LCA of data transmission and IP core networks

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Abstract

The IP (Internet Protocol) core network operated by TeliaSonera in Sweden has been studied according to a described definition (system boundary) and extrapolated to a national level for Sweden. A top-down and a bottom-up data collection approach have been used to quantify network equipment and energy consumption. The electricity consumption of the IP core network was about one fourth of the total energy consumption of the connected mobile and fixed access networks. The use stage results for the Swedish IP core network is about 0.08 kWh per GB (Gigabyte) of data traffic corresponding to about 19 g CO_2e/GB when applying a Swedish electricity mix. If instead a global average electricity mix is used, the resulting green house gas emission would be about 64 g CO_2e/GB. A method is also proposed where the amount of data traffic is used to allocate the IP core network on different usage. The method is exemplified by the 3G mobile broadband data traffic in Sweden.

1 Introduction

The ICT (Information and Communication Technology) vendor Ericsson and the telecom operator TeliaSonera have performed an LCA study of TeliaSonera's ICT networks and services in Sweden. The scope of this paper is the assessment of the data transport/transmission and IP (Internet Protocol) edge/metro/core networks (hereafter the "IP core network"), which have historically been the least studied network parts in ICT LCAs. The overall study of which the IP core network study is part of, have been summarized in [1].

2 Methodology and data

In the study, both a top-down and a bottom-up data collection approach were applied. The top-down data collection included data traffic and energy measurements for several thousands of network sites. The bottom-up data collection included user data traffic measurements and data from network equipment databases with over 100 000 entities of equipment for which about 200 energy consumption models were created that also includes cooling and power systems overhead.

Three important questions are addressed in this paper: how should the shared IP core network be defined, how can the LCA methodology be used for such a large network with thousands of kilometers of cable deployments and sites, and how can the results be allocated to different usage by different access networks or access types and primary subscription services.

2.1 The IP core network studied and its definition (system boundary)

The IP core network is defined as the shared data transport/transmission and IP edge/metro/core network that is used and controlled by different operators and enterprises and connects different access technologies, subscription and data services. Each ICT network part and its estimated electricity consumption in Sweden 2009 are shown in figure 1 with the IP core network highlighted.

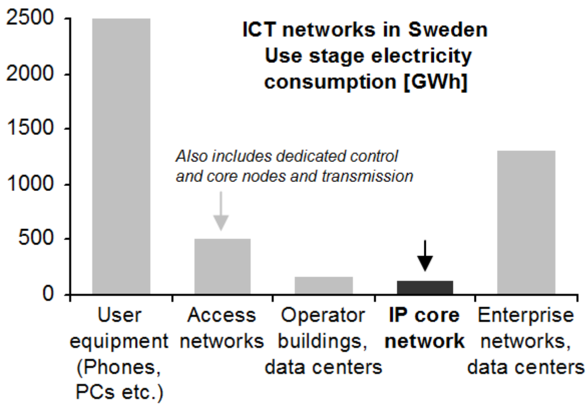

Figure 1: Electricity consumption of the ICT networks in Sweden 2009 with the IP core network highlighted, based on [1]

CPE (Customer Premises Equipment, e.g. modems and routers in homes) is defined as user equipment. Fixed broadband access network equipment and transmission dedicated to telephony and mobile base station sites are allocated to each access type and are not seen as part of the IP core network. Enterprise networks and IP network equipment used in data centers/services are also not defined as part of the IP core network. Similarly, control and core nodes for mobile and fixed networks and IP based TV (IPTV) are considered part of each access type and not as part of the shared IP core network.

The IP core network operated by TeliaSonera that form the basis for this study contains about 4 000 routers/switches and high capacity optical links plus approximately 60 000 other network link elements and it represents about 2/3 of the length of the fiber network in Sweden which is about 100 000 km. In addition to the IP core network, another 25% of the total fiber length in Sweden is related to FTTx (fiber-to-the-x, x = home, building etc.) networks or city networks as they are often called in Sweden. The total fiber network data for Sweden is based on a publicly available assessment [2].

