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# Comparison of Cost for Different Coverage Scenarios between Copper and Fiber Access Networks

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***Abstract*—As the demand for bandwidth in broadband Internet connections to private households are increasing, the current copper network in Denmark is facing a considerable upgrade to meet the governments goal of equal access to everyone. In this paper an analysis is presented concerning the coverages of households for a variety of xDSL tecnologies. A cost estimation has been made when expanding the current copper infrastructure to provide VDSL connections to all households in a municipality in Denmark. This is compared to the price of providing Fiber to the Home (FTTH) in the same area. Furthermore, the prices of providing FTTH to the coverage areas of those comparable with VDSL are estimated.**

***Index Terms*—Communication Network Planning, ICT-infrastructure, Deployment Cost, Next Generation Network Technologies, Degrees of Coverage, Upgrading Current ICT-infrastructure.**

## I. Introduction

Denmark is in a leading position among European countries when it comes to offering broadband connections to its citizens. These connections are delivered as ADSL (65%) or Cable (35%) through the existing PSTN and copper based cable networks respectively [1]. Due to these networks, Denmark has a 98% (2,448,649 of 2,498,621 households) broadband coverage [2], which means that 98% of the Danish households have the possibility to subscribe to a broadband connection. It is the Danish government's goal that Denmark should evolve into a knowledge based IT-society [3] and in this scenario the broadband coverage plays an important part, in the sense of networking private households. In a future society, as visioned by the Danish government, broadband will be an essential parameter directly related to the possibility to collect knowledge and the broadband coverage can be seen as a measure of the country's competitive status regarding knowledge based IT centered services.

### *A. Current Broadband Situation*

The current broadband situation confronts two problems. First of all it is problematic that only 98% can subscribe for broadband as the last 2% are likely to be detached from the ongoing development in society. The second problem is posed by the broadband definition [2] as customers currently understand broadband as a service that scales up to 2 Mb/s, whereas others (among these the Danish government) defines broadband as "something perceptibly better than a basic ISDN line", which is defined as 144 kb/s. Even though 144 kb/s is a better and much-needed upgrade from the previously 56k analog modems it is not likely to be sufficient even in the short term. If looking at a projection [4] of bandwidth for Internet services only for ADSL [1] (Figure 1), an average of 5 Mb/s is estimated within 10 years which is also the minimum basic capacity recommended by the Swedish ICT Comission [5]. Today the average bandwidth of an Internet connection in Denmark is approximately 700 kb/s. However, when adding more and higher demanding applications, especially triple play services which will include digital television and HDTV, requirements will increase radically. Taking the requirements for the future bundled services into account it is assumed that the required bandwidth will be at least in the range of 10-100 Mb/s. All current ADSL bandwidths fall below this threshold and it must thus be expected that the copper network must be upgraded to handle new xDSL technologies in order to meet even the short term requirements.

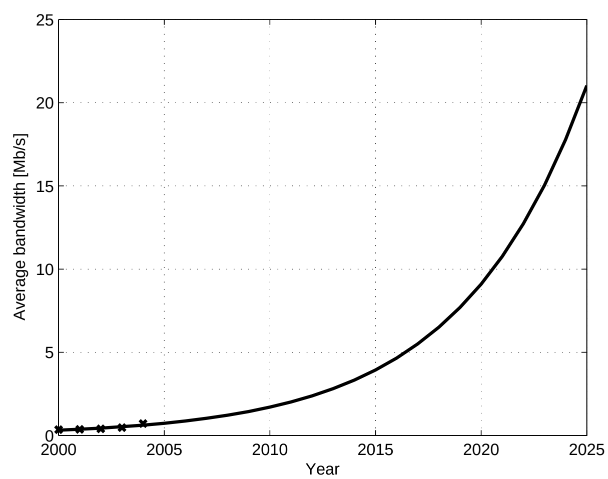


**Figure 1. ADSL bandwidth projected.**

However, it will not be sufficient to replace end-equipment only, due to the fact that copper networks in general and particular xDSL are highly dependent on the distance from the end-user to the central office (CO). The maximum obtainable bandwidth for a customer will thus be limited by the distance to the closest point of electronics.

