Duty Cycles of Wireless Applications and Activities for WiFi Exposure Assessment

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INTRODUCTION

Wireless Local Area Networks using WiFi technology are commonly deployed in office buildings and at home. People are exposed to the electromagnetic (EM) fields of these networks but not continuously as WiFi data packets are transmitted in bursts; the WiFi signals thus have a duty cycle. According to international guidelines, the exposure is to be averaged over a 6 min or 30 min time period (ICNIRP [1], IEEE C95.1 2005 [2]). The correct assessment of the exposure requires thus the knowledge of the duty cycle. Often worst-case exposure of WiFi is assessed, assuming 100 % activity and leading to overestimations. Only in [3] duty cycles of WiFi devices in schools were assessed.

In this study, duty cycles are determined for various specific activities such as voice over IP (VoIP), file transfer, video streaming, audio, surfing on the internet, etc. These duty cycles can be used for estimation and assessment of *realistic* WLAN exposure. This will enable simple and realistic WiFi exposure assessment by application of the provided duty cycles.

MATERIALS AND METHODS

We assessed exposure during the following typical activities or using different applications: (a) surfing to a news site (BBC) on the internet (b) Voice over IP (VoIP) using Skype (Skype 2012), (c) video call using Skype, (d) audio streaming using Spotify, (e) normal video streaming using YouTube (360p), (f) High Definition video streaming using YouTube (1080p, same video), and (g) file transfer (download of a large file from Ubuntu). The video streaming “360p” means that the video screen is 360 pixels wide (normal video watching), while “1080p” corresponds with high definition video, characterized by 1080 horizontal lines of vertical resolution and noninterlaced scanning (progressive scan).

To assess the duty cycle *D* of these activities, a WiFi-packet analyzer, is used. The analyzer consists of the software tool Airmagnet together with a laptop and a WiFi card (type Proxim ORiNOCO 11 a/b/g Client Combocard gold). The Airmagnet WiFi packet analyzer, measures the instantaneous duty cycle in % for different activities over an 802.11a connection between two computers in the 5 GHz band (channel 48, frequency 5240 MHz, no detected activity on neighboring channels during the measurement).

For experimental assessment, we use IEEE 802.11a technology instead of a 802.11g network as the former is deployed at 5 GHz instead of 2.4 GHz for the latter. As the 5 GHz band is less used than the 2.4 GHz, we are less susceptible to interference for our measurements. The duty cycles measured for the activities over 802.11a are also comparable for 802.11g as they share the same principles and protocols for the physical air interface with slightly different parameter sets. As access point, we use a ZOTAC NM10-A-E mini-pc with a Sparklan wireless interface card type WPEA-110N/E/11n and an omnidirectional dipole antenna.

The duty cycle for real activities is measured here for the highest (54 Mbps) and lowest (6 Mbps) data rate in an IEEE 802.11a network [4]. The computers are placed line of sight

(LOS) at a distance of 0.5 m, resulting in an optimal connection quality at the maximum physical data rate of 54 Mbps. For measurements at 6 Mbps, we limited the software of the access point to only support this data rate, while keeping all equipment at the same place.
Samples are acquired each second over at least 120 s (up to 350 s) until the video or audio fragment is finished or the file is transferred. The duration of this measurement can differ due to the use of actual activities on actual sites (YouTube, Skype, Spotify).

RESULTS

Figure 1 shows the duty cycle (%) as a function time for four applications namely VoIP, skype video, video streaming, and file transfer at 54 Mbps. Transferring or downloading the file is the most "intensive application" (*D* around 60-69%). For the video streaming (YouTube), the video file is buffered during the first 50 seconds around 60% and after this period with high duty cycle, the channel occupation reduces to 0.1% because all data has been received and only basic control information is still being sent. Skype voice and video vary less with occupations around 1 to 2%.
The measured duty cycles *D* for the considered applications at 6 and 54 Mbps are listed in Table 1. Clearly, the lowest data rate (6 Mbps) results in the highest duty cycles for all applications. When WiFi signal quality is getting poor, lower modulations will be used to still maintain a stable connection, at the expense of a lower physical data rate. But for lower modulations (and thus lower physical data rates) higher duty cycles will be obtained because the time to transmit data and control packets will be higher, while the idle durations remain the same. Thus the worse the connection, when only low physical data rates are possible, the higher the duty cycle and the resulting exposure can be. Although it might appear counterintuitive at first sight, it means that a poor connection between an access point and a user results in higher possible exposure all around the access point.
File transfer causes the highest duty cycles up to 66 % (54 Mbps) and 94% (6 Mbps), followed by video applications (at 54 Mbps: p_{95} = 65% for high quality video of 1080p while normal video of 360p and Skype video have 95th percentiles of about 2%), and voice applications (VoIP using Skype p_{95} = 1.3%). Audio streaming (using Spotify p_{95} = 0.2%, 54 Mbps) and surfing on the internet (here BBC news site, p_{95} = 1.3% at 54 Mbps) result in the lowest duty cycles.
This order of duty cycles was expected as the more intensive applications, such as downloading and video streaming, require more data to be transferred and thus result in a higher occupation of the WiFi link. From the values of Table 1 it is clear that it is important to take realistic duty cycles into account as the average values are often below the worst-case approaches of 100% activity.

