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Some experience with upgrading Wi-Fi modules in PC laptops

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***Abstract*—This article investigates the feasibility of upgrading Wi-Fi modules in older PC laptops to comply with modern IEEE 802.11 standards, aiming to enhance network performance. Experimental results show that modern Wi-Fi adapters significantly improve throughput and efficiency, particularly in the 5 GHz band. However, challenges such as driver availability, BIOS whitelists, and hardware compatibility must be taken into account. The findings suggest that Wi-Fi upgrades can extend the usability of older laptops cost-effectively, with future research planned to explore newer standards and configurations.**

***Keywords*—local area networks; wireless local area networks; throughput measurement; IEEE 802.11 standards**

I. Introduction

OBSERVATION of the PC desktop and laptop second-hand computer market since the COVID-19 pandemic lockdown in March 2020 has shown that there are many computers available that do not have most up-to-date configurations, but the resources (e.g. microprocessor computing power and capabilities, memory capacity etc.) are still sufficient to run office applications, web browsers, etc. It's worth mentioning that in September 2020 it was still possible to successfully join Zoom meeting from a netbook running under Windows XP operating system (this is no longer possible [1]). These old desktops and laptops are sometimes equipped with only a 100 Mbps Ethernet and 54 Mbps Wi-Fi interfaces.

On the other hand, during the last years, a rapid development of wireless local area networks compatible with IEEE 802.11 standard [2][1] could be observed. Since 2008, several standard amendments have been published and later incorporated into revisions, defining the new physical layers and enhancements to the data link layer; they allow for higher transmission rates and better channel utilization [3]. Some of these enhancements are listed in the Table I [2]-[5].

TABLE I
IEEE 802.11 STANDARD ENHANCEMENTS

Version	Year	Max rate [Mbps]
IEEE 802.11g	2003	54
IEEE 802.11n (“WiFi 4”)	2009	600
IEEE 802.11ac (“WiFi 5”)	2013	3468
IEEE 802.11ax (“WiFi 6”)	2021	9607
IEEE 802.11be (“WiFi 7”)	2025	23059

While desktop PC computers configuration can be easily modified and upgraded, this is usually not that easy when it comes to laptops. Nevertheless, majority of the popular laptops types allow to upgrade DRAM memories, hard disks and Wi-Fi adapters. While there are some reports in the internet fora showing that increasing operational memory capacity and replacement of a hard disk with SSD bring some improvements to overall PC computer performance (e.g., [6]), there are hardly any systematic and exhaustive results regarding the upgrade of Wi-Fi adapter. Therefore, it seems reasonable to check if such an upgrade for older computer types, that are not equipped with modern and fast microprocessors, may bring some benefits.

Upgrading a Wi-Fi adapter can bring numerous benefits, both for the user and network performance. The main reasons for such an upgrade include: improved laptop performance in network applications, higher throughput, enhanced overall network efficiency, more modern security mechanisms compared to older adapters, and lower cost compared to purchasing a new laptop. It is worth noting that the presence of older Wi-Fi clients in a modern network can degrade performance for all devices, including those equipped with newer adapters, which applies to all Wi-Fi networks, from older ones like 802.11b [7] to modern ones like 802.11ax [8], [9]. These benefits are particularly significant in applications requiring fast transfer of large amounts of data.

One of the possible uses of the upgraded computers is simple edition of video material recorded from DVB television. Modern home entertainment systems may include a standalone TV receiver running under Linux operating systems. They allow for recording from various TV channels at a time, and make it possible to download the recorded files using FTP protocol. It allows to process the recorded material on the PC-class computer, in order to remove commercial advertisements, archive the interesting recordings for future use, etc. Modern Linux-based TV receivers are equipped with Gigabit Ethernet port, and it's also possible to use the built-in or USB Wi-Fi adapters.

There are several measures of the computer network quality, such as throughput, delay, jitter, packet loss ratio, etc [10]. During downloading of large files (a recording of 2 hours FullHD movie occupies approximately 3 to 6 GB), the most important network parameter is the effective throughput that can be observed at the application level. The throughput can be affected by many factors, such as physical layer transmission rate and protocol efficiency, but also microprocessor computing power and device drivers [11].

