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Some Wi-Fi Access Points in the City of Sofia

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Abstract. **The purpose of this article is to present the results of a study of the number and type of Wi-Fi access points using applications for the collection, processing and analysis of data based on a sample collected in different areas and places with a significant concentration of people in a city Sofia, Bulgaria. Data on the number and type of access points were obtained by measurements taken at the respective locations. User equipment connects to different Wi-Fi access points located in different places in the city that are accessible. Data was collected for wireless access points that are fourth and fifth generation. Different generations in wireless networks have corresponding download and upload speeds and frequencies. In the article, the results are grouped and analyzed according to different characteristics.**

Keywords: Wi-Fi protocols and standards, Access points.

I. INTRODUCTION

The Internet plays an important role in today's communication, especially when efficiency is relied upon. Unlike other means of communication, the Internet is decentralized in such a way that any user can share, retrieve, sell or exchange goods and services with any other user within seconds..

Today, the Internet is a part of our daily life because of the great benefits we gain from it. A large number of companies are in the online space and are also engaged in e-commerce, which includes advertising, selling, buying, distributing products and providing products to customers. In addition, companies use the Internet for business-to-business and business-to-customer transactions. Individuals also use the Internet to communicate, entertain, share information, buy and sell goods and services [1].

With the widespread use of mobile terminals such as laptops, smartphones, mobile phones, Wi-Fi phones, personal digital assistants (PDAs), etc. the demand for wireless Internet access is clearly growing [8].

A wireless local area network (LAN) is one in which a mobile user can connect to a LAN via a wireless connection. Wireless local area networks (WLANs) conform to the 802.11 standards set by the Institute of Electrical and Electronics Engineers (IEEE) [8,9].

In the past few years, wireless access via Wi-Fi has grown rapidly and has become the dominant standard for wireless local area networks (WLANs). Because it operates in unlicensed frequency bands, anyone can set up a Wi-Fi network and cover an area typically from 15 to 250 meters with high-speed WLAN access and from there to the Internet [5,6,7].

Like other wireless access standards such as GSM or (Code-division multiple access) CDMA, Wi-Fi has also become a universal standard. As a result, the costs of Wi-Fi components decrease, and hence the volume and number of their use increases. Wi-Fi access is widespread and used in many different parts of the world [8,9].

Wi-Fi technology can be used to provide local area network and Internet access to devices that are within Wi-Fi range of one or more routers connected to the Internet. The coverage of one or more interconnected access points (APs, hotspots) can extend from a small area, such as a few rooms, to square kilometers. Coverage in the larger area may require a group of APs.

Wi-Fi provides services in private homes, businesses as well as in public places. APs can be set up for free or commercially, often using an access trap web page. Organizations, enthusiasts, authorities and businesses, such as airports, hotels and restaurants, often provide free or paid APs to attract customers, to provide services to

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promote business in selected areas. Routers often include a dial-up modem or cable modem and a Wi-Fi AP, set up in homes and other buildings to provide Internet access and networking for the structure.

In 2018, the Wi-Fi Alliance, a non-profit organization that owns the Wi-Fi trademark, began using a user-friendly generation numbering scheme for the publicly used 802.11 standard. Wi-Fi generations 0-6 refer to the 802.11b, 802.11a, 802.11g, 802.11n, 802.11ac and 802.11ax protocols [6,8,9].

Wireless LAN (WLAN) channels are often implemented using protocols from the IEEE 802.11 standard and equipment sold primarily under the Wi-Fi brand name. The radio frequency (RF) spectrum is vital to wireless communications infrastructure.

The 802.11 standard provides several different radio frequency bands for use in Wi-Fi communications: 900 MHz, 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, 5.9 GHz, 6 GHz, and 60 GHz. Each range is divided into multiple channels. In the protocols, channels are numbered 5 MHz apart within a band (except for the 60 GHz band where they are 2.16 GHz apart) and the number is linearly related to the center frequency of the channel. Although the channels are spaced 5 MHz apart and their transmitters are typically at least 20 MHz wide, the protocols allow them to be linked together. Thus, wider ones are formed for higher throughput.

