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Analyzing Broadband Divide in the Farming Sector

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***Abstract*—Agriculture industry has been evolving for centuries. Currently, the technological development of Internet oriented farming tools allows increasing the productivity and efficiency of this sector. Many of the already available tools and applications require high bandwidth in both directions, upstream and downstream connection. The main constraint is that farms are naturally located in rural areas where the required access broadband data rates are not available. This paper studies the broadband divide in relation to the Danish agricultural sector. Results show how there is an important difference between the broadband availability for farms and the rest of the households/buildings the country. This divide may be slowing down the potential technological development of the farming industry, in order to keep their competitiveness in the market. Therefore, broadband development in rural areas could be one of the points to focus in a near future broadband access plans.**

***Keywords*-Broadband Divide; Rural Access; ICT in Agriculture.**

I. Introduction

Denmark is recognized as one of the top countries in telecommunications and data networks development. Almost every household in the country has access to broadband, as claimed by [1]. However, the major problem in relation to these statistics is that "broadband" is usually defined as any access connection above 256 kbs (by OECD) or above 144 kbs, both referred to downstream (by EU-Comission). These definitions are very loose and outdated to be able to analyze in deep detail the real broadband possibilities the households in the country. Therefore, even though statistics reflect that almost all farms have broadband access, the reality is that in rural areas the speed and the quality of the access connections are much lower than in urban areas.

The broadband gap urban-rural has been progressively narrowed in developed countries, for example in US as address by [2]. However, there is still a significant difference between urban and rural areas in terms of ITC development. Farms and other agricultural facilities are naturally located in these rural areas, suffering also from this digital divide, including broadband availability. In the specific case of Denmark, it has been reported by local farmers in [3] that the available data rates they have available cannot support new modern internet oriented farming tools and applications. These newly available options may increase the productivity and/or revenue of this type of businesses, examples of services are: E-VET [4] or GIS based harvesting optimization [5].

In Denmark, agriculture represented 4,6 % of GDP in 2012 (the highest percentage in the EU), around 15 billion dollar [6]. Consequently, as a relevant sector, any improvement in productivity and profitability will directly benefit the country's overall development. On the other hand, the lack of future proof access infrastructure for these farms could have an impact on their competitiveness in local and international markets, as reported by the EU-Commission in [7].

The objective of this work is study the broadband access divide affecting the agricultural sector in Denmark. For this purpose, first we study the broadband possibilities of each farm in the country individually. This study is based on the methods to evaluate the upper bound performance of copper access network described in [8]. The results are compared to the official broadband statistics for the whole country published in [1], in order to quantify the broadband divide suffered by the Danish farms.

The novel contributions that to the best of our knowledge have never been covered before are: To study and quantify the broadband divide specifically for the farming sector, and to carry this study at an individual household level for the farms in the country. There are relevant studies in relation to digital divide in rural areas [9], or broadband penetration effect on rural communities [10]. But none was focused on the broadband access for farms, and have been carried at ZIP code or regional level instead of at an individual entity level.

Studies at ZIP code or municipality level are not detailed enough for the purpose of this study, as they reflect overall average results. Moreover, focusing on farms, these do not significantly contribute to the average statistics due to their much lower number in relation to the total number of household in a studied area, and their very specific location (lowly populated areas). Therefore, a feasible approach to identify the broadband situation for a specific sector with very special locations within a ZIP code or municipality region, is to treat each household/farm as an individual entity.

The results of this study show that even though Den-

mark is one of the top countries in terms of broadband accessibility, Danish farms are clearly behind in this aspect compared to the rest of the country. These results might open possibilities for new initiatives towards improving the broadband access for farms, and by extension for rural areas in general. In addition, the methodology used can be extrapolated to perform similar studies in other geographical regions or different professional sectors.

The rest of the paper is organized as follows: Section II summarizes important concepts and definitions in relation to the studied topic together with a brief literature review. Section III presents the broadband divide analysis, covering the scenario, methodology, and results. Section IV highlights the most relevant conclusions of this work.

II. Background

The following paragraphs describe very briefly important concepts and relevant literature in relation to the studied topics.

A. Concepts and Definitions

The following list summarizes important concepts in relation to the topic or the development of the work in this study.

Broadband divide: In this study, broadband divide is specifically referred to as the difference in broadband possibilities between two defined groups. In this case, the farms are compared to the rest of the country's average broadband accessibility.

