology is merely similar to PSTN emulated over NGN at the exception that the network uses DSL cards at the DSLAM instead of POTS cards. Here again, interconnection with other operators can either be a TDM interconnection which requires a MediaGateWay (MGW) or IP-IP/SIP interconnection handled by a Session Border Controler (SBC). The IP Multimedia Subsystem (IMS) manages the quality of such type of service (priority needed for the voice service).

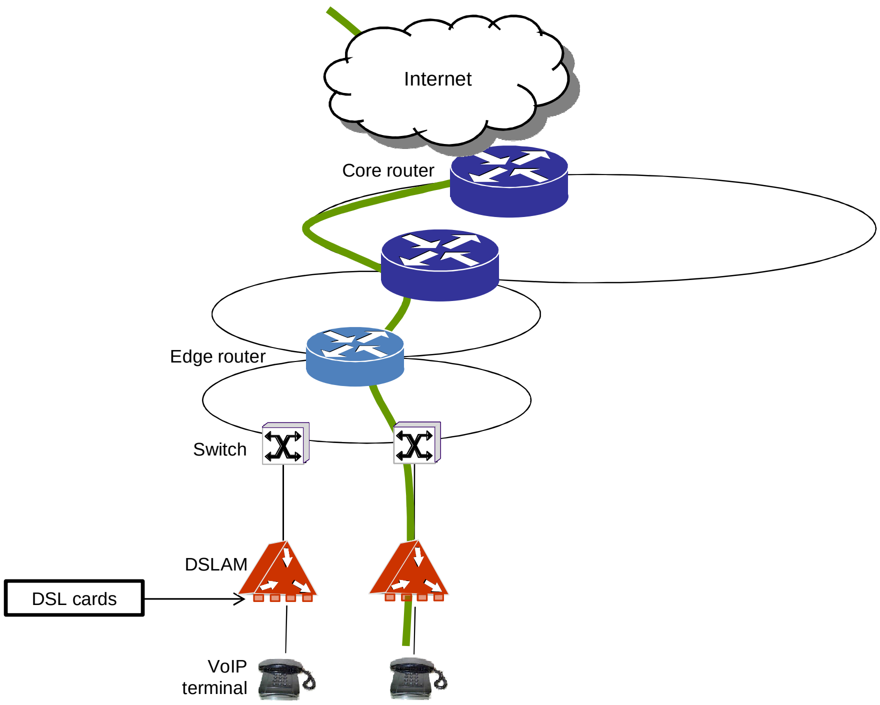
Figure 20 – PSTN simulated over NGN platform and typical route for an "off-net" call (in orange for TDM interconnection, in green for IP-IP interconnection)



Source: TERA Consultants

- **Unmanaged voice** is also a VoIP technology and corresponds to the service provided for example by Skype. This service is typically not provided by the operators but by over-the-top players and quality of service is not managed as in the previous voice solutions.

Figure 21 – Unmanaged voice and typical route for an "off-net" call



Source: TERA Consultants

As the use of PSTN technology is declining, and as TDC is likely to phase out the PSTN technology in the near future, it is required to assess whether VoIP is the modern equivalent technology for PSTN. In the previous LRAIC model, DBA implemented the PSTN emulated over NGN platform with TDM interconnection for PSTN only users and PSTN simulated over NGN platform with TDM interconnection for DSL users. This solution is a VoIP solution. The question at stake is therefore: which voice solution is the modern equivalent solution for PSTN:

- PSTN legacy;
- PSTN emulated over NGN
    - With TDM interconnection;
    - With SIP interconnection;
- PSTN simultaed over NGN
    - With TDM interconnection;
    - With SIP interconnection?[56]

3.2 MEA assessment

As for the assessment of the MEA conducted in section 2, DBA considers the following issues in this specific case:

[56] Unmanaged voice is not a service directly provided by operators and is therefore out of the scope of the analysis

- Is there any difference between PSTN and VoIP in terms of quality and services provided? This corresponds to the technological criterion (see section 3.2.1).
- What is the most cost efficient technology for production of voice-only solutions? This corresponds to the cost criterion (see section 3.2.2).
- Does the observed market behaviour support an assumption of VoIP as MEA? This question is handled through the analysis of the subscriber criterion (see section 3.2.3) and the operator's strategy criterion (see section 3.2.4).
- What are the best practices regarding the MEA of voice (see section 3.2.5)?