Countries apply their own regulations on allowable channels and maximum power levels in these frequency ranges [7,8,9].

The loaded of access points and analyzing performance of the university wireless network is verified in Wrocław University of Technology [2].

The optimization of the performance of wireless networks that use the 802.11ac wireless networks communication protocol by Markov chains and ant colony optimization models were analyzed [3].

Performance of Wi-Fi network in the cases of fading, flat fading and dispersive fading are discussed [4].

This article presents and discusses the results of measurements made of access point channels to a wireless network in public places where there is a gathering of a large number of people.

II. MATERIALS AND METHODS

The measurements were carried out in the period from 14.11.2022 to 26.11.2022 in the capital of Bulgaria - the city of Sofia with User Equipment (UE) - Samsung S20 fe with the operating system Android 13 using the mobile application Wi-Fi Monitor+ version v1.6.1 pro. [5].

The mobile application has the ability to display advanced information about Wi-Fi accessible networks of different generations and different protocols of the 802.11 standard, monitor the status and channels of the Wi-Fi TD. The information is presented and viewed in different sections: Fig.1, Fig.2 and Fig.3

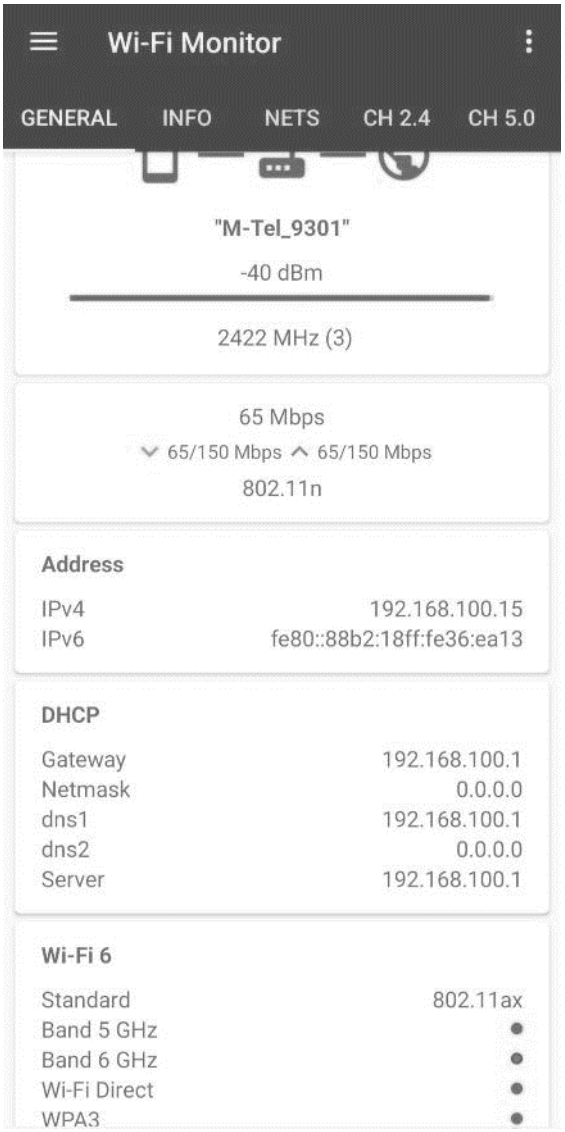

Fig. 1 Section General of application Wi-Fi Monitor +.

The GENERAL section shows the current network to which there is a connection at the moment, its power expressed in decibel-milliwatts (dBm), download and upload link speed, the specific protocol, IPv4 and IPv6 addresses, information about the Dynamic Host Configuration Protocol (DHCP), and the available options for connecting the terminal to different types of Wi-Fi networks.

The INFO section shows the identifier of the connected wireless network (SSID), the IPv4 and IPv6 used, the theoretical maximum data transmission speed between the terminal and the router (Link Speed), the Wi-Fi protocol of the connected network, frequency and connection channel, signal strength, connection level in percentage, DHCP protocol information.