### B. Current Broadband Market

The competition on the broadband market has in many countries been limited to a few larger real xDSL network operators and a larger group of providers reselling the network terminations. With respect to cable networks this is almost the same, with a few large commercial providers and a large number of private providers. Common for all of them is that they use existing copper cabling to deliver services to their customers. Now some of these companies and new companies (e.g. power companies) are beginning to deploy fiber connections. This has started the discussion of whether this deployment is economical sane in comparison to keep using the current copper based network. In the short term (less than 5 years) the conclusion is clearly that the copper network is the best investment, as it will easily meet the demands at least when considering Internet services only. However, little research has been done in how to upgrade the copper network making it able to support much higher bandwidths than today. It is currently not known what influence this will have on the coverage with respect to bandwidth. If only highly populated areas will be able to obtain high speeds, the degree of coverage for a certain bandwidth will drop and the differences between regions will be enhanced. This conflicts with the Danish government's vision for a 100% broadband coverage, as well as with the goal to even out regional differences and the desire to be competitive on knowledge through an IT society.

## II. Hypothesis

Based on the reasons above, it is considered highly relevant to investigate the effect on coverage when increasing the bandwidth through the current copper network. Furthermore, given that a Fiber To The Home (FTTH) network will be the only technology capable of handling bandwidth for a longer time frame [6], this paper will analyze to which extent it will be economical and technological favourable to upgrade the current copper network instead of deploying a new FTTH network instantly.

Currently no such analysis is publicly available and discussions are mostly concerning an expensive FTTH network compared to a free copper network. It is the hypothesis of this paper that considerable investments in the copper network will be required to deliver the bandwidth demanded in the long term, but that the copper network will be suitable for the short term with only small investments.

## III. Method for Investigating Coverage

As only little is known about the cable networks (especially the privately owned) and the fact that cables in Denmark covers only a smaller part of the broadband connections, the analysis will take basis in xDSL. With the knowledge of COs and Remote Subscriber Units (RSU) in the PSTN network and by presupposing that xDSL can be delivered from all points, it is possible to calculate the number of households within certain distances of these points.

The first part of the analysis will include a study of the coverage possible with different xDSL-technologies, using the current copper network.

The second part of the analysis will be divided into two scenarios, upgrading the current copper network to a 100% coverage with xDSL technologies and deploying a complete FTTH network along with FTTH networks with coverages comparable to those of xDSL. The xDSL-scenario will again be divided into various sub-scenarios according to the bandwidth offered. The cost of upgrading or deploying the different networks will be calculated and prices have been estimated as to a fixed cost per deployed meter cable and a fixed cost per new CO, which includes basic equipment and housing facilities. The given prices are very general, but will be sufficient for the overall comparison made:

- 1 km fiber costs 50 DKR.
- 1 km of digging costs 100.000 DKR.
- A housing facility for FTTH cost 1.000.000 DKR.
- A housing facility for VDSL cost 50.000 DKR.

The listed prices are average estimations based on several planning projects throughout the western part of Denmark.

The price estimations for housing facilities include both operational and capital expenses for approximately 10 years.

For the copper network it is assumed that marginal extra ducting will be needed compared to a complete new fiber network. Furthermore, new COs will be placed in optimal locations as no knowledge of current copper distribution frames is available. For the FTTH network it is assumed that no existing cabling or housing exists.

Calculations in both parts of the analysis has been made on a smaller part of Denmark. The municipality of Hals shown in Figure 2 is the reference area which contains both rural areas and high density populations.

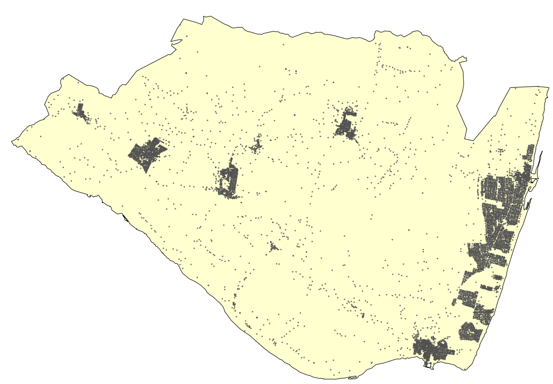

**Figure 2. The municipality of Hals**

## IV. Analysis

### A. Current xDSL Coverage

xDSL covers a large group of technologies with different parameters when it comes to bandwidth and transmission