3.2.1 Technological criterion

Operators were requested preliminary views on the quality of service and performances of the different solutions in advance of the preparation of this consultation document. If all operators agree on the fact that there is no major sound quality difference between the different solutions, they mention the fact that only PSTN legacy and PSTN emulated over NGN would continue to work in case of power blackout. Certain alarm services can also be provided only on PSTN legacy and PSTN emulated over NGN but neither on PSTN simulated over NGN nor on voice unmanaged.

Regarding interconnection solutions, in the current regulatory framework there may be drawbacks in using a pure IP interconnection such as numbering issues with IP. Indeed the information is not necessarily shared to enable an operator to determine whether a number can be reached on IP as opposed to TDM interconnection. Besides, generally speaking, national standards have not yet been chosen and specified for IP interconnection.

The outcome of the technological criterion analysis is that PSTN emulated over NGN may be the MEA of PSTN as it provides the same service in terms of quality compared to PSTN. PSTN simulated over NGN has however very similar features and only differ on power issues. Regarding the type of interconnection, IP interconnection appears to have slight differences with TDM interconnection.

3.2.2 Cost criterion

It is generally admitted that PSTN emulated over NGN or PSTN simulated over NGN brings significant cost benefits compared to PSTN legacy platforms.

When looking at the cost of the different voice service, TDC highlights that PSTN emulated over NGN is the most cost efficient technology:

> *"In TDC's point of view, taken into account that TDC holds and operate a copper access network with national coverage, POTS via cobber, (traditional subscriber stages or POTS cards in DSLAMs) is the most cost efficient. This is*

> *due to the stability of passive network with well optimized processes, simple installation at Customers premises, no additional CPE other than a telephone."*[57]

However, when moving to PSTN simulated over NGN the cost of DSL cards should be much lower than POTS cards which may lead to significant savings. First, having one single type of cards facilitates maintenance, facilitates migration in case a voice-only end-user asks for broadband and can enable to get higher volume discounts from manufacturers. Also, compared to the architecture implemented in existing DBA's LRAIC model, no separate DSLAM/MSAN supporting POTS are necessary which brings significant savings.

In that sense, PSTN simulated over NGN may be the MEA of PSTN.

Regarding interconnection, one of the alternative operators outlined the fact that TDM interconnection is not more expensive than IP-IP interconnection:

> *"We already have invested in a SS7 interconnect setup that still works. SIP interconnect with TDC is not cheaper or simpler, therefore no incentive to switch."*[58]

Indeed, the advantages of IP-based interconnection in terms of reduced costs only become significant when the TDM technology can be fully removed. As it is not the case today in Denmark there is no incentive to switch to IP interconnection, even if in the long run there may be significant savings. However, this reasoning is the reasoning of operators already in place, which is not in line with the definition of MEA detailed in section 1.2. From a new operator point of view, as SIP interconnection is neither cheaper nor more expensive, SIP interconnection can be the MEA.

In light of the analysis of the cost criterion, it appears that PSTN simulated over NGN may be the MEA of PSTN. Regarding interconnection, the cost criterion does not enable to exclude IP interconnection as the MEA, especially in the context of significant development of IP services.