2.2 Cable deployment and equipment manufacturing

Optical fiber cable production and deployment data are based on an in depth LCA study of the cable deployment between Stockholm and Gothenburg (526 km), the two largest cities in Sweden. Different types of real cable deployment sites were studied over time and they were assumed to be representative in terms of construction type (terrain type), sites and equipment. The proportionality between sites, equipment and cable length is consistent with the studied TeliaSonera part of the total IP core network.

The scope of this LCA part can be described as "from cradle to grave, except the use stage", an assumed future EoLT stage is included but it had little impact on the results in the end. Use stage data is updated annually through measurements. Transmission equipment along the cable as well as site housings is included. The life time varies between 7 and 20 years for equipment and cables and it is up to 40 years for the cable deployment. The electronic equipment manufacturing (e.g. switches and routers) is based on Ericsson's own electronic manufacturing models which in turn are based on supplier's data and publicly available LCA data.

The use of machinery and fuel consumption related emissions during deployment gave the largest contributions to the GWP (Global Warming Potential) impact. The total GWP impact was about 5 tonne CO_2e per km cable trench.

2.3 Swedish original data and a global scenario

While the study is based on Swedish conditions and are first of all aimed to be used for Swedish ICT networks, a global scenario have also been created where the Swedish electricity mix (0.06 kg CO_2e/kWh) have been exchanged to a world average electricity mix (0.6 kg CO_2e/kWh) described in [3], to make the GWP results more relevant to international conditions. Why GWP results have been chosen over other impact categories and why Sweden is a good approximation of global ICT is discussed later.

2.4 Data traffic model

To be able to apply the results for different data usage, a data traffic model had to be created. A similar approach as the one described in [4] has been used and that is to look at different user's data traffic and at the data traffic at a high level such as operators' IP core networks. No single source or measurement of the data traffic exists; it is a very complicated task which is why the term "model" is used. The model is created based on many sources [2, 5-9] besides the studied network itself. Table 1 shows the relative data traffic model which is more stable over time than the traffic in absolute terms. The mobile broadband data share has grown from less than 0.1% to 3.4% in just 4 years, other shares change more slowly. It is proposed to allocate usage of the IP core network by amount of data traffic which is the method used in this paper.

Data traffic generated by:	Traffic in %
Fixed broadband	75%
Business IP WAN and B2B	20%
Mobile broadband	3.4%
Fixed voice and dial-up modems	0.7%
Mobile voice	0.2%

Table 1: IP core network data traffic model for Sweden

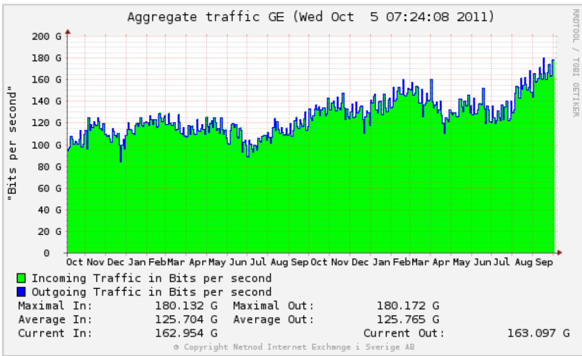

Figure 2: Netnod total data traffic exchanges in Sweden from Oct 2009 to Sep 2011 [5]

The data traffic in Sweden has been increasing and is expected to continue to increase. Figure 2 shows the data traffic in one of the larger sets of Internet traffic exchanges in Sweden outside the studied network from October 2009 to September 2011 [5], a 70% increase in two years. The long term average grows with about 30% per year. The total data traffic in Sweden is estimated to about 1.6 million TB (about 400 Gbps on average) in 2010.

3 Results and use of results

A large part of the IP core network is in fact measured (electricity consumption) and quantified as the studied TeliaSonera IP core network represent about 2/3 of the estimated total IP core network in Sweden. A summary of the total extrapolated electricity consumption results for Sweden are given in table 2. A key parameter in LCA studies of ICT networks is in most cases the electricity consumption of all network infrastructure equipment. So is also the case for the IP core network studied here.