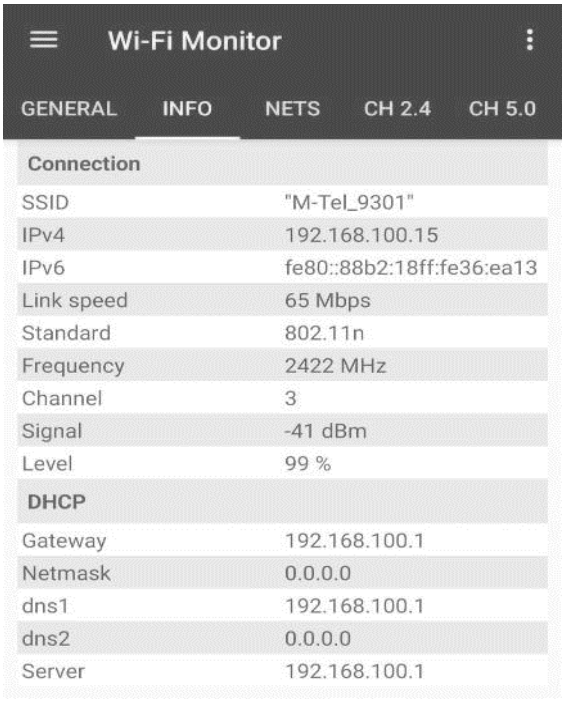

Fig. 2 Section Info of application Wi-Fi Monitor +.

The NETS section shows the available Wi-Fi networks with their identification, unique name, power, channel frequency and its number, channel width, protocol, security protocol used, MAC address of the source-manufacturer and manufacturer name of the router you connect to, if available [5].

Section CH 2.4 shows the available protocols of the 802.11 standard with a frequency of 2.4 GHz.

The CH 5 section shows the available protocols of the 802.11 standard with a frequency of 2.4 GHz.

The different protocols of the IEEE 802.11 standard also mean different generations of Wi-Fi and have different capabilities and speeds. Each of them has a different frequency and channel width of operation. [8,9]

In 2018, the Wi-Fi Alliance began using a standardization-friendly and user-friendly scheme to number the generations of public use networks of 802.11 protocols [7, 8,9].

According to Table 1, with each subsequent generation, the data transfer rate and the frequency used in the network increase. For frequencies of 2.4 GHz, the signal is spread over a greater distance, but the data transmission is at a lower speed. A Wi-Fi network with this frequency has 13 working channels for Europe with a channel width of 20 MHz.

Fig. 3 Section Nets of application Wi-Fi Monitor +.

TABLE 1 WI-FI GENERATIONS

Generation	IEEE Standard	Adopt.	Maximum Linkrate (Mbit/s)	Radio Frequency (GHz)
Wi-Fi 6E	802.11ax	2020	1376 to 46120	6[14]
Wi-Fi 6		2019	574 to 9608	2.4/5
Wi-Fi 5	802.11ac	2014	433 to 6933	5[15]
Wi-Fi 4	802.11n	2008	72 to 600	2.4/5
Wi-Fi 3	802.11g	2003	6 to 54	2.4
Wi-Fi 2	802.11a	1999	6 to 54	5
Wi-Fi 1	802.11b	1999	1 to 11	2.4
Wi-Fi 0	802.11	1997	1 to 2	2.4

It is more susceptible to interference than the network that uses the 5GHz frequency. Built-in networks with an operating frequency of 5 GHz have about twice the link distance of 2.4 GHz. Wi-Fi 5 GHz signals do not propagate as well, compared to a 2.4 GHz network. In addition, 5GHz Wi-Fi has higher speeds and is capable of more working channels - 53 for Europe. In addition, channel widths of 20, 40, 80 and 120 MHz are used and such networks are less susceptible to interference [8,9].

According to the characteristics of the different generations and protocols of the 802.11 standard, it is clear that in order to cover a larger area and provide it with high speeds, more routers and antennas should be used, which are separate or connected in different configurations.

III. RESULTS AND DISCUSION

The research was done in places with different numbers of APs next to Wi-fi networks. Each of them is characterized by the fact that it uses one of the protocols of the 802.11 standard. At the measurement sites, the signal has a certain power, channel width and frequency, according to the specific protocol.