There are multiple tools designed especially for throughput estimation in computer networks and multiple estimation methods. The work [12] precisely defines the metrics related to

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network throughput estimation and briefly describes end-to-end capacity estimation tools. In [13], available bandwidth estimation tools are listed and analysed. In turn, [14] compares different tools and compares them to iPerf, which is said to be a widely-used for end-to-end performance measurement and has become the unofficial standard in network measurement.

There are some papers describing the usage of iPerf for the measurement of network throughput. Among them, [15] seems the most interesting as it compares network measurement tools like iPerf and Network Weather Service to FTP, GridFTP and SCP transfers. Unfortunately, the aforementioned papers do not state precisely which version of iPerf and operating system was used. There are also some reports (eg.,[16]) showing that there can be a difference between results achieved with iPerf2 and iPerf3. In our previous work [17] we presented the unexpected results that were achieved during network throughput tests using FTP and different versions of iPerf, showing that the iPerf version used for throughput measurement has a big and difficult to explain impact on the results.

This paper can be regarded as a continuation of [17]. The rest of the article is organised as follows. In chapter II we describe the experimental network with regard to the hardware and software used to measure the throughput. In chapter III, we present the results and discuss them. In chapter IV, we discuss the possible difficulties a user can meet when trying to successfully upgrade the Wi-Fi adapter. Finally, summary discusses, among others, the achieved results and possible future directions of our work.

II. Experimental network

The experimental network was configured in one of the university laboratories. Unfortunately, there were multiple wireless networks operating at this location which might affect our results. Their configuration and operation was beyond our control. We therefore carefully configured the test network to minimise any possible influence from neighbouring networks. In both 2.4 and 5 GHz band the strongest neighbour network power reported by OpenWRT router software was about -75 dBm.

A. Hardware used in tests

During the tests, we used the following laptops (see table II for details):

- Asus 1215B (two versions),
- MSI U270 (four versions),
- Sony VAIO SVE111,
- Acer Aspire V5-122P,
- Fujitsu A512 and A532

We also used the following routers and other hardware:

- Linksys WRT32X router,
- Asus TUF AX4200 router,
- Octagon SF8008 4K UHD digital TV receiver.

We tested the following Wi-Fi adapters (table III):

- Intel Dual Band Wirteless-AC 8260 and 8265,
- Intel Wireless-AC 9260
- Dell Wireless DW1550,
- Qualcomm QCA6174A,
- Realtek RTL8822CE and RTL8852BE,
- Intel Wi-Fi 6E AX210,
- MPC-AX1800H,
- Alfa AWUS1900 and AWUS036ACH USB adapters,
- Comfast CF-972AX USB adapter.

TABLE II
LAPTOPS USED IN TESTS

Name	Processor	Clock [MHz}	Memory Type	Mem.Clk [MHz]
Asus 1215B	C-50	1000	PC3-10700	533
Asus 1215B	E-450	1650	PC3-10700	533
MSI U270	E-350	1600	PC3-10700	533
MSI U270	E-450	1650	PC3-10700	533
MSI U270	E2-1800	1700	PC3-10700	667
MSI U270	E2-2000	1750	PC3-10700	667
Sony SVE111	E2-2000	1750	PC3-12800	533
Acer V5-122P	A6-1450	1000	PC3-10600	667
Fujitsu A512	i3-2328M	2200	PC3-12800	800
Fujitsu A532	i5-2340M	2400	PC3-12800	800

TABLE III
WI-FI ADAPTERS USED IN TESTS [19]-[20]

Name/circuit	Class	Channel width	MIMO streams	2.4G rate	5G rate
Intel 8260	AC1200	80 MHz	2×2:2	300	867
Intel 8265	AC1200	80 MHz	2×2:2	300	867
Intel 9260	AC1733	160 MHz	2×2:2	300	1733
DW1550	AC1200	80 MHz	2×2:2	300	867
QCA6174A	AC1200	80 MHz	2×2:2	300	867
RTL8822	AC1200	80 MHz	2×2:2	300	867
RTL8852	AX1800	160 MHz	2×2	574	2400
Intel AX210	AX1800	160 MHz	2×2:2	574	2400
MPE-AX1800H	AX1800	80 MHz	2×2:2	574	1200
AWUS036ACH	AC1200	80 MHz	2×2:2	300	867
AWUS1900	AC1900	80 MHz	4×4:3	600	1300
CF-972AX	AX5400	160 MHz	2×2	574	2400

