OS07-06

In-situ assessment of uplink duty cycle for 4G and 5G wireless communications

Dr Günter Vermeeren, Mrs Leen Verloock, Dr Sam Aerts, Dr Luc Martens, Dr Wout Joseph
imec - UGent - WAVES, Ghent, Belgium

Abstract Subject Area(s)

["Experimental dosimetry","RF/Microwave"]

Summary

With the fifth generation (5G) wireless communication technology, new and higher frequency bands, beamforming, and massive multiple-input multiple-output (MIMO) techniques are introduced to further enhance the efficiency of the radio access network (RAN) allowing ultra-reliable communications, broadband communication, and massive deployment of wireless IoT devices. As electromagnetic field (EMF) exposure quantities are time-averaged quantities, knowledge of the duty cycle – a measure of the fraction of the time a mobile phone is transmitting – for realistic use cases plays a key role in the accurate evaluation of the EMF exposure assessment. In this study, we measured in-situ the uplink duty cycles of a smartphone for 5G NR and 4G LTE for a total of six use cases covering voice, video, and data applications. The duty cycles were assessed at ten positions near a 4G and 5G base station site in Belgium. For Twitch, VoLTE, and WhatsApp, the duty cycle ranged between 4% and 22% in time for 4G and between 4 % and 14 % for 5G NR. The maximum duty cycle for 5G NR was 20%, based on the used TDD slot format DDDSU. For 5G NR, these duty-cycles resulted in a higher UL-allotted time due to Time Division Duplexing at 3.7 GHz frequency band. Ping showed median duty cycles of 2% for 5G NR and 50% for 4G LTE. FTP upload and iPerf resulted in duty cycles close to 100% for 4G LTE and 20 % for 5G NR.

Full abstract

Download file

In-situ assessment of uplink duty cycle for 4G and 5G wireless communications

Günter Vermeeren, Leen Verloock, Sam Aerts, Luc Martens & Wout Joseph
imec - WAVES, Department of Information Technology at Ghent University, Ghent, Belgium
[2] Ghent University

*Corresponding author e-mail: Gunter.Vermeeren@UGent.be

INTRODUCTION

With the fifth generation (5G) wireless communication technology, new and higher frequency bands, beamforming, and massive multiple-input multiple-output (MIMO) techniques are introduced to further enhance the efficiency of the radio access network (RAN) allowing ultra-reliable communications, broadband communication, and massive deployment of wireless IoT devices. As electromagnetic field (EMF) exposure quantities are time-averaged quantities [1 – 2], knowledge of the duty cycle – a measure of the fraction of the time a mobile phone is transmitting – for realistic use cases plays a key role in the accurate evaluation of the EMF exposure assessment [3].

In this study, we focused on the assessment of the uplink (UL) – from smart phone towards radio access network – duty cycle of a 5G enabled smartphone. Before a smartphone is introduced to the market, the smartphone must comply with exposure limits in terms of local specific absorption rate (SAR) averaged over 10 g [1] or 1g of tissue [2] following standardized measurement methods [4]. However, in realistic use cases, a smartphone will almost never be continuously transmitting, i.e., at a duty cycle of 100%, depending on the application or service used. The assessment of the realistic EMF exposure to the uplink of a smartphone, thus, requires the knowledge of the duty cycle.

MATERIALS AND METHODS

The uplink duty cycle of a smartphone under realistic exposure conditions was measured using the setup shown in Fig 1. The setup consisted of a smartphone with the drive test tool QualiPoc (Rohde & Schwarz, Germany), a tripod, and a laptop that connects to the smartphone using a USB cable. To avoid interference from the operator, the smartphone was connected to a laptop with a 5 m USB cable to remotely control it using the Vysor app. The drive test tool QualiPoc logs the relevant parameters of the smartphone chipset to determine the uplink duty cycle. We measured the duty cycle for different smartphone applications at ten positions from a 4G/5G base station antenna. During the measurements the smartphone was placed in a plastic holder on a tripod at a height of 1.5 m (Fig 1).