3.2.3 Subscriber criterion

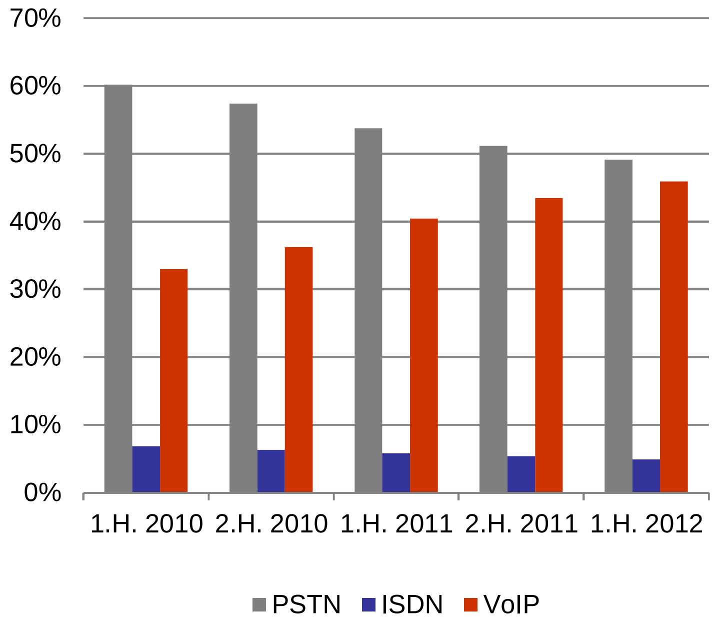
When looking at the evolution of fixed telephony in Denmark, managed VoIP (PSTN emulated over NGN or PSTN simulated over NGN, also called Voice over Broadband) has increased steadily over the last years reaching almost the same level as PSTN. In the meantime, PSTN market share has constantly decreased which supports the

[57] Source: TDC's answers to ERST/TERAs questions, Ref: KBP 1. feb. 2013

[58] Source: TELIA, Answers to DBA's questions to the LRAIC forum

assumption that managed VoIP (PSTN emulated over NGN or PSTN simulated over NGN) is the MEA of PSTN.

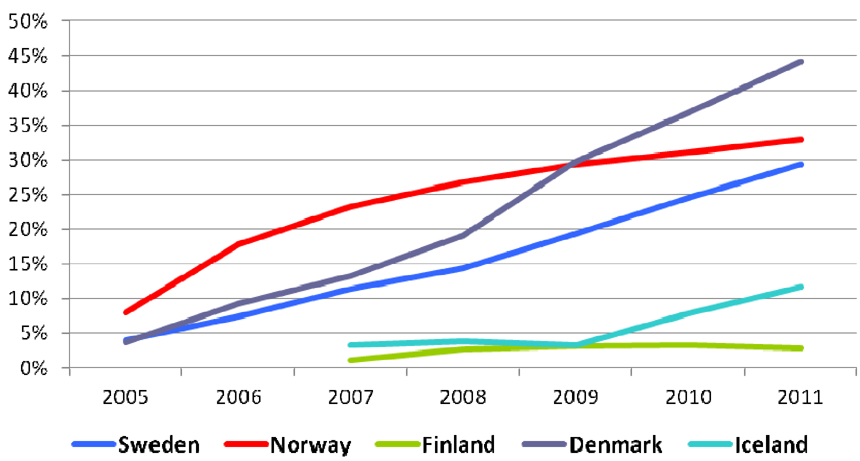
Figure 22 – Telephony market share by technology



Source: TERA Consultants' analysis based on DBA's data

It is to be noted that the development of managed VoIP has been also observed in other Nordic countries and that Denmark is the country where managed VoIP market share has grown fastest.