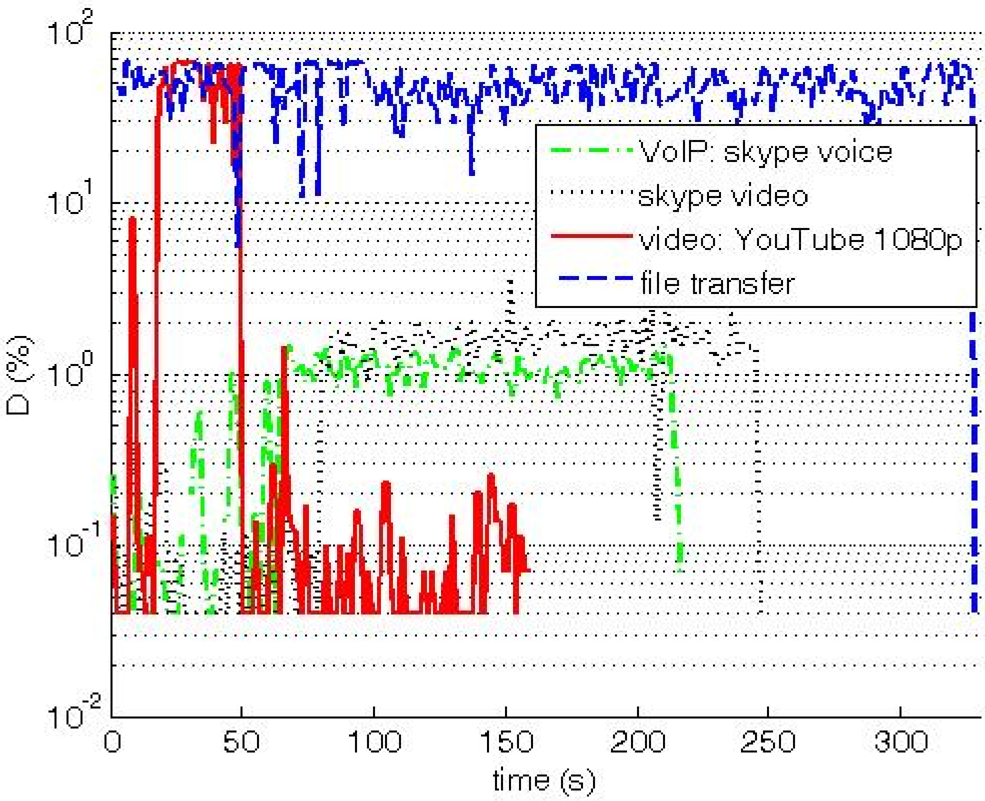

Figure 1: WiFi duty cycle D during time for different VoIP, video streaming, and file transfer at 54 Mbps.

TABLE 1: Duty cycles at 54 and 6 Mbps for different applications (average, 50^th^, 95^th^ percentile, and maximum).

application	**PHYdata rate (Mbps)**	**avg (%)**	**p_{50} (%)**	**p_{95} (%)**	**max (%)**
Surfing news site	6	1.57	0.33	2.89	89.37
Skype voice	6	3.10	3.18	4.52	11.05
Skype video	6	5.42	5.24	10.77	15.65
Audio: Spotify	6	6.70	0.17	91.15	92.84
YouTube video 360p	6	14.54	0.40	90.75	93.29
YouTube video 1080p	6	81.39	91.12	92.81	93.45
File transfer	6	87.41	91.46	93.14	93.58
Surfing news site	54	0.25	0.04	0.62	14.49
Skype voice	54	0.80	1.01	1.34	1.48
Skype video	54	1.08	1.41	2.02	3.65
Audio: Spotify	54	0.13	0.04	0.23	6.33

YouTube video 360p	54	2.35	0.07	2.14	65.56
YouTube video 1080p	54	10.69	0.07	64.53	66.23
File transfer	54	46.18	47.57	65.18	66.40

PHY data rate = physical data rate; D = duty cycle; avg = average duty cycle

CONCLUSIONS

Duty cycles are experimentally assessed for various activities and applications. For lower physical data rates (lower modulation schemes) higher duty cycles will occur. Although counterintuitive at first sight, poor WLAN connections may result in higher exposures. File transfer at maximum data rate results in median duty cycles of 47.6%, while it results in median values of 91.5% at minimum data rate. Surfing and audio streaming are less intensively using the wireless medium and therefore have median duty cycles lower than 3.2%.

ACKNOWLEDGMENTS

W. Joseph is a Post-Doctoral Fellow of the FWO-V (Research Foundation - Flanders).

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