A Comparison of the Energy Consumption of Broadband Data Transfer Technologies

November 23, 2021

Author: Joonas Nuutinen, Aalto University, joonas.nuutinen@aalto.fi
Supervisor: Prof. Jukka Manner, Aalto University, jukka.manner@aalto.fi

1. Introduction

Global internet traffic increased by a factor of 17 between 2010 and 2020 (Kamiya, 2021). At the same time, the number of global internet users doubled, with 60 % of the world population having internet access in 2020 (ITU, 2020; Kemp, 2020). The rising trend is estimated to continue during the following years due to increases in global internet users, IoT devices and video streaming, among other things (Cisco, 2020).

At the same time, the energy intensity of internet traffic has been halving approximately every two years (Aslan et al., 2017, p. 797). Due to improved energy efficiency, the total energy consumption of internet data transmission networks has remained relatively stable (IEA, 2019), accounting for 1.1–1.4 % of global electricity use in 2020 (Kamiya, 2021). However, due to the significant growth of internet traffic, the total internet energy consumption is estimated to grow by 60 % from 2020 to 2030, and access network energy consumption is estimated to triple (Andrae, 2020, p. 22).

This literature review focuses on access network energy consumption. It aims to understand the differences in energy consumption between different network technologies. The study focuses on current energy usage with the existing infrastructure, leaving out the production of the network devices and cables, and the construction of the infrastructure. In other words, the existing fibre network is used as a base point of comparison, with additional copper, cellular or WLAN networks acting as additional consumers of electricity.

The study aims to answer two research questions: 1) How do the per-bit energy consumption of fibre, DSL, and mobile networks differ? 2) How can a consumer reduce their per-bit network energy consumption? The study is restricted to the energy efficiency of networks, leaving out other aspects, such as data centers, production and construction of network infrastructure, end user devices, and limiting the growth of internet traffic.

The report is organised as follows. Part 2 focuses on the energy consumption of mobile networks, while Part 3 focuses on the energy consumption of fixed access networks. Part 4 discusses the results and presents topics for future research.

2. Mobile networks

The per-bit energy consumption of mobile networks in Finland was 0.22 kWh/GB in 2020 (Ussa, 2020), indicating a 98 % drop since 2010 (Pihkola et al., 2018, p. 5). Thus, mobile networks have witnessed dramatic efficiencies in electricity use (Figure 1).

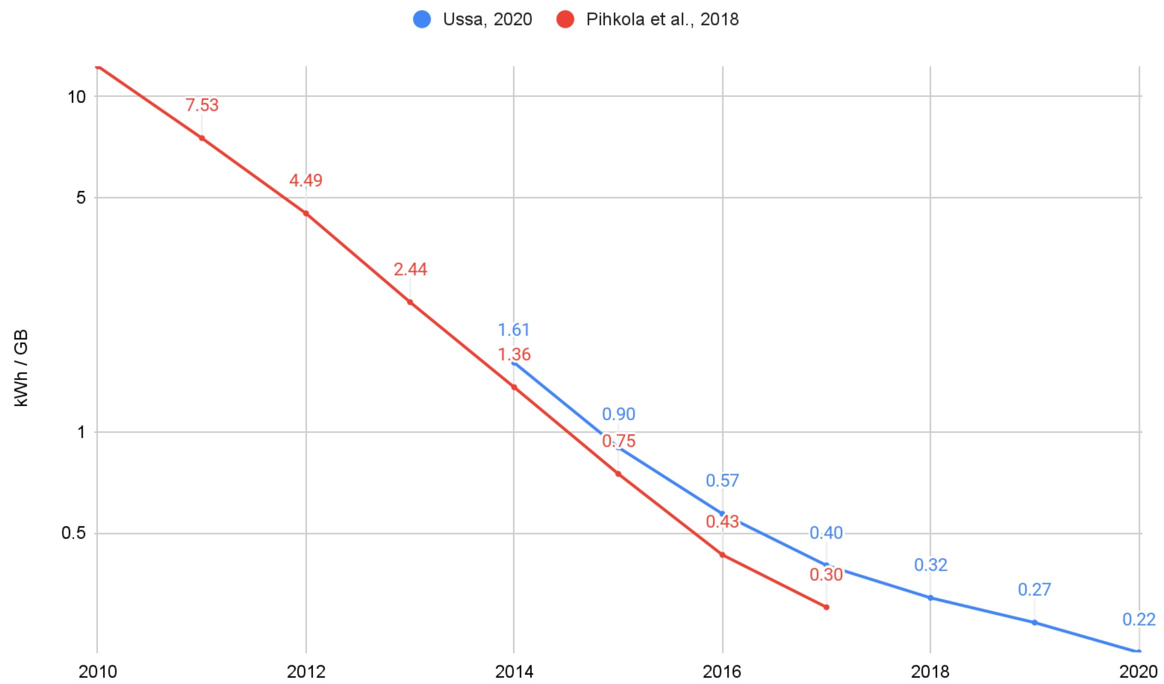

Figure 1. Energy intensity of mobile networks in Finland, 2010–2020.