Network part:	**Electricity consumption**
Switches/routers and optical high-capacity links (approx. 6 000 entities of equipment)	33 GWh
All other network link elements (approx. 100 000 entities)	93 GWh
Sweden IP core network total	**126 GWh**
Gives 0.08 kWh per GB of data traffic	
Dedicated transmission allocated to other (access) networks:	***Electricity consumption***
Older fixed transmission links - allocated to PSTN access	*19 GWh*
Mobile transmission links - allocated to mobile access	*2G: 13 GWh 3G: 8 GWh*

Table 2: Electricity consumption of the IP core network in Sweden 2010

The GWP results show that cable deployment is associated with more GHG emissions than the manufacturing of the related network equipment, but less GHG emissions than the electricity consumption in the use stage, see figure 3. The use stage electricity consumption of the assessed IP core network was about one fourth of the energy consumption of the corresponding access networks (telephony, 2G and 3G mobile and fixed broadband). Figure 1 shows the electricity consumption of the IP core network compared to other parts of the ICT networks in Sweden.

The GWP results are expressed per GB of data traffic in 2010. Total results based on total electricity consumption, see figure 6, and total amount of cable infrastructure and equipment deployed are more stable over time, but are harder to interpret and use.

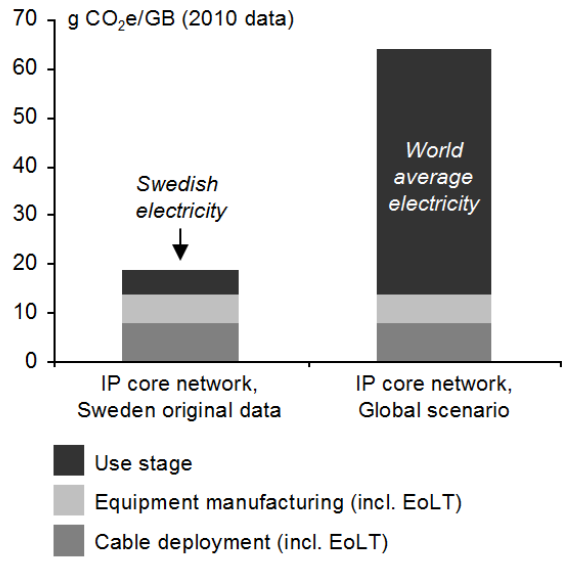

Figure 3: GWP results for the IP core network expressed per GB data traffic in 2010

The global scenario with a world average electricity mix (0.6 kg CO_2e/kWh) will be used throughout the rest of the paper as the GWP results generated by the global scenario are more relevant to international conditions.

Although the results per GB are based upon measured energy and data traffic, it is an average or a snapshot of the IP core network conditions in Sweden in 2010. As data traffic is increasing fast, results per GB of data also change rapidly. The data traffic in Sweden has been increasing, see figure 2, and is expected to continue to increase and this need to be taken into account in future use of the results.

New equipment with higher energy efficiency (measured as energy/data) is constantly replacing old equipment, but the constant build-out of IP network nodes has resulted in a small but steady net increase of the energy consumption over time.

Note also that the figures are based on average conditions and are not suitable to use for specific user and data traffic conditions, such as very high bit rates and data traffic, e.g. B2B data traffic or high-end video conferencing. The large number of users, node and link equipment is nearly impossible to account for in a data traffic model. However, the simpler average approach used in the study for average data traffic generated by different subscription services works in most cases also well for other data services.

3.1 Use of results case study: 3G mobile network and an average subscription

This section gives a detailed example on how the results have been used to quantify the use of the IP core network by 3G mobile networks and for an average 3G mobile subscription, and put the results in comparison to the connected radio access, dedicated transmission and data centers/services network parts.