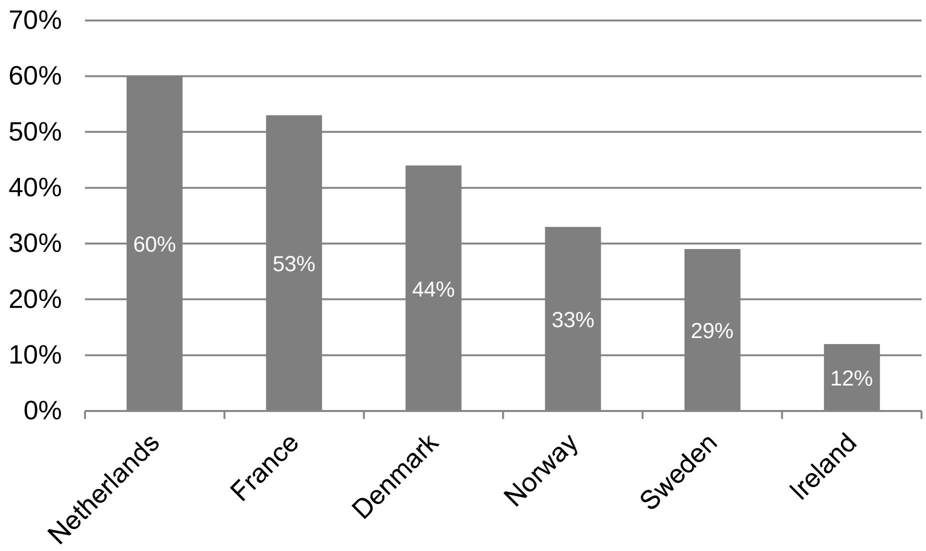
Figure 23 – Evolution of the managed VoIP market share in Nordic countries



Source: NRAs from Iceland, Sweden, Denmark, Finland and Norway, Telecommunication Markets in the Nordic Countries, 31st December 2011

Nonetheless, the managed VoIP market share in Nordic countries still lags a bit behind other eastern European countries such as the Netherlands and France. This outlines that the evolution of managed VoIP market share is still on-going and may increase in the upcoming years.

Figure 24 – managed VoIP market share by country in 2011



Source: Report for OFCOM dated 15th May 2012, NRAs figures for 2011 and 2012

All these indicators therefore suggest that voice managed through managed VoIP technologies are more and more subscribed by end-users in Denmark.

However, this analysis does not enable to specify whether end-users prefer PSTN emulated over NGN or PSTN simulated over NGN among the VoIP managed technologies. Indeed, it is not possible to know, for each operator, in each country presented above, what the preferred technology is. However, it appears that managed VoIP is generally sold in bundles with DSL broadband subscriptions. This implies that DSL broadband end-users are being provided voice services through the PSTN simulated over NGN solution (a single port on DSLAM/MSAN is needed with PSTN simulated over NGN). As DSL broadband penetration is very high in Europe, this should mean that the vast majority of VoIP end-users are being provided through the PSTN simulated over NGN solution (this is the case for example in France, for all VoIP end-users). Also, cable TV operators generally provide managed VoIP services which have the same technical features has PSTN simulated over NGN solution.

The analysis of the subscriber criterion suggests that PSTN simulated over NGN may be the MEA of PSTN.

With regards to interconnection (TDM or IP), subscribers cannot observe any difference as interconnection is transparent for them. As a consequence, the subscriber criterion is not relevant.

3.2.4 Operator's strategy criterion

When assessing the MEA, it is very relevant to observe the strategy followed by new operators, as it very related to the definition of MEA.

Generally speaking, alternative operators have much higher market share with the managed VoIP technology than with the PSTN technology (see Table 8). For providing managed VoIP services, it appears that alternative operators prefer to use PSTN simulated over NGN offers as it does not require the use of specific cards but enables the use of DSL cards. This appears to be the case in Denmark but also in other European countries to our knowledge.

Table 8 – PSTN and VoIP market shares in H1 2012 and H1 2011

	H1 2011		H1 2012	
	PSTN	VoIP	PSTN	VoIP
TDC	52%	14%	47%	17%
Alternative operators	13%	22%	12%	23%
TOTAL	65%	35%	60%	40%

Source: TERA Consultants using DBA statistics

TDC argues that the shift towards PSTN simulated over NGN may occur within the next 5 years:

> *"If volumes continue to develop as the last few years, a migration to simulated POTS via DSLAMs using TDC's IMS platform will be optimal in 2017-18. PSTN is planned to be phased out (as a network, not as a service) after the migration of POTS and ISDN lines. Expected not before 2019. As mentioned above TDC intends to use simulated POTS over IMS platform"*[59]

As a consequence, the operator's strategy seems to suggest that PSTN simulated over NGN is the MEA for PSTN.