GIS data: The work is carried out using real Geographical Information System data for Denmark. The information consists of databases containing the location and other relevant information of farms, roads, and access points.

Cooper infrastructure: The copper infrastructure is connected to the distribution network by fiber at the access points. The xDSL active equipment is placed there, and the distance between these points and the households is one of the most relevant factors to calculate their broadband possibilities over copper, this distance is referred to as *"loop length"*. Theoretically, the attenuation suffered by the signals is over copper 13,81 dB/km, however in reality this value is higher [11]. This attenuation can be related to the maximum deliverable data rates over the cooper lines. Information about the attenuation and data rates speeds in xDSL transmissions can be found in [12], or [13] among others. Also, a graphical representation of the maximum speed vs. distance for the currently available xDSL technologies can be found in [8].

Other factors may influence the performance of the copper based connections such as electromagnetic interferences (EMI) [14], but since these are dynamic in time, are not considered in this study.

B. Related work

Basically, digital divide is any type of analysis or study that provides a comparison of the capabilities of using modern information technology between groups in society, geography, or any other relevant division. The nature of these groups can be very diverse: In [15], a study related the use of ICT to the income by households in Canada. In [16] the divide is quantified between countries based on a set on indicators in relation to network infrastructure and users' skills. More specifically, in relation to broadband and rural areas, some of the most recent examples are [2], or [17] where broadband availability is studied in different counties, in order to illustrate the technological difference between urban and rural regions.

However, it is difficult to find examples of studies carried out at a household level due to the magnitude of the problems. Even to analyze small communities requires an enormous amount of time and computational resources, due to the size of the databases involved (households, roads and other relevant GIS information). One example found in literature is [18] where authors estimate the cost of three types of access technologies to provide high speed connections to most of the households in the state of Victoria, Australia.

III. Broadband Divide Analysis

The following paragraphs describe in detail the broadband divide analysis carried out for the Danish farming sector.

A. The Scenario

The analysis consists of a study of the farms in Denmark distributed in five regions, the information about the farms has been taken from a publicly available industrial database [19] . Table I shows the numerical details about the scenario and the geographical information used, and Fig. 1 illustrates the five different regions.

Table I
GIS Input Data.

Region	Farms	Access Points	Segments	Area (Km^2)
Nordjylland	1.759	416	740.679	7.885
Midtjylland	2.546	742	1.236.145	13.090
Syddanmark	2.784	416	1.061.931	12.090
Sjealland	1.136	237	605.749	7.254
Hovedstaden	372	105	382.328	2.553
Totals	8.597	1.916	4.026.832	42.872

B. Methodology

The following paragraphs describe the methodology followed to study the broadband divide affecting the farms. For the rest of the document the farms are referred to as NT (Network Termination), and the access points as AP.

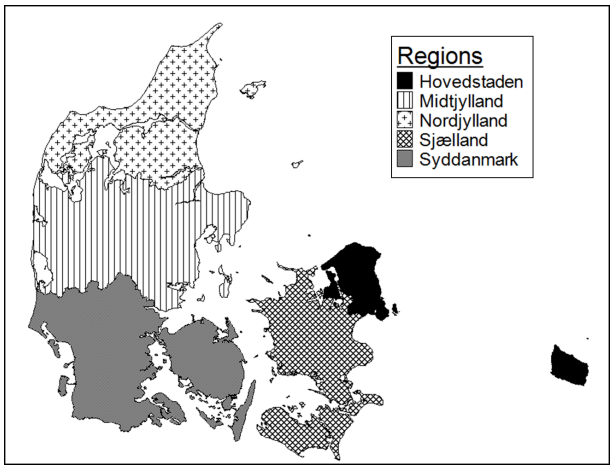


Figure 1. Danish Regional Division.

