Energy Footprint of Mobile communications in the 21st century

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Zusammenfassung

deutsche Version

Abstract

englische Version

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1 Introduction

Since around 2010, mobile communication has been a vital part of everyday-life for most of the western world. In 2007, we saw the launch of the iPhone, arguably one of the most influencial inventions in the mobile market ever. With the introduction of 4G in late 2009 came a massive increase in mobile communication over the internet. For almost one and a half decades, more and more technology has been invented for the mobile phone market.

In addition, the Oculus Rift has ushered in the reincarnation of the idea of Virtual Reality and spacial computing, plainly meaning the usage of 3D-space as a way to distribute user interfaces. More and more, we rely on small, wireless devices with a sleek, modern and fashionable design and people seem to keep buying in. With that in mind, most mobile user equipment has had one spatial constraint that has so far never been overcome: Battery life and usage breaks to recharge at a wall socket. This paper focuses on the effectiveness of energy consumption in respect to the overall environmental impact of modern mobile communications. To this end, the following chapter 2 summarizes other work done in the field and its topics. Chapter 3 introduces a definition of environmental footprint and its relevance to this topic. The chapters 4 and 5 go into detail about the energy production and consumption in Germany both in general and related to mobile communications. Chapter 6 then names a few opportunities for saving energy.

2 Related Work

3 Energy footprint

3.1 Indicators for energy footprint

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4 Influence of mobile communication on national power consumption

4.1 National averages of Germany

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6.3 Reduced Capability NR

6.4 Sidelink enhancements

6.5 Sleep Modes

7 Conclusion

A Acronyms

BS Radio Base Station.

UE User Equipment.

B References

3GPP Release 17: Completing the first phase of the 5G evolution. Technical report, Qualcomm, March 2022.

5G mmWave - Unlocking the Full Potential of 5G. Technical report, GSMA, 2022.

3GPP. Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Requirements (3GPP TS 28.304 version 17.0.0 Release 17). Technical report, April 2022.

Omar Dawood Sulaiman Al-Gburi. General Overview of 4G and 5G with Field Measurements and Performance Comparison. Master's thesis, Tampere University, March 2021.

Zaiwar Ali, Lei Jiao, Thar Baker, Ghulam Abbas, Ziaul Haq Abbas, and Sadia Khaf. A Deep Learning Approach for Energy Efficient Computational Offloading in Mobile Edge Computing. *IEEE Access*, 7:149623–149633, 2019. ISSN 2169-3536. doi: 10.1109/ACCESS.2019.2947053.

Manly Battery. 5G-Basisstation Anwendung von Lithium-Eisen-Phosphat-Batterie Vorteile rollende Blei-Säure-Batterien, January 2021. URL `https://de.manly-battery.com/info/5g-base-station-application-of-lithium-iron-ph-53504656.html`.

Bayerisches Landesamt für Umwelt. Alle Umweltindikatoren auf einen Blick, January 2024. URL `https://www.lfu.bayern.de/umweltdaten/indikatoren/liste_indikatoren/index.htm`.

Helge Buchheister. 5G jetzt für 90 Prozent der Bevölkerung. *Vodafone Newsroom*, August 2023.

Bundesnetzagentur. Frequenzauktion 2019, 2019a. URL https://www.bundesnetzagentur.de/DE/Fachthemen/Telekommunikation/Breitband/MobilesBreitband/Frequenzauktion/2019/Auktion2019-node.html.

Bundesnetzagentur. Frequenzauktionauswertung 2019, 2019b. URL https://www.bundesnetzagentur.de/_tools/FrequenzXml/Auktion2019_XML/497.html.

Bundesnetzagentur. Marktdatenvisualisierung, January 2024a. URL https://www.smard.de/page/home/marktdaten/78.

Bundesnetzagentur. Mobiles Breitband, 2024b. URL https://www.bundesnetzagentur.de/DE/Fachthemen/Telekommunikation/Frequenzen/OeffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html.

Bundesnetzagentur. Mobilfunk-Monitoring Karte, January 2024c. URL https://gigabitgrundbuch.bund.de/GIGA/DE/MobilfunkMonitoring/Vollbild/start.html.

Kuo-Chi Chang, Kai-Chun Chu, Hsiao-Chuan Wang, Yuh-Chung Lin, and Jeng-Shyang Pan. Energy saving technology of 5g base station based on internet of things collaborative control. *IEEE Access*, 8:32935–32946, 2020. ISSN 2169-3536. doi: 10.1109/ACCESS.2020.2973648.

DESTATIS Statistisches Bundesamt. Bruttostromerzeugung in deutschland, April 2023a. URL https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Erzeugung/Tabellen/bruttostromerzeugung.html.

DESTATIS Statistisches Bundesamt. Bruttostromerzeugung 2022, 2023b. URL https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/_Grafik/_Interaktiv/bruttostromerzeugung-erneuerbare-energien.html.

DESTATIS Statistisches Bundesamt. Stromverbrauch der privaten Haushalte nach Haushaltsgrößenklassen, September 2023c. URL https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/UGR/private-haushalte/Tabellen/stromverbrauch-haushalte.html.