A key parameter when studying ICT networks in operation is the number of users or subscriptions the network serves. Figure 4 shows the number of mobile subscriptions in Sweden between 2006 and 2010. There are two 3G (UMTS/WCDMA) networks shared by four operators.

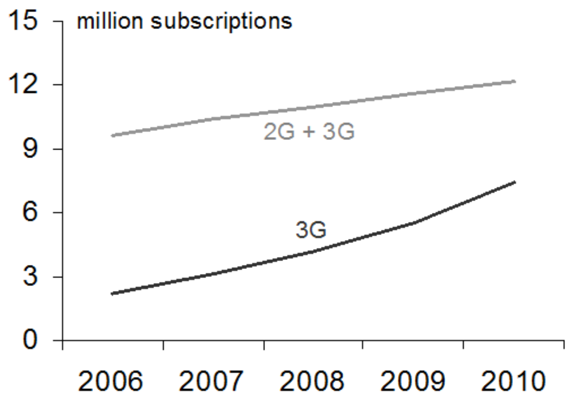

Figure 4: Mobile subscriptions in Sweden 2006-2010, based on data from [6-9]

Another key parameter is the mobile data traffic which literally exploded in Sweden from 2006 and onwards, see figure 5.

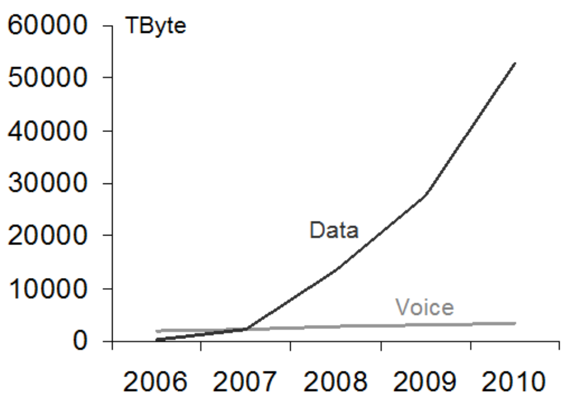

Figure 5: Mobile data and mobile voice traffic in Sweden 2006-2010, based on data from [6-9]

Data traffic passed voice traffic in 2007, some years before the rest of the world, and has increased by a factor of more than 200 between 2006 and 2010. The electricity consumption of the IP core network and the mobile access networks in Sweden 2006-2010 is shown in figure 6. The data is based on the same top-down and bottom-up data collection approach described earlier of which the mobile networks is more described in [1]. The 3G network's electricity consumption has grown faster to now become on par with the electricity consumption of the IP core network. But the 3G networks still use only a fraction of the IP core networks data capacity.

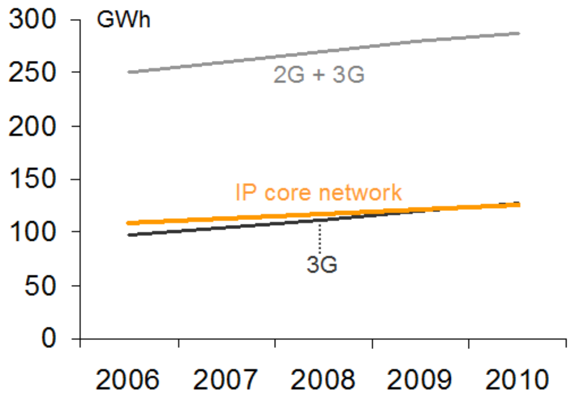

Figure 6: Electricity consumption of the IP core network and mobile access networks in Sweden 2006-2010

4G (LTE) access nodes are currently being built in Sweden but they are not included in the study. The number of 4G subscriptions was very small at the end of 2010.