With regards to interconnection, TDC is according to the market 3 decision obliged to offer both TDM and SIP interconnect. According to TDC, over the last 5 years 46 typically smaller operators have routed traffic through the SIP interface. At present, 34 operators use TDC's SIP interconnection offers. But, even if traffic terminated in TDC's fixed network through SIP interconnection has been multiplied by 10 between 2007 and

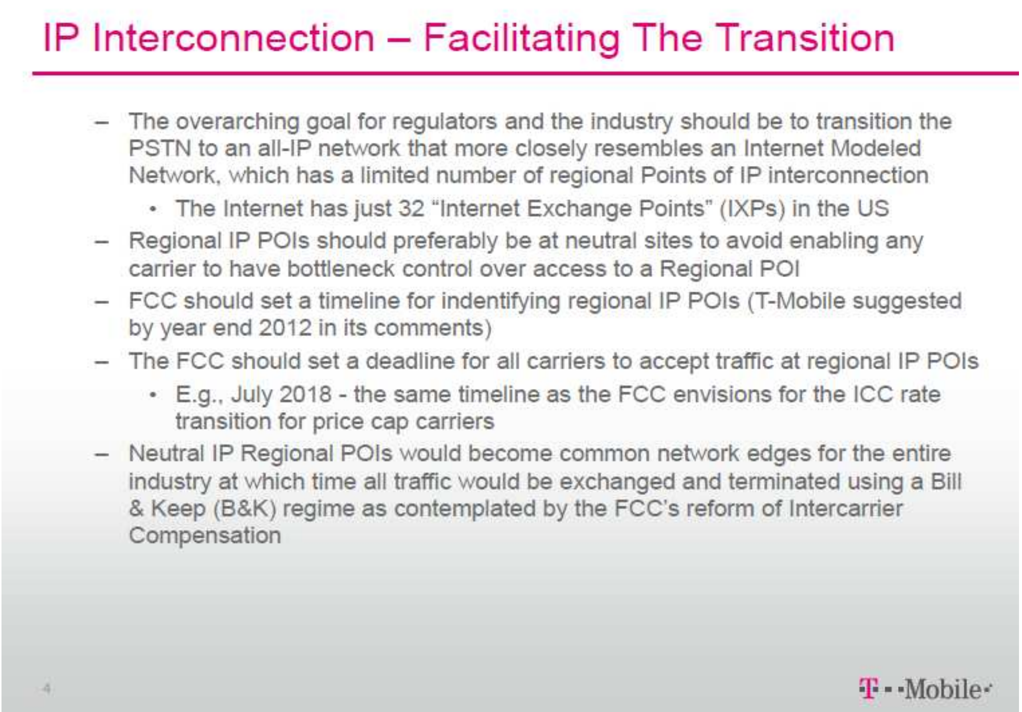
[59] Source: TDC's answers to ERST/TERAs questions, Ref: KBP 1. feb. 2013

2012, this still represents a very small share of traffic terminated in TDC's fixed network (126 millions of minute in 2012).

This might be due to the fact that operators having previously invested in a TDM interconnection are not willing to migrate to IP-IP interconnection due to the fact that it would require additional investments. However, some alternative operators[60] including new operators in Denmark have preferred IP-IP interconnection when building up their networks.

More generally speaking, there is a trend towards a greater use of IP-IP interconnection. Even large operators, such as T-Mobile in the USA[61], are advocating a move to IP-IP interconnection. The current deployment of LTE by mobile operators should enable IP-IP interconnection to develop as with LTE, packet-switching is introduced for voice using IMS.

Figure 25 – Extract of T-Mobile slideshow in May 2012 on IP-IP interconnection



Source: T-Mobile

The operators' strategy criterion suggests that PSTN simulated over NGN and IP-IP interconnection is respectively the MEA of PSTN and TDM interconnection.