At the same time, wireless internet traffic has grown by a factor of 95 (Traficom, 2021), causing the total electricity use of wireless networks in Finland to grow by 70 % from 2010 to 2020 (Figure 2). In other words, while the energy efficiency has increased dramatically, the even more dramatic increase in mobile network usage has offset the gains in efficiency.

In 2019, mobile networks accounted for half of the global network traffic (Clement, 2021) but two thirds of the global network energy consumption (Kamiya, 2021), indicating a higher energy intensity than fixed networks.

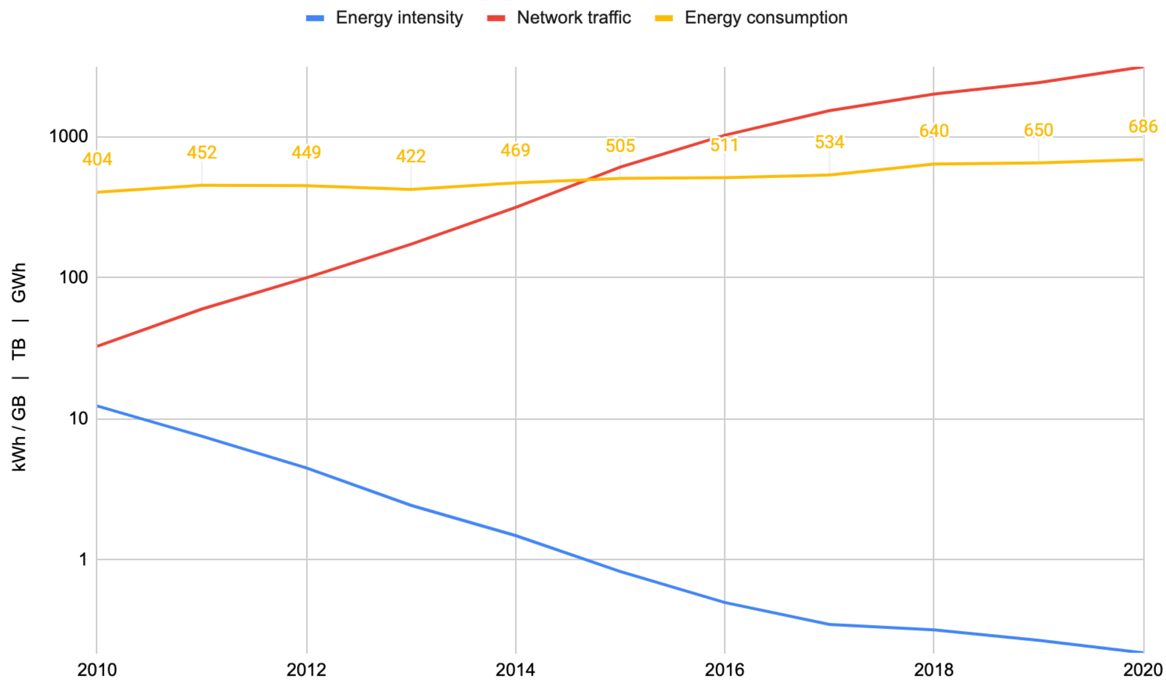

Figure 2. Energy intensity (Ussa, 2020; Pihkola et al., 2018, p. 5), network traffic (Traficom, 2021) and energy consumption of mobile networks in Finland, 2010–2020. Energy consumption has been calculated as the product of energy intensity and network traffic.

3. Fixed access networks

According to Breide et al. (2021), fibre to the home is the least energy consuming network technology, with a consumption of 2×10^{-5} kWh/GB. This is four orders of magnitude less than the mobile energy consumption numbers presented in Part 2. The energy efficiency of fibre networks is due to the physical advantage of light not requiring active network elements, as well as the high data rates allowed by the technology (Breide et al., 2021).

A VDSL2-Vectoring access network introduces active network elements, increasing the energy consumption to 2×10^{-4} kWh/GB (Breide et al., 2021). This is still one thousandth of the consumption of mobile networks.