**Table 1. xDSL specifications.**

| Technology | | Maximum Bandwidth | | Distance [km] | |
|---|---|---|---|---|---|
| | | Down | Up | Spec. | Cor. |
| ADSL | 1 | 1.5 Mb/s | 64-640 kb/s | 5.5 | 4.4 |
| | 2 | 2 Mb/s | | 4.9 | 3.9 |
| | 3 | 6 Mb/s | | 3.6 | 2.9 |
| SDSL | | 2.3 Mb/s | 2.3 Mb/s | 3.7 | 3.0 |
| G.SHDSL | | 1.2 Mb/s | 1.2 Mb/s | 6.1 | 4.9 |
| VDSL | 1 | 13 Mb/s | 1.6-2.3 Mb/s | 1.4 | 1.1 |
| | 2 | 25.8 Mb/s | | 1.0 | 0.8 |
| | 3 | 51.8 Mb/s | | 0.3 | 0.2 |

distances. Table 1 provides an overview [7] [8] of the considered technologies. A scaling factor of 0.8 is used to correct for limitations on the actually distance compared to the specifications caused by parameters such as; the quality of the copper, crosstalk in larger cable bundles or installation of equipment.

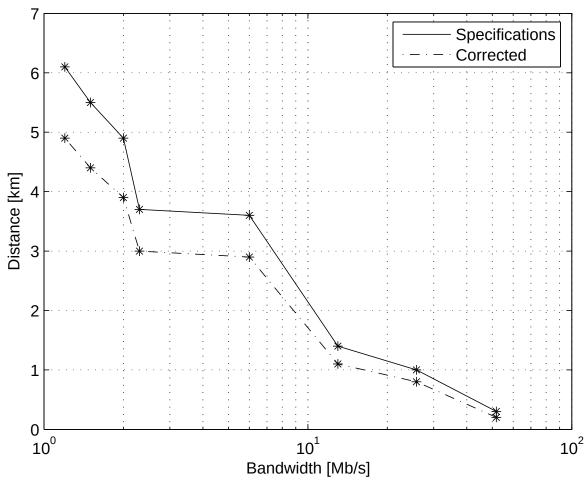


**Figure 3. Bandwidth as a function of the distance for xDSL-technologies.**

The same numbers, seen from Figure 3, give a good impression of the large drop in bandwidth when increasing the distance.

Setting up scenarios for needed bandwidth in the future is a complex issue and is not the subject of this analysis. However, some scenarios are needed in order to calculate coverage and cost. The VDSL bandwidths are used as milestones for the development in bandwidth over the next decade, depending on individual judgment.

It should be noted that development in xDSL-technologies is likely to increase the limits upon the bandwidth and distance. However, an upper limit upon the increases must be expected, especially when considering current problems related to crosstalk, which will worsen as the usage of the copper cables increases.

Figure 4 shows the distribution of NTs according to the their distance to the nearest CO. This is converted into the coverage degrees seen from Table 2 where the VDSL-values are of the most interest.

From the previous numbers it is clear that the copper

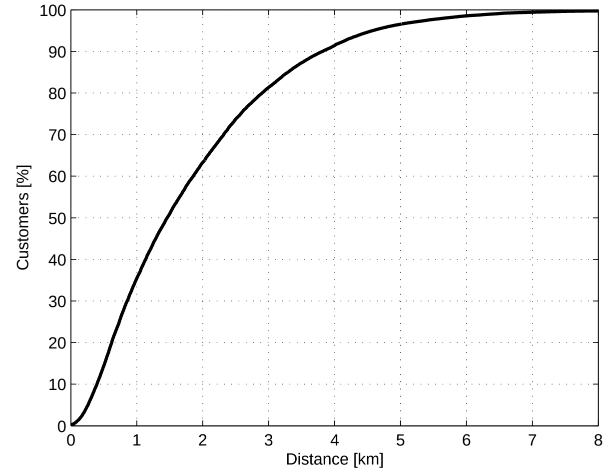


**Figure 4. Accumulated distance distribution of NTs.**

**Table 2. xDSL degrees of coverage.**

| Technology | | Coverage | |
|---|---|---|---|
| | | Buildings | Percent |
| ADSL | 1 | 7,292 | 96.5 |
| | 2 | 6,807 | 90.1 |
| | 3 | 5,308 | 70.2 |
| SDSL | | 5,564 | 73.6 |
| G.SHDSL | | 7,517 | 99.5 |
| VDSL | 1 | 2,644 | 35.0 |
| | 2 | 2,221 | 29.4 |
| | 3 | 405 | 5.4 |

network will need major upgrades to support 10-50 Mb/s to more than a minor part of the Danish population. New COs must be deployed in order to decrease the distances to the farthest NT.