The experimental network structure is presented in Fig. 1. The tuner was connected to a router with 1 Gbps Ethernet cable (about 5 m long), while the communication between the router and the client was wireless. The distance between the router and the client was about 2.5 m, with no obstacles between them.

During the tests, Linksys WRT32X and Asus TUF AX4200 router were running under OpenWRT software 23.05.3 version, while Octagon SF8008 receiver under OpenATV version 7.1.20221130.

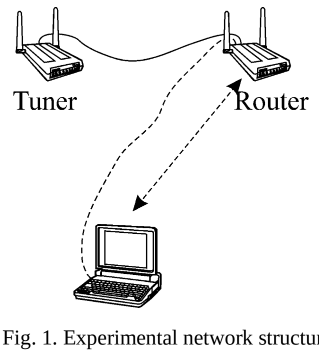

Fig. 1. Experimental network structure

B. Software used in tests

We used the same test procedure as described and discussed in detail in [17]. The throughput was measured using built-in Windows FTP client, and few versions of iPerf:

- iPerf 3.1.3 for Windows, in 32- and 64-bit versions,
- iPerf 2.1.8 for Windows,
- iPerf 3.11 at OpenATV,
- iPerf 3.7 and 2.0.13 at OpenWRT.

The Windows 7 installations were not experimental – instead, we used the installations ready to work in office applications. Windows 10, in turn, was a clean installation with only the applications necessary for the research.

The Windows installations were cloned between the computers, so the application settings as well as hard disk structure were the same. All the necessary device drivers were also installed. The installed applications and services might generate some additional network traffic, although we believe its influence on the results was negligible.

III. RESULTS AND DISCUSSION

A. Number of antennas

The laptops used in our research were equipped with 1 or 2 Wi-Fi antennas. Generally, those which were originally equipped with 802.11g adapter, had 2 antennas, while those which had 802.11n sometimes had only a single antenna. The Wi-Fi adapters that we used may cooperate with 2 antennas, so the presence of a single antenna may reduce their capabilities. In this test, we used Fujitsu A512 with Windows 10 64-bit and Linksys WRT32X router. The measurement results for 2.4 GHz band are collected in table IV, whereas for 5 GHz – in table V.

TABLE IV
THROUGHPUT FOR DIFFERENT NUMBERS OF ANTENNAS (2.4 GHZ)

Adapter	#ant	FTP	iPerf2	iPerf3 (32b)	iPerf3 (64b)
DW1550	2	9,17	8,89	6,19	8,63
DW1550	1	3,79	4,17	4,17	4,18
i8265	2	17,48	16,67	9,82	15,66
i8265	1	5,98	5,70	5,49	5,70
QCA6174A	2	19,39	18,18	9,48	17,08
QCA6174A	1	10,36	9,55	6,47	9,78
AX210	2	18,39	17,23	7,86	15,21
AX210	1	7,39	4,91	4,47	6,06

TABLE V
THROUGHPUT FOR DIFFERENT NUMBERS OF ANTENNAS (5 GHZ)

Adapter	#ant	FTP	iPerf2	iPerf3 (32b)	iPerf3 (64b)
DW1550	2	67,99	68,32	19,38	42,24
DW1550	1	30,16	29,22	13,70	21,90
i8265	2	72,94	63,40	18,72	42,77
i8265	1	15,89	14,87	10,54	16,45
QCA6174A	2	65,61	68,31	13,61	37,60
QCA6174A	1	17,97	20,15	10,61	18,90
AX210	2	74,74	71,78	15,36	33,78
AX210	1	35,72	29,51	12,31	24,40