The largest consumer of electricity in fixed networks is the customer premises equipment (CPE), including a modem router unit and a possible optical network termination (Breide et al., 2021) (Figure 3).

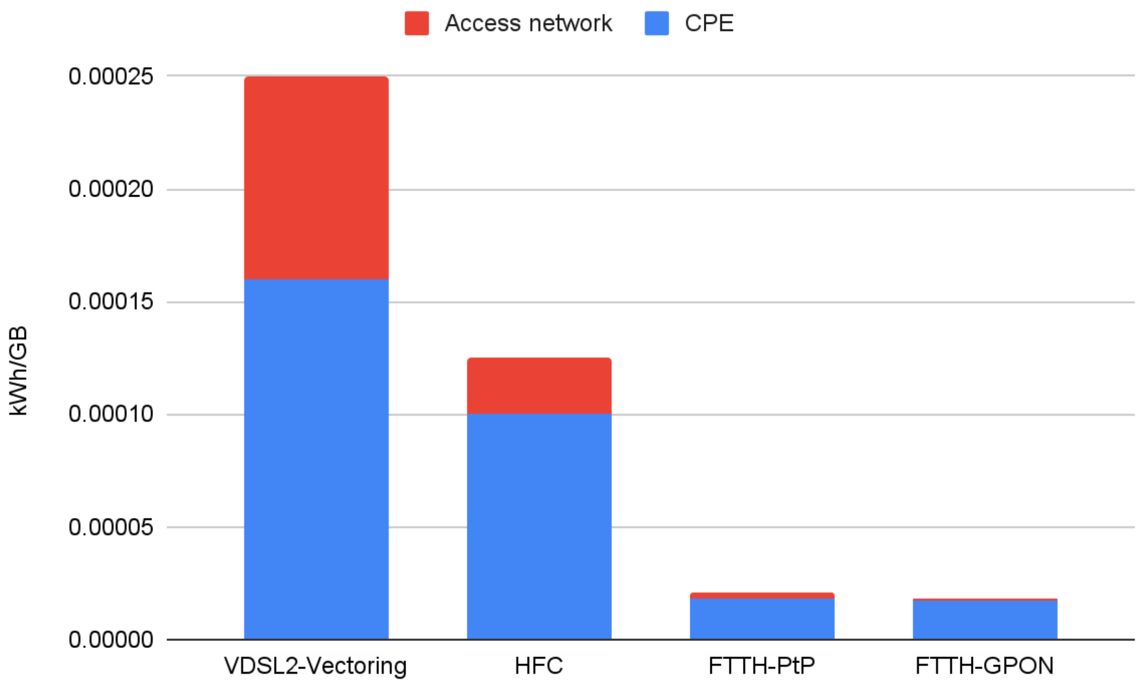

Figure 3. Energy intensity of fixed access networks and customer premises equipment (Breide et al., 2021).

Andrae (2020, p. 28) presents more conservative numbers, with 0.07 kWh/GB as an average fixed access network energy consumption in 2020, estimated to drop to 0.017 kWh/GB by 2030.

4. Conclusions

Energy consumptions of different network technologies in 2020 and projections to 2030, when applicable, are combined in Table 1.

Although the numbers vary, network energy consumption in 2020 seemed to be between 0.00002 and 0.22 kWh/GB, with mobile networks on the higher end, fibre networks on the lower end and copper networks in the middle. According to Andrae, mobile networks will bypass the energy efficiency of fixed networks by 2030, which seems counter-intuitive given that wireless antennas add energy-consuming elements to the wired core network. Either Andrae’s estimations contain an error or they give very large weight on active network elements in copper connections.

Year	2020	2030
Mobile (Ussa, 2020)	0.22	
Mobile (Andrae, 2020, p. 28)	0.18	0.014
Fixed (Andrae, 2020, p. 28)	0.07	0.017
VDSL2 (Breide et al., 2021)	0.002	
FTTP (Breide et al., 2021)	0.00002	

Table 1. Energy intensity (kWh/GB) of different network technologies.

Of course, the numbers are not strictly comparable between the studies. Firstly, the results by Prysmian represent the scenario where the capacity of the network is fully utilised. In reality, network elements will likely spend a large amount of their time idle, consuming power without transferring data. If this is taken into account, the numbers will probably increase closer to the fixed network estimates by Andrae. Secondly, they are based on multiple sources that may use different methodology. Specifically, the selection of the system boundary can cause variation between studies. A common system boundary contains the IP core network and access networks (Aslan et al., 2017, p. 787) but for example Breide et al. (2021) considers customer premises equipment in addition to the common system boundary.

