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Analysis of Home Wi-Fi Internet Access Networks Situation in Vilnius City

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Introduction

During past years usage of wireless communications was increasing rapidly not only in commercial areas but also in private households. According to IHIS iSupply research [1], only during 2010 year more than 360 million standalone Wi-Fi units were shipped, and it is a 135 % increase from 2009 year. During the next year the Wi-Fi chip-sets shipment should exceed 1 billion units [1]. This caused the noticeable increase of Wi-Fi access availability and usage in a private sector. Also, during past years it became as a norm that the customer-premises equipment (CPE) supplied for customer by Internet service provider (ISP) is equipped with Wi-Fi, and is extensively used to access the Internet from laptops or other mobile devices.

With increasing number of wireless devices like laptops, Wi-Fi Web Cams, network extenders, etc., a new kind of problems appeared to network administrators and call centers of ISP. These new problems are related to users complains about poor Wi-Fi throughput or communication problems between Wi-Fi client device and Wi-Fi access point (AP) The problems mostly arise in urban areas with overloaded Wi-Fi environment [2].

In this paper an investigation on Wi-Fi networks and it's saturation in Vilnius City and its surrounding is presented, covering the main problems of wireless saturation and network load.

In the first part of the paper, a closer look into Vilnius city Wi-Fi network environment will be done to analyze the Wi-Fi network situation, load, users activities and habits during 16 days monitoring period. Afterwards, main problems that influent performance of Wi-Fi networks will be stated and their solutions will be discussed. Finally short investigation on wireless saturation and its situation in Vilnius city and its surroundings will be done.

Related works

During last ten years a large number of studies and analyzes on IEEE 802.11 wireless communications and saturations were done [2–7]. Most of them were focused on characterization how the IEEE 802.11 radio itself behaves, in terms of the error models and signal characteristics in different environments [7]. Other investigations are concentrated on large Wi-Fi installations, in campus or office buildings [3, 5, 7]. In most of the studies the main problem was considered to be a large number of Wi-Fi clients, which were connected to one or few Wi-Fi AP and generate a large load [2, 4].

In other type of investigations some models were proposed for wireless traffic utilization using modeling tools like ns-2 or Opnet [7], which allowed of simulating more distinctive environments, but without accounting the real client habits and activities.

It is need to mention that some studies were made to understand the client activities [4, 5] and habit's, but in most cases the data collection were made in public places of campus networks, such as conferences, with specific type of clients.

So, in order to better understand the Wi-Fi networks situation in Vilnius city and also to find out habits of Wi-Fi clients, an investigation on home Wi-Fi networks situation and their users activities was performed.

Data collection

In order to find out the situation of Wi-Fi networks environment in Vilnius city and its surroundings the monitoring system was developed. The system periodically, during 16 days, from 11th until 27th of January, 2011, collected statistical and client activity information from 39 940 number of Wi-Fi AP. Data collection automation was made by TCL scripts that periodically downloaded the statistical data about connected Wi-Fi client, wireless networks saturation and used wireless channel from Wi-Fi APs. If the particular device at the request moment was not available (down) or request timeout was triggered, the script moved further in

the device list. During monitoring period more than 1.1 million unique data records were collected.

The main and most important difference of obtained statistical data from research described in [3, 4] is that the information source was not one specific network, but a large set of different private Wi-Fi networks. Differently from public hot spots or corporative networks, private householders' Wi-Fi networks were used not only during work hours, but also even during night and weekends.

Within the data collection time it was found some hardware limitation regarding the Wi-Fi AP devices. The counters of some specific parameters (send, received frames count, byte count and lost, retransmitted frame count) have limited length, after reaching the limit they resets. This hardware limitation can be overcome be increasing the device scanning frequency during monitoring period.

So, during monitoring period the data representing the Wi-Fi network situation (client count, working channel, and wireless saturation) in Vilnius city and its surroundings was collected and analyzed.

Wireless Networks Situation

For the first investigation a time function of average successive measurement during the day was made in order to find out the average deviation of measurements throughout the day, because of most of monitored Wi-Fi AP are installed in private householders and could be turned off during the night or working hours.

From the obtained results we can state that the difference between the maximum and minimum amount of measurements does not exceed 20 % of total average 3000 measurements. Based on this it can be stated that the deviation of measurements (number of active AP around and Wi-Fi clients count) was not heavily impacted by changing number of monitored devices during monitoring period. In addition, it is clear that most of the clients don't turn off home network equipment during the night or working hours.