The presented results clearly show that using two antennas consistently results in significantly higher throughput compared to a single antenna across all adapters and test scenarios, with reductions in throughput ranging from approximately 47–52% when using only a single antenna. The 5 GHz band outperforms the 2.4 GHz band substantially, with adapters like the AX210 achieving up to 74.74 Mb/s (FTP, 2 antennas) in the 5 GHz band compared to 18.39 Mb/s in the 2.4 GHz band, owing to wider channel bandwidth and lower interference. The AX210 and QCA6174A adapters demonstrate superior performance, with the AX210 leading in the 5 GHz band (e.g., 71.78 Mb/s in iPerf2) and the QCA6174A excelling in the 2.4 GHz band (e.g., 19.39 Mb/s in FTP). Notably, iPerf3 tests, particularly in 32-bit mode, yield lower throughput values than FTP and iPerf2, especially in the 5 GHz band, likely due to implementation differences or sensitivity to latency (this behavior of iPerf3 has been found and described in [17]).

B. Microprocessor computing power

For this test, we selected a few laptops that had a similar architecture, but different microprocessor types. This includes two Asus 1215B with AMD C50 and E450 microprocessors, four MSI U270 with AMD E350, E450, E2-1800 and E2-2000, and Sony VAIO with AMD E2-2000 microprocessors. All these microprocessors are 2-core, 2-thread units with a single memory channel. Each laptop was equipped with DW1550 Wi-Fi adapter and ran under control of Windows 7 32-bit (the same system details as used in [17]). For comparison, we tested Ethernet throughput as well, bearing in mind that Asus laptops are equipped with 100 Mbps while the others have 1 Gbps Ethernet interfaces. We also used Linksys WRT32X router. The measurement results for Ethernet, 2.4 Ghz band and 5 GHz band are collected in tables VI to VIII, respectively.

The presented results show that microprocessor computing power may have a significant influence over network throughput. Generally, we can see that the throughout increases with increasing microprocessor clock frequency for both Ethernet and Wi-Fi networks. For Asus 1215B, the throughput in all the test is close to the theoretical maximum even for the slowest C-50 microprocessor (the second Asus laptop had a defective Ethernet interface), which suggests that its

TABLE VI
THROUGHPUT FOR DIFFERENT MICROPROCESSORS (2.4 GHZ)

Laptop	Processor	FTP	iPerf2	iPerf3 (32b)
Asus 1215B	C50			
Asus 1215B	E450	15,13	14,23	7,98
MSI U270	E350	14,68	15,13	7,33
MSI U270	E450	14,35	13,53	7,07
MSI U270	E2-1800	15,19	13,58	7,94
MSI U270	E2-2000	15,17	12,60	6,93
Sony VAIO	E2-2000	16,56	15,09	7,85

TABLE VII
THROUGHPUT FOR DIFFERENT MICROPROCESSORS (5 GHZ)

Laptop	Processor	FTP	iPerf2	iPerf3 (32b)
Asus 1215B	C50	19,56	17,12	11,11
Asus 1215B	E450	26,05	28,13	16,21
MSI U270	E350	25,63	23,40	12,42
MSI U270	E450	21,18	20,06	11,08
MSI U270	E2-1800	29,32	28,49	15,87
MSI U270	E2-2000	28,88	29,17	16,38
Sony VAIO	E2-2000	26,82	24,05	16,38

TABLE VIII
THROUGHPUT FOR DIFFERENT MICROPROCESSORS (ETHERNET)

Laptop	Processor	FTP	Ethernet	iPerf2	iPerf3 (32b)
Asus 1215B	C50	11,48	100	10,73	9,66
Asus 1215B	E450				
MSI U270	E350	41,96	1000	44,29	35,56
MSI U270	E450	32,12	1000	31,18	28,99
MSI U270	E2-1800	44,11	1000	46,86	39,60
MSI U270	E2-2000	41,47	1000	43,75	41,70
Sony VAIO	E2-2000	39,81	1000	47,06	33,16

processing power is sufficient for this network. Similarly we can say about the transmission in 2.5 GHz band (300 Mbps). But this is not the case for the remaining cases. The results clearly show that the modern fast networks require more computing power from the microprocessor to utilize the link capacity and reach higher throughput. This is a bit more visible for Wi-Fi than Ethernet. However, our earlier tests [17] show, that there can be a significant influence from the operating system. For example, Windows XP seems more suitable for low-processing-power microprocessors [17] (on Asus 1000HG with Atom N270 microprocessor we reached over 20 MBps throughput for 300 Mbps Wi-Fi link under Windows XP and only about 10 MBps for 867 Mbps link under Windows 7).