1) Assumptions:

- For this study it is assumed that the farms only have traditional copper line access. In reality, very few of these farms would have any other source of fixed wired broadband connection, unless they pay for the wired installation themselves (Km of cable and trenches). In Denmark cable and fiber is only installed in urban areas [1].
  The situation is similar regarding mobile wireless, 3G and 4G. These networks are only covering the cities, and the signal strength in rural areas is weak, limiting the available data rates. In any case, these networks are designed to be provide mobile support more than to be a fixed broadband solution for professional activities.
  In relation to wireless fixed broadband, Wimax solutions are not offered since July 2012, the only company providing access using this technology went bankrupt and stopped all services. Satellite broadband could be an option for private users when there is no other data connection available, however is not considered as a solution for professional activities. Briefly summarized, some of the main constraints of this type of connection are: long latency (minimum of 600 ms), high dependence of connection's availability and quality on external factors such as weather [20], restricted available bandwidth at any time due the Fair Access Control FAC.
- Unfortunately, information regarding the location the lines follow is not available. Thus, it is assumed that copper lines are installed along the roads and the traces between each NT and its AP follow the shortest path.
- The calculated available data rates are always given as an upper bound trying to depict the best possible situation, based on the loop length for each individual farm. As commented above, interferences or quality of the copper may affect the transmitted signals and the real bandwidth available could be even lower than the estimated.

Table II
LOOP LENGTH THRESHOLDS [M].

	Downstream	Upstream
>30 Mbs	900	300
>10 Mbs	2500	900

2) Procedure:

The principles of procedure to estimate the broadband possibilities for each NT are very simple. First, a spanning tree for each MN and its associated NT is calculated, using the road as to interconnect them. The result provides the shortest possible paths between each individual NT and its MN, and implicitly the loop lengths. The obtained loop length for each NT is computed according to the maximum deliverable data rates by distance. This approach allows to analyze the broadband possibilities for each farm individually and independently from any other household. A similar procedure has been followed in [8]

Then, the obtained data rates for the farms are compared to the official statistics about broadband coverage and speed for the whole country's households, based on [1]. More specifically, four groups of accessible data rates are studied, farms/households having access to connections above 30 Mbs and above 10 Mbs for both upstream and downstream directions. These are the reference groups in the official broadband report and consequently, the ones used for the comparison.

Table II presents the considered threshold loop lengths for the different data rate groups. For example, for an NT with a loop length of 900 m, it is considered that the maximum accessible data rates are 30 Mbs downstream and 10 Mbs upstream.

C. Results

The results of the analysis are summarized in the following paragraphs. Firstly, Fig. 2 presents the coverage of farms in relation to their loop length for the five regions of the country. It can be clearly identified how the coverage is more or less uniform across Denmark. The maximum difference between the curves is around 10%.

Secondly, Fig. 3 presents the quantification of the broadband divide for the Danish farms. The four mentioned groups are presented, accessibility of connections of at least 30 Mbs and of at least 10 Mbs. Again, the results are illustrated for each of the five regions and also for the whole country, and the obtained values are presented in terms of percentage of covered farms/households. As an illustration, looking at the right bar in Fig. 3(a), above 90% of the Danish households have access to a connection of at least 10 Mbs downstream, but only 40% of the farms have it available.

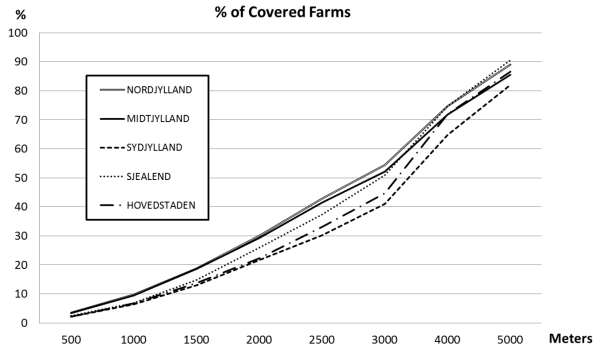


Figure 2. Farm Coverage vs. Loop Length.

It is important to remark that the values for the country's households are taken from an external broadband report, and the values for the farms are calculated specifically for this study.

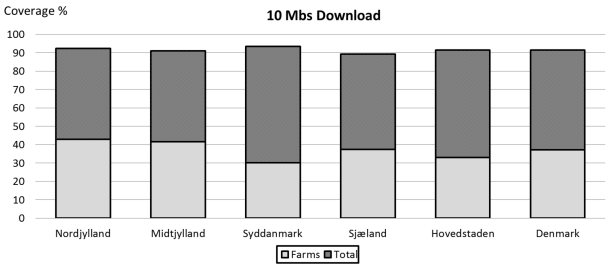
Briefly commenting the results, the divide in relation to downstream data rates is significant, as mentioned above less than half of the farms in the country have access to 10 Mbs. Only 7% could reach 30 Mbs while 80% of the rest of the country has access to it. In connection upload data rates, the divide is even broader, only 7% of the farms have availability to 10 Mbs, being 50% the availability for the whole country. Also, less than 2% of the farms can have access to 30 Mbs while this percentage goes up to 35% for the rest of the households.