Further, in order to find more about clients' activity and habits of Wi-Fi usage throughout the day, the monitoring script logged all clients', who were associated to specific monitored Wi-Fi AP. By filtering obtained results based on MAC, which is unique to all network equipment, it was found out that 39 421 unique devices were seen. In average it is one client on every monitored Wi-Fi AP. In addition, a time graph of average number of connected clients during the day was made (Fig. 1).

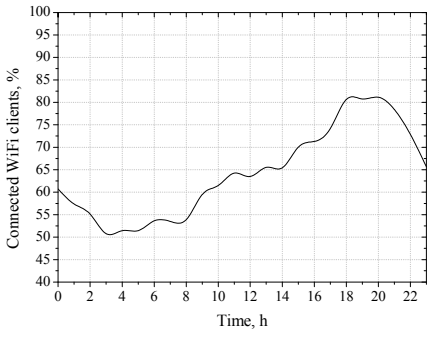

Fig. 1. Average number of connected client during the day

From results shown in Fig. 1 it can be seen that most of the clients start using Wi-Fi access at 8 AM and this number rapidly increases until 12 PM. At dinnertime settling of client growth until 2 PM is seen. After that the number of active clients starts increasing again, and the maximum saturation of the Wi-Fi network (80 %) is reach at 6 PM–8 PM. Afterwards it starts to decrease until 3 AM, where the minimum number of connected Wi-Fi clients (50 %) is reached. The difference between the maximum and minimal number of Wi-Fi client during the day is approximately 30 %, and its also proves that most of the clients are not used to turn off there Wi-Fi devices at nighttime or working hours.

Further more detailed investigation of per day analysis of associated clients was made. It is seen that at 12 PM and 5 PM a degradation of number of active clients is observed. It can be seen in the Fig. 2, where two-day activity of associated Wi-Fi clients is shown.

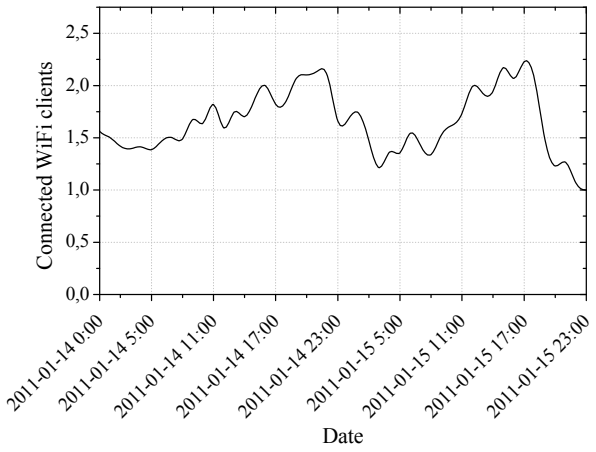

Fig. 2. Number of connected Wi-Fi clients from 14th until 15th of January 2011

It can be explained that some of clients are used to take mobile Wi-Fi devices (Smartphone, notebooks) out with them thus reduce the associated Wi-Fi AP clients' count.

Wireless Radio Saturation

During the past five years the number of network devices working in 2.4 GHz frequency range was increasing rapidly. This is mostly observed in heavily saturated areas, like business centers or blockhouse. In order to perform stable and efficient wireless equipment must work in free, non-overlapping Wi-Fi channels. However, one of the biggest disadvantage of IEEE 802.11 b/g/n standard is that there is only three (1, 6, 11) no overlapping channels considered.

Further we will investigate the Wi-Fi networks saturation in Vilnius city to show current situation and try to depict possible problematic areas due to overloaded Wi-Fi environment. For this a periodical "active" Wi-Fi scan (Broadcast request) was performed every time the TCL script connected to Wi-Fi AP. An Active scanning mode was preferred instead the passive (by monitoring every channel for specific time), because of shorter data collection time, and not effecting connected Wi-Fi clients

Fig. 3 represents the average number of active Wi-Fi AP devices during the day hours. It is observed that deviation of active Wi-Fi AP during the day is low (approximately of 20 %), and this value is weakly related to measurement count during the time. It is need to note that by using active scanning mode some neighboring Wi-Fi AP are not seen if the Wi-Fi AP is very busy (loaded) or working in invisible (hidden) mode. So the actual number of active Wi-Fi AP could be bigger.