Despite we did our best to eliminate any differences other than microprocessor computing power, there might be some other details is the laptop architecture, or in the network, that have influence on the resulting throughput.

C. *Wi-Fi adapter type*

In this test, we used Fujitsu A532 and Acer V5-1222P laptops, both running under Windows 10 64-bit, and Asus TUF AX4200 router. Unfortunately, Acer is equipped with only a single antenna, so we connected two antennas from the display lid of another laptop in order to minimize the influence of the number of antennas.

Unfortunately, in the Acer laptop some tests could not be conducted. Some of the Wi-Fi adapters, despite being visible and enabled in the device manager, didn't see any networks. Additionally, AWUS036 adapter could detect and display the 802.11ac network, but could not connect, while the 802.11n network did work with this adapter. Also, Comfast CF-972AX adapter worked well only with FTP and iPerf3 64-bit, while other tests could not be started, finished, or the measured throughput was 0 MBps. This phenomena was observed in all the hardware and software combinations. Thus, the results for this adapter are not included.

The tests were divided in two groups, the first was included in [18] while the second are new results. The first tests were to expand our previous results shown in [17] with the results obtained for Windows 10, however, only for selected adapters compatible with at least AC1200 class. These results, however, can't be directly compared to our previous results, because they were gathered in another environment, and with another router and laptop. Nevertheless, we can see some similarities between the previous and the new results. The second tests expands the previous results with throughput obtained for adapters not considered in [17] because of lack of drivers for earlier Windows versions.

Some of the results are a little bit surprising. For example, the performance of DW1550 card is quite good in AC test, but in the N test it gives the worst results among all the tested cards. When comparing the results for DW1550, i8260, i8265 and QCA6174A with the results shown in [17], we can see some difference. It is worth emphasize that we used exactly the same laptop for the tests. However, the differences include operating system, router type, router software version and environment. It could happen that an increased interference from other Wi-Fi networks occurred in 2.4 GHz band during the test of DW1550 card, but of course there can be more reasons for the behavior of this card. On the other hand, performance of AX210 card is the highest, which is also a bit surprising, because the network

TABLE IX
THROUGHPUT FOR WI-FI ADAPTERS

Adapter	Test	Fujitsu AC	Fujitsu N	Acer AC	Acer N
DW1550	FTP	72,39	11,03	-	-
DW1550	iPerf2	76,08	9,38	-	-
DW1550	iPerf3-32	23,15	7,81	-	-
DW1550	iPerf3-64	46,87	10,45	-	-
i8260	FTP	62,82	16,28	57,53	16,95
i8260	iPerf2	76,08	18,03	73,79	16,14
i8260	iPerf3-32	25,15	10,43	14,58	9,54
i8260	iPerf3-64	44,92	15,32	36,17	14,42
i8265	FTP	62,53	15,57	49,88	14,79
i8265	iPerf2	76,22	16,41	45,94	14,72
i8265	iPerf3-32	25,13	10,01	21,69	9,89
i8265	iPerf3-64	47,31	14,17	41,34	14,12
QCA6174A	FTP	71,67	16,95	-	-
QCA6174A	iPerf2	75,56	17,39	-	-
QCA6174A	iPerf3-32	18,03	7,49	-	-
QCA6174A	iPerf3-64	36,88	13,47	-	-
Intel AX210	FTP	83,21	22,48	-	-
Intel AX210	iPerf2	85,10	21,78	-	-
Intel AX210	iPerf3-32	21,96	13,37	-	-
Intel AX210	iPerf3-64	45,57	19,61	-	-
AWUS036A	FTP	32,22	17,30	32,76	21,56
AWUS036A	iPerf2	33,06	17,48	32,29	20,26
AWUS036A	iPerf3-32	17,56	10,57	18,74	10,31
AWUS036A	iPerf3-64	26,64	16,10	28,88	18,00
AWUS1900	FTP	27,09	19,06	-	17,17
AWUS1900	iPerf2	27,29	16,55	-	16,15
AWUS1900	iPerf3-32	16,73	9,96	-	10,88
AWUS1900	iPerf3-64	25,76	15,40	-	12,63