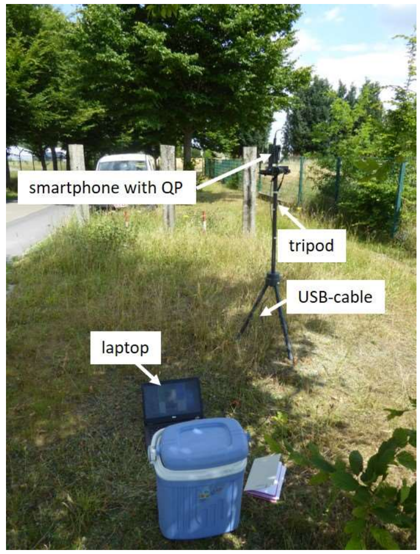


Fig 1: Measurement setup consisting of a smartphone with QualiPoc on a plastic tripod. The smartphone is connected via a USB-cable to a laptop for remote control with the Vysor app.

The in-situ measurement campaign was performed in the vicinity of a collocated 4G LTE and 5G NR base station in Leuven, Belgium. Measurements were conducted at ten positions covering Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) paths between the smartphone and the base station antenna with a distance between base station antenna and the measurement positions ranging from 96 m up to 1067 m. We used a Samsung S20+ 5G (SM-G986) enabled with the drive test tool QualiPoc (Android Ver. 21.03 SP2, Rohde & Schwarz, Germany). QualiPoc logged the relevant parameters of the Exynos chipset, used in the Samsung S20+ 5G smartphone, to determine the uplink duty cycle. As there were no parameters that directly reports the UL duty cycle, we calculated the uplink duty cycle as follows:

$$\text{DC [-]} = \text{Average number of TB [/s]} / (\text{\# TTI} / \text{s}) \quad (1)$$

$$\text{Average number of TB [/s]} = \text{Throughput [MBit/s]} * 10^6 \text{ [bit/Mbit]} / (\text{TBS [bytes]} * 8) \quad (2)$$

with TTI = Transmission Time Interval, TB = Transport Block, and TBS = Transport Block Size.

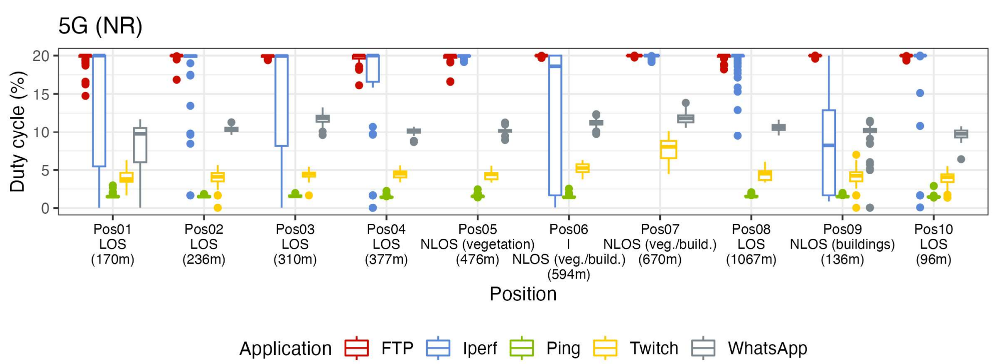
At each measurement position, six use cases were assessed for 4G LTE and five for 5G NR: voice call (VoLTE; only for 4G-LTE), voice call via WhatsApp (VoIP), twitch video upstream, ping, iPerf (maximum traffic), FTP upload of 10 GB file. In total, 110 experiments were performed.

For 5G, a Time Division Duplex (TDD)-factor of five (DDDSU slot configuration) was used resulting in time slot allocation of 1/5 for uplink and 4/5 for downlink. Consequently, the maximum uplink duty cycle for 5G equaled 20 %.