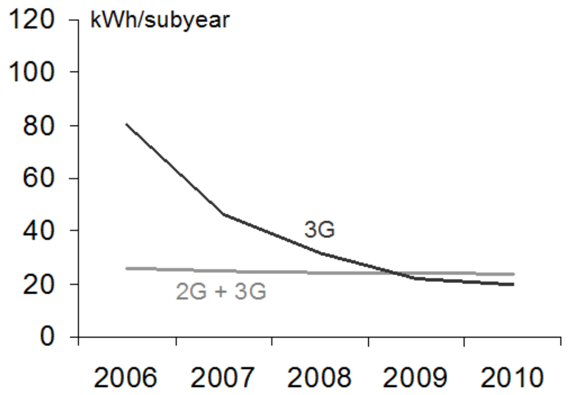

Figure 7: Electricity consumption per subscription, only used as a reference

The electricity consumption per subscription and year (subyear) has decreased for 3G as the 3G network serves more and more 3G subscriptions, see figure 7. In reality, 3G subscribers also use 2G networks for example when no 3G coverage exists, and since the kWh/subyear figures are so close to each other, different ways of allocating voice and data gives little difference in results.

Based on the presented key parameters and the data traffic model, it is possible to quantify, or allocate, an average 3G subscription's share of the IP core network. For 2010, an average 3G mobile subscription with about 8.5 GB/year can be associated with about 0.55 kg CO_2e from the average use of the IP core network. The corresponding figure for an average 3G data subscription with about 20 GB/year is about 1.3 kg, a 3G data only subscription with about 30 GB/year is about 2 kg, and an average fixed broadband line with about 400 GB/year in 2010 is about 26 kg when the same allocation method as proposed in this paper have been used.

Figure 8 shows the GHG emissions related to the IP core network part which has increased per subscription as each subscription generated more and more data traffic between 2006 and 2010.

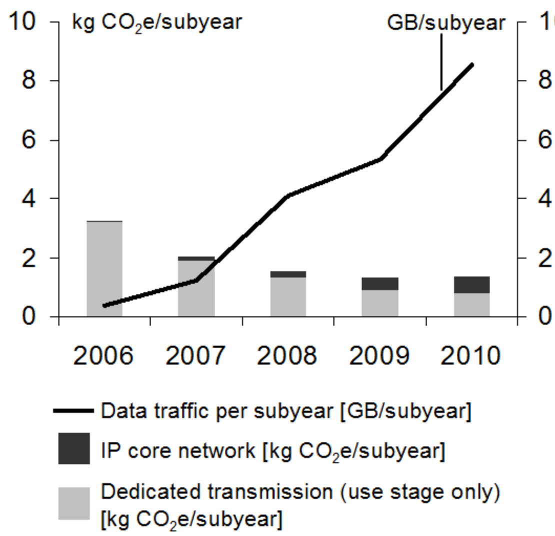

Figure 8: Total GHG results per subyear for the IP core network and dedicated transmission related to an average 3G mobile data subscription

The GHG emissions depend on the 3G data traffic share of the total IP core data traffic. At the same time, the GHG emissions per subscription related to the dedicated transmission, which is dependant on subscriptions served by the network, has decreased as more and more subscriptions are served by the 3G mobile access network.

Figure 9 shows the GHG emissions for an average 3G subscription from 2006 to 2010 related to the IP core network and the dedicated transmission together with data centers/services. The same allocation method used for the IP core network, the share of data traffic, has also been used to allocate data centers/services and the GWP contribution is about 4 times as high as the IP core network. The servers and data storage part of "the cloud" simply consume more energy. The largest GWP contribution from network usage is still coming from the mobile radio access network (base stations) which is used as a reference object in figure 9.