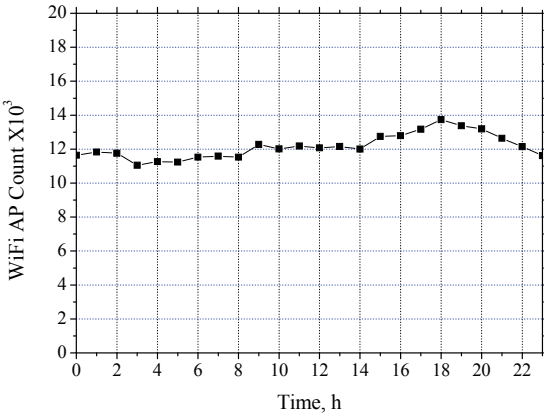

Fig. 3. Average number of active Wi-Fi clients during day

Again, by filtering obtained results based on Basic Service Set Identification (BSSID), the total number of 79 096 unique Wi-Fi AP were found, in average every monitored device could see two additional Wi-Fi AP in its surrounding.

Fig. 4 represents the worst-case scenario of wireless environment; this is a reflection of Wi-Fi networks saturation in peak hours, from 6 PM to 8 PM.

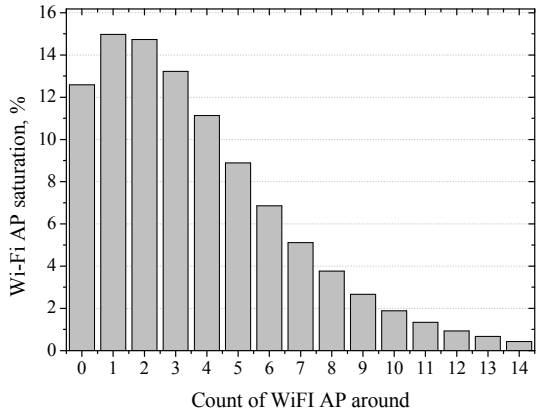

Fig. 4. Histogram of Wi-Fi AP saturation based on seen around AP count

As it can be seen in Fig. 4, the Wi-Fi network saturation is were high, and more than 87 % presents of the Wi-Fi AP can see 3 or more Wi-Fi devices around them. Of course, in some cases this number can be bigger because we monitored not only in Vilnius city but also in its surrounding, where likely network saturation is much lower.

Since most of monitored home environments to have only one hot spot with a single-AP service set, i.e. there are no Extended service sets (ESS), it's performance and reliability is mostly depended from working channel condition that is influenced by near AP density and network load. In order to clarify the relation between wireless saturation and working channels an investigation on AP channel selection mechanisms was performed.

From collected data a channel usage histogram was made (Fig. 5). As it was expected most of the Wi-Fi AP were using non-overlapping the 1, 6 or the 11th channels, and the usage probability was almost equal. This indicates that most of the clients use the default Wi-Fi settings and don't change the working channel (using auto mode).

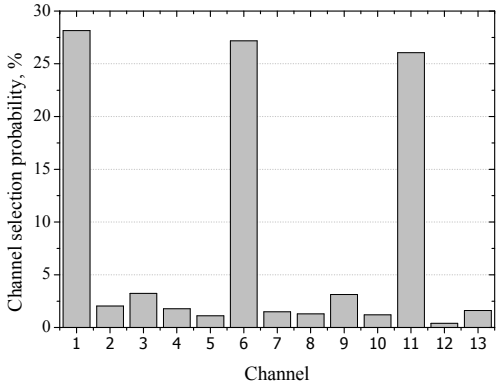

Fig. 5. Wi-Fi channel resource histogram

By performing more detail analysis, a dependence of channel (1, 6 and 11th channels) selection probability based on AP count was made (Fig. 6). This shows how dynamic channel selection algorithm is depending from APs count in near surrounding.

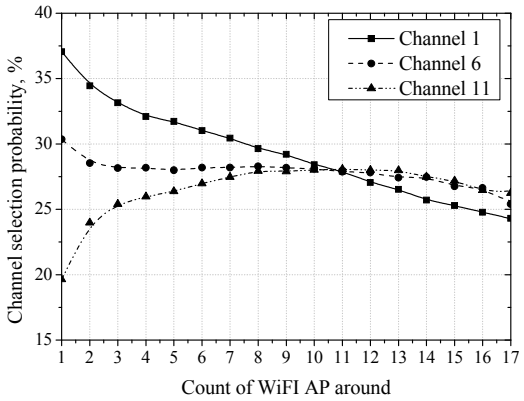

Fig. 6. Channel selection probability based on AP count

With lower AP count, the channel selection algorithms don't work as good as expected and a bigger probability that lower Wi-Fi channels (1–37 % or 6–30 %) will be used. When AP count increases the channel selection probability equilibrates and even start going to opposite way.

These results are not directly related to channel selection algorithms working badly, but indicate that some of Wi-Fi AP devices have some problems with proper channel allocation.