TABLE X
THROUGHPUT FOR WI-FI ADAPTERS

Adapter	Test	Fujitsu AC	Fujitsu N	Fujitsu AX
i9260	FTP	70,32	19,26	66,14
i9260	iPerf2	79,46	19,10	78,77
i9260	iPerf3-32	23,93	13,41	23,93
i9260	iPerf3-64	44,06	18,39	44,67
Intel AX210	FTP	83,21	22,48	82,96
Intel AX210	iPerf2	85,10	21,78	86,59
Intel AX210	iPerf3-32	21,96	13,37	22,07
Intel AX210	iPerf3-64	45,57	19,61	47,49
RTL8822	FTP	55,98	19,70	69,37
RTL8822	iPerf2	70,90	17,30	67,58
RTL8822	iPerf3-32	24,84	13,07	24,36
RTL8822	iPerf3-64	48,85	18,47	48,56
RTL8852	FTP	87,47	22,40	83,89
RTL8852	iPerf2	79,47	21,79	93,55
RTL8852	iPerf3-32	12,42	8,85	12,32
RTL8852	iPerf3-64	36,23	18,41	35,46
AX1800H	FTP	76,22	21,96	73,48
AX1800H	iPerf2	91,84	21,35	85,19
AX1800H	iPerf3-32	28,40	14,60	28,53
AX1800H	iPerf3-64	55,35	20,90	57,09

operated in AC mode, so the new capabilities of AX-compatible hardware should not have any influence on the results. On the other hand, the results for the AX210 card in the second group show that there is almost no difference between AC and AX results. But for RTL8852 we observed a similar phenomenon. It looks like this observation requires further research.

The performance of the AWUS036 and AWUS1900 USB adapters is, on the other hand, much lower than expected. One of the possible reasons is that these are USB 3.0 adapters which might limit the maximum throughput or case additional delays when compared to the PCI Express cards. This statement requires however further research with other USB Wi-Fi adapter types.

The results for Acer, where successfully acquired, show that the throughout also depends on the microprocessor computing power. A6-1450 has a lower efficiency than i5-2340M which has an influence on the results – but only for PCI Express cards. No significant difference between Acer laptop results for AWUS adapters lets us think that the throughput is limited by the adapters themselves, or the USB connection, and not by the microprocessor.

D. Additional tests

For comparison, and in order to have a broader set of results, we conducted a short series of tests using more recent laptops, namely, Lenovo Legion Y530-15 and Lenovo Thinkbook 14 G4 IAP [18]. They are equipped with i5-8300H and i5-1235U microprocessors, as well as Atheros QCA9377 (AC600 class [20]) and Intel AX211 (AXE3000 class [20]) Wi-Fi adapters, respectively. They were tested in AC mode. The maximum throughput was about 36 MBps for Legion and 91 to 100 MBps for Thinkbook. When comparing these results to those obtained using much older laptops we can see that sometimes Wi-Fi adapters placed in modern laptops do not allow them reach the throughput that a user might expect when buying a new hardware. On the other hand, using an old laptop with a sufficient computing power and a Wi-Fi adapter upgraded to the most recent standard allows to obtain the throughput comparable to much more modern laptops.

IV. Technical difficulties

In the modern PC laptops, users can face several difficulties when trying to upgrade a Wi-Fi adapter. Here we mention those that we have met during our research.