The results in relation to broadband accessibility in farms for the different regions are consistent, illustrating that the global picture of the situation is similar all across the country. In addition, the broadband gap between the farms and the average broadband conditions in the country can be clearly identified and quantified from the obtained figures. If this gap was quantified between farms and urban areas, the difference could probably even be more significant.

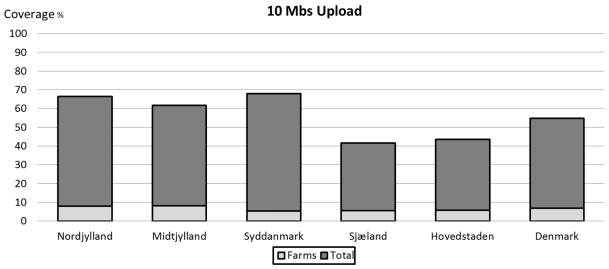
These concrete results cannot be extrapolated to other countries or regions, as the broadband coverage information and geographical parameters may differ significantly from the ones used for this Danish study. However, the same methodology can be used together with the relevant input data (GIS databases and reliable broadband statistics), in order to perform a similar analysis in other regions or for different sectors.

IV. Conclusion

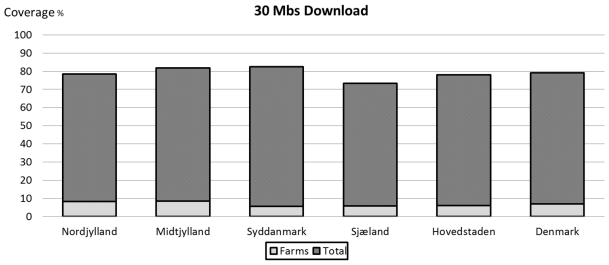
This paper analyzes the broadband divide for the Danish agricultural sector. Usually, digital divide type of studies are carried at a regional or ZIP code level, however this approach does not reflect the real situations of farms as these do not contribute significantly to the regional statistics. Instead, a more detail framework is proposed and each farm in the country is treated as an individual entity. Then, the



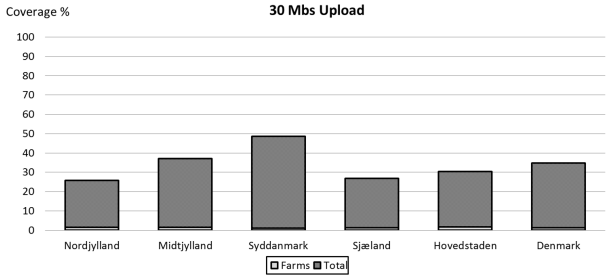
(a) 10 Mbs Download.



(b) 10 Mbs Upload.



(c) 30 Mbs Download.



(d) 30 Mbs Upload.

Figure 3. Agriculture Broadband Divide.

broadband possibilities for each of them are calculated. The obtained results are compared to the general broadband statistics for the whole country, in order to quantify the broadband divide suffered by the agricultural sector.

The novel contributions of this work can be summarized in two main points:

- Study and quantification of broadband divide for the Danish agricultural sector.
- Entity level approach to the problem, each farm is treated and analyzed individually.

The divide analysis reveals that there is a significant

difference between the farms and the rest of the country's households in terms of broadband accessibility. Four different data rate groups are studied, accessibility to connections of at least 30 Mbs and of at least 10 Mbs, in both downstream and upstream directions.

In relation to the obtained results, only 40 % of the farms have access to a connection of at least 10 Mbs downstream while for the rest of the country this value goes above 90%. For the rest of the studied groups (at least 30 Mbs upstream and at least 10 Mbs up/downstream) the percentage of covered farms is always below 10 %.

The resulting figures show how an important economic sector as the agriculture is significantly behind the country's average when it comes to broadband availability. The presented conclusions may contribute to enhance or speed up the development of broadband in rural areas, now that some concrete numbers about the situation are available. The improvement of broadband availability in farms, and by extension for the surrounding rural population, may require efforts from all the parties involved (farmers, carriers, public institutions...), as the geographical location may not allow to apply a traditional market driven plan.

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