Even though the numbers are not strictly comparable, they give a sense of magnitude. Mobile networks plausibly consume several times more energy per gigabyte than fixed networks. As a consequence, a consumer can significantly reduce the energy consumption of their internet usage by avoiding mobile data connections when a fixed network is available.

Potential future research topics could include attempting to normalise the different energy consumption estimates by standardising the system boundary and the bandwidth utilisation. Another topic could be a critical evaluation of per-bit energy consumption as a unit. As networks are becoming faster, their theoretical maximum bandwidth exceeds realistic practical usage. However, active network elements consume energy even when they are idle, which causes the actual energy consumption to be higher than the product of energy intensity and transferred data. Thirdly, access networks are only one part of the internet. Different use cases, such as video streaming, AR applications or web browsing, have different computational requirements for data centers and end user devices (Yan et al., 2019, p. 9). While this study concentrated on access networks, internet energy consumption as a whole is much more complex and requires further attention. Finally, it would be interesting to see how the numbers presented in this study will change between 2020 and 2030, and how well Andrae's estimations will hold true.

References

Andrae, A. S.G. (2020, Jun 30). New perspectives on internet electricity use in 2030. *Engineering and Applied Science Letters*, *3*(2), 19-31. DOI:10.30538/psrp-easl2020.0038

Aslan, J., Mayers, K., Koomey, J. G., & France, C. (2017, Aug 4). Electricity Intensity of Internet Data Transmission. *Journal of Industrial Ecology*, *22*(4), 785-798. https://onlinelibrary.wiley.com/doi/pdf/10.1111/jiec.12630

Breide, S., Helleberg, S., Schindler, J., & Waßmuth, A. (2021). *Energy consumption of telecommunication access networks*. Prysmian Group. Retrieved Nov 10, 2021, from https://europacable.eu/wp-content/uploads/2021/01/Prysmian-study-on-Energy-Consumption.pdf

Cisco. (2020). *Cisco Annual Internet Report (2018–2023)*. Cisco. Retrieved Nov 10, 2021, from https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf

Clement, J. (2021, Apr 28). *Percentage of mobile device website traffic worldwide from 1st quarter 2015 to 1st quarter 2021*. Statista. Retrieved Nov 23, 2021, from https://www.statista.com/statistics/277125/share-of-website-traffic-coming-from-mobile-devices/

IEA. (2019, Nov 25). *Electricity use by internet data transmission networks, 2015-2021*. International Energy Agency. Retrieved Nov 10, 2021, from https://www.iea.org/data-and-statistics/charts/electricity-use-by-internet-data-transmission-networks-2015-2021

ITU. (2020). *Measuring digital development: Facts and figures 2020*. International Telecommunication Union. Retrieved Nov 10, 2021, from https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2020.pdf

Kamiya, G. (2021). *Data Centres and Data Transmission Networks*. International Energy Agency. Retrieved Nov 10, 2021, from https://www.iea.org/reports/data-centres-and-data-transmission-networks

Kemp, S. (2020, Oct 20). *Digital 2020: October Global Statshot*. DataReportal. Retrieved Nov 10, 2021, from https://datareportal.com/reports/digital-2020-october-global-statshot

Pihkola, H., Hongisto, M., Apilo, O., & Lasanen, M. (2018, Jul 17). Evaluating the Energy Consumption of Mobile Data Transfer—From Technology Development to Consumer Behaviour and Life Cycle Thinking. *Sustainability*, *10*(7), 2494. https://doi.org/10.3390/su10072494

Traficom. (2021, Sep 30). *Volume of data transferred in mobile network*. Traficom. Retrieved Nov 10, 2021, from https://www.traficom.fi/en/statistics/volume-data-transferred-mobile-network

Ussa, E. (2020, Jun 22). *Digiratkaisuilla energiatehokkuuteen – mutta ei ilman sähköä*. FiCom. Retrieved Nov 10, 2021, from https://www.ficom.fi/ajankohtaista/uutiset/digiratkaisuilla-energiatehokkuuteen-mutta-ei-ilman-sahkoa/

Yan, M., Chan, C. A., Gygax, A. F., Yan, J., Campbell, L., Nirmalathas, A., & Leckie, C. (2019, Jan 7). Modeling the Total Energy Consumption of Mobile Network Services and Applications. *Energies*, *12*(1), 184. https://doi.org/10.3390/en12010184