A. Placement of Wi-Fi adapter

In all the laptops that we used it was possible to access the internal exchangeable elements. However, depending on the laptop model, it required removal a service cover (a size of which varies depending on a model), or an entire bottom panel. While HDD or memory can be typically easily accessed, this is often not the case with Wi-Fi modules. In many laptops with a service cover, it's necessary to remove entire bottom panel to access Wi-Fi adapter. Sometimes the Wi-Fi adapter is placed right beyond the outline of the service cover, as if the producer wanted to discourage users to upgrade their laptops. In some laptops, particularly Asus 1201 and 1215 series, only a memory is accessible through a service cover, and an access to a HDD or Wi-Fi requires removing of a palmrest and a keyboard, despite both HDD and Wi-Fi card are placed at the bottom of the housing.

B. Number of antennas

Some laptops, especially netbooks from the 2008-2013, are equipped with a single antenna only. Obviously it is possible to add an extra antenna, but it requires many more operations to mount it. Nevertheless, our tests show that a single antenna may significantly limit the network performance, lowering the throughput and probably transmission range.

C. White list

Some laptops, often regarded as professional models, may have a whitelist in BIOS. The whitelist allows to use only some particular elements, and when a different one ("illegal") is installed, the laptop won't even boot an operating system! The most particular example we have met is Lenovo T540 which only allows Intel 7260 (single or dual band) Wi-Fi adapters. Removal of a whitelist is technically possible, but it requires and unauthorized BIOS modification, thus, we have not tested this possibility.

D. Band support

While all of the adapters we have used in our research support 2.4 GHZ band (channels 1 to 13) and 5.25 GHz (channels 32 to 68), some do not support 5.65 GHz (channels 100 to 177). This limits the usable channel availability, which increases mutual interference in locations where multiple wireless LANs exist.

E. Drivers availability

It can be surprising, but there may be no device drivers available for certain Wi-Fi adapters for older operations systems. For example, we couldn't find any working drivers for 802.11ac adapters for Windows XP (the only exception, Dell DW1550 card driver, installed and recognized the hardware properly, but couldn't run the card). To say more, not all 802.11ac adapters have drivers for Windows 7. 802.11ax adapters generally require at least Windows 8 or Windows 10. This will probably continue for future adapters and Windows versions. Also, even if drivers for older Windows version did exist, they may be no longer available from official vendors websites. Downloading drivers and software from independent websites is frequently possible, but seems risky sometimes. Generally, finding the most up-to-date driver for an older adapter and operating system is not always an easy task.

F. Compatibility problems

Sometimes the card just doesn't work properly in a certain laptop. It may result in inability to connect to the wireless LAN in one of the bands while it works with properly the other band, or in surprisingly low throughput results. Sometimes the system crashes with BSOD after some time of work with some Wi-Fi adapter, while it can work without any problems with another card type. Fortunately these cases are relatively rare, but still possible and difficult to solve, particularly when using the latest BIOS and driver versions doesn't help.

Conclusion and future work

In this article, we presented and discussed the test results that re the continuation of our earlier work. In that work, we concentrated on the differences between iPerf versions in both test methodology and the result. In this work, we present the results from a different point of view, but still bearing in mind that different software type and version can give different network performance result.

The results still show that iPerf2 is much more accurate than iPerf3 (in either 32- or 64-bit version) when estimating the throughput of a local area network configured using up-to-date elements, such as 1Gbps Ethernet and 802.11ac/ax wireless networks. The results achieved with iPerf2 do differ sometimes from FTP measurements; this may be the result of different measurement method used in these applications. We also observed that iPerf3 measurements for the laptop-router and laptop-tuner transmissions differ; when iPerf3 on laptop connects to the router as iPerf server, the measured throughout is higher, but still not as high as for iPerf2. This observation deserves a further research.

The results and conclusions presented here are, again, limited to this particular experimental network. Especially network environment may have a significant influence on the results. Thus, despite the relations between FTP, iPerf2 and iPerf3 measurements are still similar to our earlier results, a direct comparison of the old and the new results may lead to false conclusions.

It might happen that using other network hardware, operating systems, application versions, etc., completely different results could be achieved, leading to completely different conclusions. Therefore, it is important to continue the research with other network configurations, including more up-to-date operating systems, computer configurations, network elements (e.g., 802.11be routers and adapters), and so on. Particularly, the results should be compared with Windows-to-Windows and Linux-to-Linux transmissions. It would allow to present more general conclusions.

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