[60] Source: Answer of Concepy ApS to TDC's questions

[61] Source: *Source: http://www.in.gov/iurc/files/Haas_IP_Interconnection_for_NCRA_-_TMO_%282%29.pdf*

3.2.5 Best practices in Europe

The aim of this section is to determine what type of voice service and what type of interconnection have been considered by NRAs when building up their LRAIC models. LRAIC models are not always publicly available and even when they are publicly available, this information is not necessarily easy to find. To that extent, the report analyses the decision made in Belgium, France, Romania, Sweden and Malta.

Results show that the IP based interconnection is generally not the solution retained. NRAs favoured the TDM interconnection. Regarding PSTN simulated over NGN this has been considered as the MEA in 2 out of 5 countries for which data could be found.

Table 9 – Benchmark of the MEA related to voice service and interconnection

Country	Is PSTN simulated over NGN the MEA?	Is IP based interconnection the MEA?
Belgium	NO	NO
France	YES	NO
Romania	YES	NO
Sweden	NO	NO
Malta	NO	IP and TDM

Source: TERA Consultants‘ analysis based on models’ documentation

3.2.6 Overall findings

For the vast majority of criterions, the analysis supports the assumption that PSTN simulated over NGN is the MEA of all other voice services. This is especially the case when looking at new entrant strategies, including in Denmark, which is in line with the definition of the MEA specified in section 1. In terms of costs, PSTN simulated over NGN can be considered as the MEA for PSTN. In terms of quality of service, there are however some differences with PSTN and PSTN emulated over NGN, but with the high and increasing level of broadband penetration in Denmark, more and more end-users are being migrated to PSTN simulated over NGN solutions.

While existing operators have generally not switched to IP-IP interconnection, this type of interconnection seems to be favoured by new entrants and can bring many benefits for a new entrant (as interconnection is needed at a very limited number of points and avoid having to invest in a legacy technology). However, IP-IP based interconnection has technical differences with TDM interconnection, no NRA has considered IP-IP interconnection as the MEA and TDM interconnection is still very largely used by operators. As a consequence, IP

based interconnection is not considered as the MEA for TDM interconnection. This could however change in the future, as TDM interconnection volumes decrease. It is therefore proposed to model both types of interconnection in the model.

Table 10 – Summary Overall findings

Criterion	Is PSTN simulated over NGN the MEA?	Is IP based interconnection the MEA?
Technological criterion	-	-
Cost criterion	+	+
Subscriber criterion	+	/
Operator's strategy criterion	+	+
Best practices	/	-

Source: TERA Consultants

4 Conclusions and next steps

The preliminary assessment carried out in this report shows that:

- FTTH is the MEA of copper and cable TV access networks;
- VoIP technology is the modern equivalent technology of PSTN.

As a consequence, DBA intends to develop the following LRAIC models:

- For the passive part of the access network, DBA intends to develop a LRAIC model for the copper technology and for the FTTH technology. While FTTH is considered as a MEA for copper, it is indeed considered that the computation of copper-based regulated product prices requires the development of a LRAIC model for copper to identify cost differences between copper and FTTH. Especially, as TDC does not intend to deploy a large scale FTTH network in the medium term, it appears necessary to calculate the cost of a copper access network. For the passive part, it does not appear necessary to develop a LRAIC model calculating the costs of a coax network as the passive part of cable TV access network is already significantly based on fibre and fibre will be more and more deployed in the coming years which should make the passive part of the network very similar between cable TV and FTTH. This should also simplify the understanding of the models for the industry. However, for the active part of the network (OLT for fibre, DSLAM for copper, optical nodes and amplifiers for cable TV), these assets will have to be modelled to identify cost differences between technologies. These assets have shorter asset lives and are very different from a technology to another.
- For voice, DBA intends to model VoIP technology with voice simulation over NGN using both TDM and IP-based interconnection. PSTN simulated over NGN appears to be the MEA of PSTN today. It is noted that the previous model was based on voice emulation over NGN using TDM interconnection configuration. The current proposal is therefore not a significant difference with the previous model and represents the MEA of PSTN.