### *B. Cost of Extending the Current Copper Network*

To be able to provide more bandwidth to all households more COs must be located. In order to obtain a realistic analysis with respect to number and location of COs some prerequisites must be setup: 1. COs can be added anywhere and 2. As much as possible of the copper network should be reused. This leads to a straight forward algorithm for placing COs: From the most distant NT add a CO in a distance equal to the technologically range of reach from the NT going towards the CO, that it was previously connected to. Using this algorithm with the range of reaches obtained for VDSL, gives the results seen from Table 3.

### *C. Cost of Deploying a FTTH Network*

The previous results should be compared to the cost of deploying a complete FTTH network, however, if it is considered acceptable that a part of the population will be lagging behind the development of the surrounding society due to their address, it will be relevant to investigate the

**Table 3. Cost of deploying VDSL to all households.**

| | | Number | Cost[1000 DKR] |
|---|---|---|---|
| VDSL 1 | Lines | 53,2000 | 266 |
| | Ducts | 124,000 | 12,400 |
| | COs | 100 | 5,000 |
| | Total | | **17666** |
| VDSL 2 | Lines | 840,000 | 420 |
| | Ducts | 156,000 | 15,600 |
| | COs | 170 | 8,500 |
| | Total | | **24520** |
| VDSL 3 | Lines | 3,750,000 | 1,875 |
| | Ducts | 290,000 | 29,000 |
| | COs | 775 | 38,750 |
| | Total | | **69,625** |

cost of deploying fiber to coverage areas equal to VDSL. With basis in the current COs, access networks have been planned to cover the complete area and those areas currently covered by VDSL. The results can be seen from Table 4.

**Table 4. Cost of deploying fiber to all households and to households with possible access to VDSL in the current copper network.**

| Coverage | | Number | Cost[1000 DKR] |
|---|---|---|---|
| Fiber 100% | Lines | 10,200,000 | 5,100 |
| | Ducts | 410,000 | 41,000 |
| | COs | 6 | 6,000 |
| | Total | | **52100** |
| Fiber 35.0% | Lines | 1,150,000 | 575 |
| | Ducts | 70,000 | 7,000 |
| | COs | 6 | 6000 |
| | Total | | **13,575** |
| Fiber 29.4% | Lines | 860,000 | 430 |
| | Ducts | 57,000 | 5,700 |
| | COs | 6 | 6000 |
| | Total | | **12,130** |
| Fiber 5.4% | Lines | 58000 | 29 |
| | Ducts | 13,000 | 1,300 |
| | COs | 6 | 6,000 |
| | Total | | **7,329** |

## V. Conclusion and Discussion

The high penetration of ADSL has given Denmark the status of being in the European lead in offering broadband connections to the population. However, in this paper it has been shown that when increasing the definition of broadband from the current 144kb/s the Danish government will be further away from the ambition of having a 100 % broadband coverage.

In the worst case scenario the existing copper infrastructure will only be able to supply 5-10% of the population with the highest possible bandwidth that can be provided with todays copper technologies. Taking the lowest offered bandwidth of the three VDSL scenarios in consideration only 35 % of the Danish population will benefit from bandwidth up to 13 Mb/s.

It is obvious that an expansion of the current copper infrastructure is impending in order to provide an equal access for everybody to the ICT-infrastructure.

An investigation of the possible expansion and cost estimation has been done in this paper using three different scenarios with VDSL solutions. It has been shown that the upper limit for the distance of VDSL will require a serious increase of network nodes containing electronic equipment and thereby causing high network complexity and vulnerability. Scaling up the scenario from the municipality of Hals it would require more than 150.000 nodes to cover a rather small country as Denmark

Taking this into consideration and the fact that the requirements of bundled future services is likely to exceed the bandwidth offered in VDSL, a comparison was made between expanding the copper infrastructure and completely replace it with a fiber based infrastructure.

This comparison shows that it should carefully be considered to which extent the copper infrastructure should be expanded. Assuming that xDSL technologies only are to be considered as transition technologies before a fiber based infrastructure is required, it will not be cost effective to aim for a large penetration of VDSL.

If it is accepted that only a smaller part of the Danish households can be provided with high bandwidth, the results showed that the cost of deploying fiber will be greatly decreased. It is actually those partially prices and not the cost of full coverage that should be compared to the considered "free" cost of the copper network. If disregarding the price of the COs the cost of providing FTTH in an coverage range similar to VDSL 3 will be less than 1.5 million DKR and usability and lifetime of this scenario will greatly outperform those of VDSL.

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