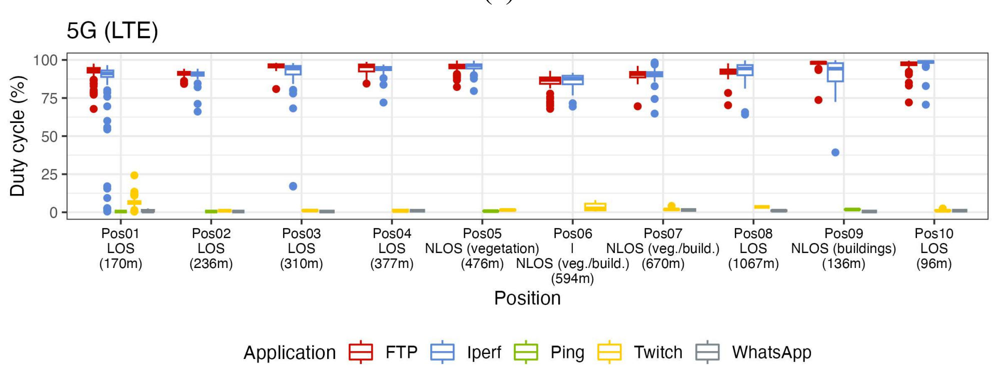
RESULTS

We calculated the duty cycles according to Equation (1). Figure 4 shows the boxplots of the calculated duty cycles for 5G NR, 5G LTE – to distinguish from LTE in case of 4G connectivity, we define 5G LTE as LTE in case of 5G NSA – and 4G LTE at the investigated positions.

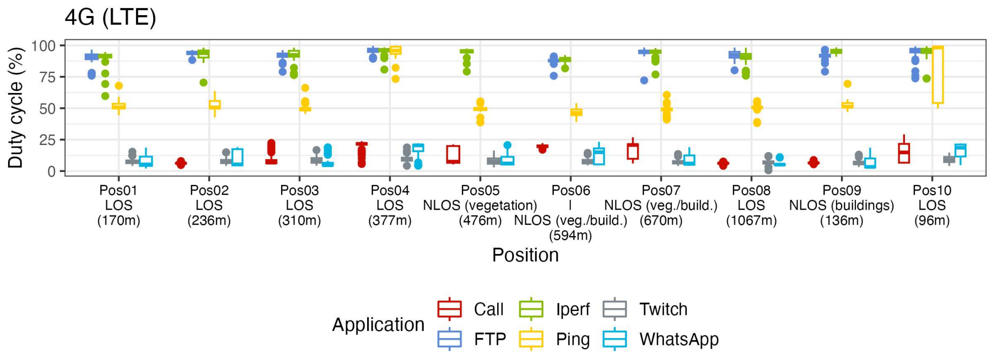
We observe that data-intensive applications, as expected, result in the largest duty cycles: for 5G-NR, FTP upload showed a duty cycle of 20 % for all measurement positions and iPerf also showed duty cycles larger than 20 % for all positions except at Pos 6 (19 %) and Pos 9 (8 %). The duty cycles for Ping and Twitch were below 2 % and 8 %, respectively. For WhatsApp, we observed duty cycles between 10 % (Pos 10) and 12 % (Pos 7). For 5G-LTE, the uplink duty cycle for FTP and iPerf exceeded 90 % except from position Pos 6 (FTP upload: 87 %; iPerf: 88 %); the duty cycle for Ping and WhatsApp was below 2 % for all positions; and for Twitch, the duty cycle ranged between 1 % (Pos 1) and 2 % (Pos 7). We note that the maximum duty cycle for 5G NR was 20%, based on the used TDD slot format DDDSU. For 4G-LTE, the uplink duty cycle for FTP and iPerf exceeded 90 % except at Pos 6 (FTP upload: 88 %; iPerf: 89 %); Ping showed duty cycles around 50 % except at Pos 4 and Pos 10, where a duty cycle above 95 % was observed; Twitch shows duty cycles below 10 %; the duty cycles for WhatsApp (VoIP) and VoLTE call follow a similar trend with duty cycles below 10 % except from Pos 4 (WhatsApp: 20 %; Call: 22 %), Pos 6 (WhatsApp: 15 %; Call: 20 %), and Pos 10 (WhatsApp: 19 %; Call: 15 %).



(a)



(b)



(c)

Figure 2. One-second averaged duty cycles as function of distance to the base station antenna per use cases and per technology: (a) 5G-NR, (b) 5G-LTE, and (c) 4G-LTE. Remark that for 5G NR, there was an upper duty cycle limit of 20% t, considering the used TDD slot format DDDSU.