DESTATIS Statistisches Bundesamt. Stromerzeugung im 3. Quartal 2023: Ein Fünftel weniger Strom als im Vorjahresquartal, December 2023d. URL https://www.destatis.de/DE/Presse/Pressemitteilungen/2023/12/PD23_462_43312.html.

DESTATIS Statistisches Bundesamt. Bruttostromerzeugung nach Energieträgern in Deutschland ab 1990, 2024a. URL https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Erzeugung/bar-chart-race.html.

DESTATIS Statistisches Bundesamt. Energieerzeugung, January 2024b. URL https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Energie/Erzeugung/_inhalt.html.

Huawei Technologies. 5G Power Whitepaper. Technical report, HUAWEI TECHNOLOGIES CO., LTD, February 2019.

Josip Lorincz, Tonko Garma, and Goran Petrovic. Measurements and Modelling of Base Station Power Consumption under Real Traffic Loads. *Sensors*, 12(4):4281–4310, 2012. ISSN 1424-8220. doi: 10.3390/s120404281. URL https://www.mdpi.com/1424-8220/12/4/4281.

Xiaoyan Ma, Yunfei Mu, Zhe Liu, Xinyang Jiang, Jiarui Zhang, and Yi Gao. Energy consumption optimization of 5G base stations considering variable threshold sleep mechanism. *Energy Reports*, 9:34–42, 2023. ISSN 2352-4847. doi: https://doi.org/10.1016/j.egyr.2023.04.026. URL https://www.sciencedirect.com/science/article/pii/S2352484723003876. 2023 the 7th International Conference on Energy and Environmental Science.

Qualcomm. 5 key technology inventions in 5G NR Release 17, April 2022. URL https://www.qualcomm.com/news/onq/2022/04/5-key-technology-inventions-5g-nr-release-17.

Qualcomm. Everything you need to know about 5G., January 2024. URL https://www.qualcomm.com/5g/what-is-5g.

Fatma Ezzahra Salem, Tijani Chahed, Zwi Altman, and Azeddine Gati. Traffic-aware Advanced Sleep Modes management in 5G networks. In *2019 IEEE Wireless Communications and Networking Conference (WCNC)*, pages 1–6, April 2019. doi: 10.1109/WCNC.2019.8886051.

Pengfei Shen, Yulin Shao, Qi Cao, and Lu Lu. Dynamic gNodeB Sleep Control for Energy-Conserving 5G Radio Access Network, 2022.

Olimpjon Shurdi, Luan Ruci, Aleksander Biberaj, and Genci Mesi. 5G Energy Efficiency Overview. *European Scientific Journal, ESJ*, 17(3):315, Jan. 2021. doi: 10.19044/esj.2021.v17n3p315. URL https://eujournal.org/index.php/esj/article/view/13918.

Statista. Nettostromverbrauch in Deutschland in den Jahren 1991 bis 2022, January 2024. URL https://de.

statista.com/statistik/daten/studie/164149/umfrage/netto-stromverbrauch-in-deutschland-seit-1999/.

Alain Sultan. 5G System Overview, August 2022. URL https://www.3gpp.org/technologies/5g-system-overview.

Telefónica Deutschland. Mobilfunkstandards, January 2024. URL https://www.telefonica.de/netze/mobilfunknetz/standards.html.

Umwelt Bundesamt. Stromverbrauch, January 2024a. URL https://www.umweltbundesamt.de/daten/energie/stromverbrauch.

Umwelt Bundesamt. Umweltbelastung, January 2024b. URL https://sns.uba.de/umthes/de/concepts/_00025128.html.

Muhammad Usama and Melike Erol-Kantarci. A Survey on Recent Trends and Open Issues in Energy Efficiency of 5G. *Sensors*, 19(14), 2019. ISSN 1424-8220. doi: 10.3390/s19143126. URL https://www.mdpi.com/1424-8220/19/14/3126.

Anne Weißbach. Stromverbrauch im Haushalt, January 2023. URL https://www.stromspiegel.de/stromverbrauch-verstehen/stromverbrauch-im-haushalt/.

Ming Yan, Chien Aun Chan, André F. Gygax, Jinyao Yan, Leith Campbell, Ampalavanapillai Nirmalathas, and Christopher Leckie. Modeling the Total Energy Consumption of Mobile Network Services and Applications. *Energies*, 12(1), 2019. ISSN 1996-1073. doi: 10.3390/en12010184. URL https://www.mdpi.com/1996-1073/12/1/184.

De-Gan Zhang, Lu Chen, Jie Zhang, Jie Chen, Ting Zhang, Ya-Meng Tang, and Jian-Ning Qiu. A Multi-Path Routing Protocol Based on Link Lifetime and Energy Consumption Prediction for Mobile Edge Computing. *IEEE Access*, 8:69058–69071, 2020. ISSN 2169-3536. doi: 10.1109/ACCESS.2020.2986078.

Xu Zhu. Breaking the energy curve: Network energy consumption modeling and energy saving technologies, August 2023. URL https://www.ericsson.com/en/blog/2023/8/breaking-the-energy-curve.