In the study, the results from the different locations are sorted into categories based on the number of APs available and the protocol used to access the network.

Table 2 shows the number of APs at the respective locations for 802.11n (4G), 802.11ac (5G) and 802.11ac (6G). The data is obtained from the NETS section. The first column from table 2 shows the exact address, and the total column the total number of all APs on it.

TABLE 2. NUMBER OF ACCESS POINTS.

Place	802.11n	802.11ac	802.11ax	total
st. Kaufland bul.Totleben	26	3	1	30
st. Kaufland2 bul. Totleben	5	2	52	59
Streetbar&co bul. Vitosha 12	10	4	0	14
bus stop Pirogov	10	4	0	14
st. Billa Hipodruma	31	2	1	34
Bulgarian National Bank	17	19	1	37
bul. Vitosha 1	26	1	1	28
Military Academy "G.S.Rakovski"	10	3	0	13
entranceof National Palace Of Culture	22	35	1	58
bul. Graf Ignatiev 1	30	30	3	63
playground housing estate Zona B-5-3	10	4	0	14
checkout st. Kaufland bul.Totleben 36	4	2	46	52
coffee bar Military hotel Shipka	10	4	0	14
entrance of Ministry of Health	16	28	8	52
entrace of Department of Justice	21	5	5	31
entrance of Ministry of Finance	24	9	3	36
Mall "Mall of Sofia" first floor	12	3	0	15
Mall "Mall of Sofia" second floor	12	3	0	15
Mall "Mall of Sofia" third floor	12	3	0	15
Mall "Serdika" first floor	25	35	14	74
Mall "Serdika" second floor	17	18	2	37
Mall "Serdika" third floor	18	35	9	62
entrance of National theater "Ivan Vazov"	13	3	1	17
entrance of bulding of National Assembly	17	19	1	37
entrance of bulding of Presidency	17	19	1	37
entrance of Ministry of Defence bul. Totleben	11	0	0	11
entrance of University General Hospital "Pirogov"	10	1	0	11
entrance of Military Hotel "Shipka"	16	3	0	19
entrance of Courthhouse Sofia	19	7	0	26
entrance of DSK Bank Sofia	25	11	0	36
wi fi entrance of South Park Sofia	35	12	0	47
lobby of Military Hotel "Shipka"	14	1	0	15
near to Alexander Nevsky monument temple	17	19	1	37
entrance of National Gallery Sofia	28	4	0	32
center of South park Sofia	28	28	0	56

During the measurement period, data was collected on Wi-Fi networks from 35 places where there are often a large number of people. A different number of APs are available at each address. They are characterized by the fact that they offer the possibility of working in a wireless network of a different generation. At each significant location, the number of possible APs was counted. An identifier name was reported for each network. For each address, the received data is displayed and sorted, according to the protocol with which the different APs work. The total number of APs for each location was also received and recorded.

During the research in the city of Sofia, APs were observed next to Wi-Fi networks of three different generations (Wi-Fi 4, Wi-Fi 5 and Wi-Fi 6), operating in the respective protocols with different frequencies.

According to the measurements made and Table 2, 618 results are from the 4th generation wireless access

technology, 379 from the 5th generation and 151 of the obtained results are from the 6th generation Wi-Fi.

In percentage terms, 54% are from the 4th generation, 33% from the 5th and 13% from the 6th generation.

From the research done, it is clear that on average there are 32.8 APs on site, of which 17.7 are from the 4th generation, 10.8 from the 5th generation and 4.3 from the 6th generation of the Wi-Fi standard.

The largest percentage of all results are from 4th generation Wi-Fi. From the averaged results again the largest number are TD to the 802.11n standard or 4th generation protocol.

IV. Conclusions

Access point measurements were made to Wi-Fi networks in 35 places with a large number of people. From the data obtained, the largest percentage falls into the 4th generation (802.11n) category, while the corresponding values for other generations of Wi-Fi are less. From the obtained data, it was established that for one place, on average, nearly 33 APs of different generations of the Wi-Fi standard are available. The findings show that knowledge of the generation and operating frequencies of APs is important for accurate estimates of RF EMF exposure from mobile network equipment.

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