Table 1 lists the duty cycles per application (or use case) and technology calculated from the in-situ measurements at Leuven, Belgium. The duty cycle for Twitch, VoLTE, and WhatsApp ranged between 4 % and 22 % in time for 4G LTE and between 4 % and 14 % for 5G NR. The maximum duty cycle for 5G NR was 20%, based on the used TDD slot format DDDSU. Due to TDD for 5G NR, 5G NR uses a higher fraction of the UL-allocated slots. Ping has a median duty cycle of 4 % and 50 % for 5G NR and 4G LTE, respectively. Remark that for 4G LTE the 95th percentile of the duty cycle equalled 99 %. Finally, FTP upload and iPerf nearly fully uses the UL-allocated time as the median duty cycle equals close to 92-93 % for 4G LTE and 20 % for 5G NR.

Table 1 Summary of the duty cycles, median and 95th percentile, of the considered applications and encountered path types obtained from in-situ measurements at Leuven, Belgium. Remark that for 5G NR, there was an upper duty cycle limit of 20%, considering the used TDD slot format DDDSU.

	4G (LTE)		5G (LTE)		5G (NR)	
Application	p_{50}(DC) (%)	p_{95}(DC) (%)	p_{50}(DC) (%)	p_{95}(DC) (%)	p_{50}(DC) (%)	p_{95}(DC) (%)
Call (VoLTE)	7	23	-	-	-	-
WhatsApp (VoIP)	6	21	1	2	11	13
FTP	93	98	94	99	20	20
Iperf	94	98	93	99	20	20
Ping	50	99	1	2	2	2
Twitch	7	15	5	12	4	8

CONCLUSIONS

This study presented the uplink duty cycles and related parameters determined from in-situ measurements near a 4G and 5G base station antenna in Belgium. Six use cases were considered for 4G LTE. The use cases were repeated for 5G NR except from the use case 'Call', which was VoLTE.

The duty cycles remained relatively stable during each of the use cases. For Twitch, VoLTE & WhatsApp the duty cycle ranged between 4% and 22% in time for 4G LTE and between 4 % and 14 % for 5G NR. The maximum duty cycle for 5G NR was 20%, based on the used

TDD slot format DDDSU. For 5G NR, these duty-cycles resulted in a higher UL-allotted time due to Time Division Duplexing at 3.7 GHz frequency band. Ping showed median duty cycles of 2% for 5G NR and 50 % for 4G LTE. FTP upload and iPerf resulted in duty cycles close to 100 % for 4G LTE and 20 % for 5G NR.

ACKNOWLEDGEMENT

This research was funded by Mobile & Wireless Forum (MWF). The authors would like to thank Ken Joyner and Kai Niskala for their support in the course of this study.

REFERENCES

[1] International Commission on Non-Ionizing Radiation Protection. Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz). Health Physics 2020, 118, 483, doi:10.1097/HP.0000000000001210.

[2] Federal Communications Commission. 447498 Mobile and Portable Device, RF Exposure, Equipment Authorization Procedures, 1.1307, 2.1091, 2.1093 Available online: https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?switch=P&id=20676 (accessed on 18 January 2024).

[3] Joseph, W.; Pareit, D.; Vermeeren, G.; Naudts, D.; Verloock, L.; Martens, L.; Moerman, I. Determination of the Duty Cycle of WLAN for Realistic Radio Frequency Electromagnetic Field Exposure Assessment. Progress in Biophysics and Molecular Biology 2013, 111, 30–36, doi:10.1016/j.pbiomolbio.2012.10.002.

[4] International Electrotechnical Commission / Institute of Electrical and Electronics Engineers. IEEE 62209-1528:2020 - Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-worn wireless communication devices - Human models, instrumentation and procedures (Frequency range of 4 MHz to 10 GHz). Available online: https://webstore.iec.ch/publication/62753

BioEM 2024 CRETE GREECE

THE THIRD ANNUAL CONFERENCE OF BioEM

Full abstract book

16 - 21 June 2024

Minoa Palace

Chania, Crete

BioEM