It is reminded that the next step of the project will consist in preparing a Model Reference Paper for the LRAIC models and will therefore take into account the conclusions of this report as a starting point, once comments from the industry have been considered.

5 Appendices – Access network cost estimates

Comparing costs of the different technologies available for fixed access networks must be conducted by making sure that the scope of costs calculated for each technology is similar. It is necessary to make sure that the geographical scope, the network scope and the level of economies of scale are similar to be able to achieve a true cost comparison:

- Geographic scope: when compared, the networks should have the same geographic coverage otherwise one technology may look more costly only because it is covering more territory;
- Network scope: the equipment included in each network should reflect the same part of the network;
- Economies of scale: to avoid the potential issue of using different numbers of active lines supported by each type of access network, the total investment required to cover a given area for each network is considered rather than a cost per active line and per month.

With DBA's existing models[62], it is not possible to compute the investment cost of rolling out the cable TV network on the whole country. On the contrary, FTTH and copper access network costs can be calculated over the whole country. It is therefore not possible to compare the three networks at once. Also, it is not possible to map easily FTTH and cable TV networks and the network scope of cable TV networks cannot be easily compared with the network scope of FTTH.

Therefore, only a comparison between copper and FTTH can be carried out.

Copper is deployed all over Denmark. FTTH network costs need therefore to be calculated on the whole country. The model has thus been configured to reflect this situation. The following changes have been made to the existing network:

Table 11 - Nationwide P2P FTTH network, no trench sharing

Model	Sheet	Cell(s)	Value
CATV + Fibre Access	A1_I_Ctrl	E85:E104	PTP
CATV + Fibre Access	A1_I_Ctrl	K85:K104	2010
CATV + Fibre Access	A1_I_Ctrl	L85:L104	1

[62] Final hybrid model Fv4.2 (December 2012) which can be found at http://www.erhvervsstyrelsen.dk/prisafgoerelse

CATV + Fibre Access	A1_I_Ctrl	E107	100 %
Expenditures C + F	A4_I_Demand	M170:CK189	100%
Expenditures C + F	A4_I_Demand	M193:CK212	0%
Expenditures C + F	A4_I_Demand	M216:CK235	0%
CATV + Fibre Access	A3_I_NwDsScen	E333:F335	0 %

Source: TERA Consultants

Table 12 - Nationwide GPON FTTH network, no trench sharing

Model	Sheet	Cell(s)	Value
CATV + Fibre Access	A1_I_Ctrl	E85:E104	PON
CATV + Fibre Access	A1_I_Ctrl	K85:K104	2010
CATV + Fibre Access	A1_I_Ctrl	L85:L104	1
CATV + Fibre Access	A1_I_Ctrl	E107	100 %
Expenditures C + F	A4_I_Demand	M170:CK189	100%
Expenditures C + F	A4_I_Demand	M193:CK212	0%
Expenditures C + F	A4_I_Demand	M216:CK235	0%
CATV + Fibre Access	A3_I_NwDsScen	E333:F335	0 %

Source: TERA Consultants

Table 13 - Nationwide copper network, no trench sharing

Model	Sheet	Cell(s)	Value
CATV + Fibre Access	A1_I_Ctrl	D29:D48	FALSK
CATV + Fibre Access	A1_I_Ctrl	E85:E104	None

CATV + Fibre Access	A1_I_Ctrl	D134:D153	0 %
Access	B3_I_Share_Routes	F43:F45	0 %
Access	B3_I_Share_Routes	K112:L112	100 %
Access	B3_I_Share_Routes	N112	100 %

Source: TERA Consultants

The investments for FTTH can be found in the file “CATV+Fibre Access Fv4.2.xls” in the sheet “B2_C_FAopex” between the cells C6 and I505.

The investments for copper can be found in the file “Access Fv4.2.xls” in the sheet “B8_O_to_Consolidation” between cells O10 and O225 for equipment capex, between cells X10 and X225 for installation CapEx and AG10 and AG225 for annualised OpEx.

Results are presented in section 2.2.2.

6 Illustrations table

List of tables

List of figures