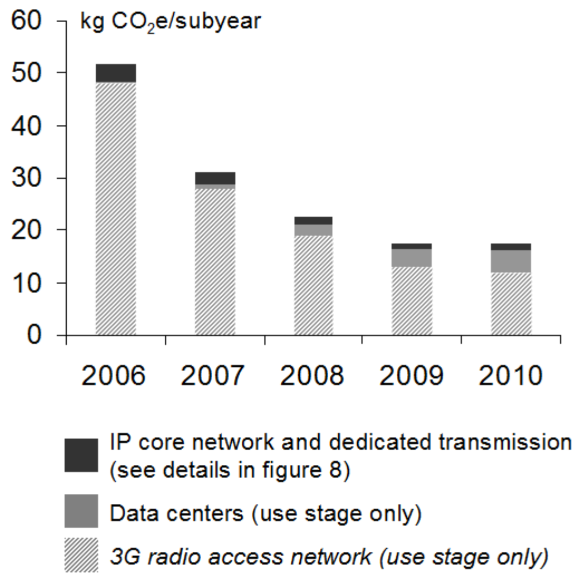

Figure 9: Total GHG results per subyear for the IP core network and dedicated transmission, data centers/services and the mobile radio access network related to an average 3G subscription

Even though the number of served subscriptions impacts the results more, see figure 8 and 9, the increasing data traffic impact results more and more.

4 Discussion

Only energy/electricity consumption and GWP results are presented in this paper although many different environmental impact categories have been studied. The main reason is that energy and GWP results are currently of most interest and in general less uncertain. GWP can also be used as a more or less direct proxy for fossil fuel resource depletion and a more indirect proxy for many other impact categories where fossil fuel incineration is a significant contributor through other emissions, e.g. acidification (NOx, SOx) and POCP (Photo-Oxidant Creation Potential). GWP or more precisely CO_2 is also causing ocean acidification. Toxic impacts are more uncertain, but fossil fuel incineration gives also toxic impacts, e.g. through particles.

The equipment manufacturing is the most uncertain part in the study but gives at the same time only a small (9%) contribution to the total GWP results.

Sweden is assumed to be a good approximation of global ICT networks if the electricity mix is changed from a Swedish average to a global average which is done in this paper. There are factors that reduce the electricity consumption in Sweden such as a colder climate with less need for cooling, but there are also factors that increase the electricity consumption such as higher ICT use and higher data traffic. The electricity consumption per mobile subscription and per fixed line in Sweden has been benchmarked against a world average which in turn is based on a large sample of countries [3]. The electricity consumption is higher per mobile subscription (about +20%), but lower per fixed line (about -10%).

The IP core network does not stop in Sweden, it is a global network. It can however be assumed that as much data traffic in the IP core network that is generated in Sweden and then crosses Swedish borders is also generated outside Sweden related to data services in Sweden. Sweden is hosting more and more data centers, for example Facebook is building a new large international data center in the north of Sweden. Sweden can host (export) data services that run on low-carbon electricity but data services accessed abroad (imported) uses other electricity mixes, and this has not been accounted for in the study. Work is ongoing to also include these aspects in future studies.

A study of fiber optic submarine cables has been carried out in another project [10] showing that for the most trafficked route, the Atlantic between US and Europe (in 2009) the GHG emission was 44 g CO_2e/GB (7350 km) corresponding to 0.006 g CO_2e/GBkm. The result is lower than for the land based IP core network studied as submarine cables is designed for very high data traffic. If also the much longer distance for the submarine cables is factored in, the result per GBkm is in the order of 10-100 times lower for the submarine cables than for the IP core network, assuming average distances of data traffic of 50-500 km. The metric GBkm may be a way to describe data transmission work in analogy with the often used transport work metric used in LCAs, tonkm.

5 Conclusions

The electricity consumption of the defined IP core network was about one fourth of the energy consumption of the corresponding access networks (telephony, 2G and 3G mobile and fixed broadband) in Sweden.

The use stage results for the Swedish IP core network is about 0.08 kWh per GB of data traffic and the total GHG emission is about 19 g CO_2e/GB of which 5 g comes from the use stage, 8 g from cable deployment and 6 g from equipment manufacturing. If the Swedish electricity mix is changed to a global average, the total results changes to about 64 g CO_2e/GB.

A method is proposed where the amount of data traffic is used to allocate the IP core network on different usage by different access networks or access types and primary subscription services. The method is exemplified by the 3G mobile broadband data traffic in Sweden.

The results per GB in 2010 must be used with care as data traffic increases rapidly over time. Total data traffic has been increasing with about 30% per year in Sweden.

6 Literature

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