Energy Footprint of Mobile communications in the 21st century

Andreas Nicklaus

5. Februar 2024

Zusammenfassung

deutsche Version

Abstract

englische Version

Contents

1	Inti	roduction	2
2	Rel	ated Work	2
3	Ene	ergy footprint	2
	3.1	Indicators for energy footprint	2
	3.2	Relevancy of indicators	2
4	Influence of mobile communication on national power con-		
	sun	nption	2
	4.1	National averages of Germany	2
	4.2	Base Stations	2
	4.3	User Equipment	2
5	Sources of energy consumption		
	5.1	Base Stations	2
	5.2	User Equipment	2
6	Energy saving opportunities		
	6.1	Giga-MIMO	2
	6.2	NR-Light	2
	6.3	Lower Transmit Power for IoT devices (Reduced Capability	
		NR)	2
	6.4	Sidelink enhancements	2
	6.5	Sleep Modes	2

A References 3			
1	Introduction		
2	Related Work		
3	Energy footprint		
3.1	Indicators for energy footprint		
3.2	Relevancy of indicators		
4	Influence of mobile communication on national power consumption		
4.1	National averages of Germany		
4.2	Base Stations		
4.3	User Equipment		
5	Sources of energy consumption		
5.1	Base Stations		
5.2	User Equipment		
6	Energy saving opportunities		
6.1	Giga-MIMO		
6.2	$\operatorname{NR-Light}$		
6.3	Lower Transmit Power for IoT devices (Reduced Capability NR)		
6.4	Sidelink enhancements		
6.5	Sleep Modes		
7	Conclusion		

7 Conclusion

 $\mathbf{2}$

A References

- [1] 5G Power Whitepaper. Technical report, HUAWEI TECHNOLOGIES CO., LTD, February 2019.
- [2] 3GPP Release 17: Completing the first phase of the 5G evolution. Technical report, Qualcomm, March 2022.
- [3] 5G mmWave Unlocking the Full Potential of 5G. Technical report, GSMA, 2022.
- [4] 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.
- [5] Omar Dawood Sulaiman Al-Gburi. General Overview of 4G and 5G with Field Measurements and Performance Comparison. Master's thesis, Tampere University, March 2021.
- [6] 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.
- [7] Manly Battery. 5G-Basisstation Anwendung von Lithium-Eisen-Phosphat-Batterie Vorteile rollende Blei-Säure-Batterien, January 2021.
- [8] Helge Buchheister. 5G jetzt für 90 Prozent der Bevölkerung. Vodafone Newsroom, August 2023.
- [9] DESTATIS Statistisches Bundesamt. Bruttostromerzeugung 2022, 2023.
- [10] DESTATIS Statistisches Bundesamt. Bruttostromerzeugung in deutschland, April 2023.
- [11] DESTATIS Statistisches Bundesamt. Stromerzeugung im 3. Quartal 2023: Ein Fünftel weniger Strom als im Vorjahresquartal, December 2023.

- [12] DESTATIS Statistisches Bundesamt. Stromverbrauch der privaten Haushalte nach Haushaltsgrößenklassen, September 2023.
- [13] DESTATIS Statistisches Bundesamt. Bruttostromerzeugung nach Energieträgern in Deutschland ab 1990, 2024.
- [14] DESTATIS Statistisches Bundesamt. Energieerzeugung, January 2024.
- [15] Umwelt Bundesamt. Stromverbrauch, January 2024.
- [16] Umwelt Bundesamt. Umweltbelastung, January 2024.
- [17] Bundesnetzagentur. Frequenzauktion 2019, 2019.
- [18] Bundesnetzagentur. Frequenzauktionauswertung 2019, 2019.
- [19] Bundesnetzagentur. Marktdatenvisualisierung, January 2024.
- [20] Bundesnetzagentur. Mobilfunk-Monitoring Karte, January 2024.
- [21] Bundesnetzagentur. Mobiles Breitband, 2024.
- [22] 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.
- [23] Telefónica Deutschland. Mobilfunkstandards, January 2024.
- [24] Bayerisches Landesamt für Umwelt. Alle Umweltindikatoren auf einen Blick, January 2024.
- [25] 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.
- [26] 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. 2023 the 7th International Conference on Energy and Environmental Science.
- [27] Qualcomm. 5 key technology inventions in 5G NR Release 17, April 2022.
- [28] Qualcomm. Everything you need to know about 5G., January 2024.
- [29] 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.

- [30] Pengfei Shen, Yulin Shao, Qi Cao, and Lu Lu. Dynamic gNodeB Sleep Control for Energy-Conserving 5G Radio Access Network, 2022.
- [31] Olimpjon Shurdi, Luan Ruci, Aleksander Biberaj, and Genci Mesi. 5G Energy Efficiency Overview. European Scientific Journal, ESJ, 17(3):315, Jan. 2021.
- [32] Statista. Nettostromverbrauch in Deutschland in den Jahren 1991 bis 2022, January 2024.
- [33] Alain Sultan. 5G System Overview, August 2022.
- [34] Muhammad Usama and Melike Erol-Kantarci. A Survey on Recent Trends and Open Issues in Energy Efficiency of 5G. Sensors, 19(14), 2019.
- [35] Anne Weißbach. Stromverbrauch im Haushalt, January 2023.
- [36] 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.
- [37] 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.
- [38] Xu Zhu. Breaking the energy curve: Network energy consumption modeling and energy saving technologies, August 2023.