With increasing number of Wi-Fi AP seen around most channels probably will overlap, by leading to higher noise floor and smaller SNR level. In our investigations it showing a noticeable noise level increase in heavy saturated environments of approximately 6 dBm.

By performing per day analysis, the noise level was monitored during the daytime (Fig. 7) with different number of Wi-Fi AP seen around. The obtained results were similar to wireless saturation monitoring results (Fig. 3), where the most saturated environment was seen from 6 PM to 8 PM, with noise level increase of 0.4–1 dBm compared with 4 AM in the nighttime.

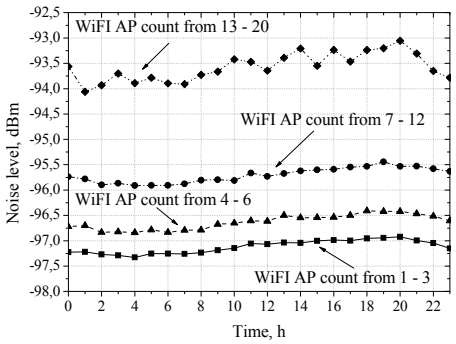

Fig. 7. Wi-Fi channel noise level during the daytime

Due to rare information gathering period and low measurements count, some results are slightly deviating, what is seen in Fig. 7, with Wi-Fi AP count from 13 – 20.

Results and conclusions

In this paper an investigation on residential Wi-Fi networks in Vilnius city and its surroundings was presented. The research was made using data collected from more when 39 000 unique Wi-Fi AP located all around the Vilnius city.

From obtained results the conclusions were drawn:

- By analyzing Wi-Fi users habits and activities it is seen that Wi-Fi access is very popular and frequently used not only during the day but also the nighttime. During the monitoring period was found that clients were most active during 6 PM – 8 PM, in average 80 % of all Wi-Fi clients. The minimum number of connected Wi-Fi clients where noticed at 3 AM (in average 50 %of all Wi-Fi clients).
- The investigation on Wi-Fi network saturation in Vilnius city showed that Wi-Fi network saturation is high, and in peak hours it reaches 87 % of the all Wi-Fi clients that can see 3 or more Wi-Fi hot spots.
- With increase of number of Wi-Fi AP seen around the noise level could increase up to 6 dBm, and in the peak hours from 6 PM to 8 PM the noise is 0.4–1 dBm higher compared minimum at 4 AM.
- More detail analysis shows that most of seen Wi-Fi AP use automatic channel selection mechanism, which in less saturated environments, don't work as expected. Lower Wi-Fi channels (1 – 37 % and 6 – 30 %) tend to be selected by Wi-Fi AP.
- The fact that IEEE 802.11 n can work in dual band mode, and the growth of that standard supporting Wi-Fi AP will tend to have a bad impact on performance of Wi-Fi networks due to heavy its saturation in near future.

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During recent years usage of Wi-Fi communications were increasing rapidly not only in commercial areas but also in private households. With increasing number of Wi-Fi devices a new kind of problems appeared, mostly related to poor Wi-Fi throughput or communication problems. In this paper an investigation on Wi-Fi networks in Vilnius City and it's surrounding is presented, covering the main problems of Wi-Fi network saturation and load during day. Also an investigation on dependence of Wi-Fi saturation on noise levels was made, showing the impact of neighbor AP to SNR. Ill. 7, bibl. 7 (in English; abstracts in English and Lithuanian).

A. Statkus, S. Paulikas. Belaidžio kanalo parametrų įtaka transliuojamai vaizdo kokybei // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 2(118). – P. 77–80.

Sparčiai populiarėjant bevielio ryšio sistemoms ir didėjant duomenų perdavimo kiekiams, vis dažniau bevielis ryšys yra naudojamas kaip vienas iš pagrindinių apsikeitimo duomenimis būdų ne tik įmonėse ar komerciniuose tinkluose, bet ir privačių klientų segmente. Didėjant klientų ir įrangos skaičiui, kuris, kaip manoma 2012 metais viršys 1 mlrd., vis sunkiau užtikrinti kokybišką ir patikimą ryšį bei įrenginių tarpusavio suderinamumą. Šiame straipsnyje aprašytas Vilniaus miesto ir jo apylinkių bevielių tinklų tyrimas, išnagrinėtos tinklo tankumo ir saugumo problemos, atlikta tinklo dienos apkrovos analizė. Tai pat, remiantis tyrimo metu surinktais statiniais duomenimis, atlikta signalo ir triukšmo lygių priklausomybės nuo aplinkinių bevielių AP skaičiaus ir jo kitimo per dieną analizė. Il. 7, bibl. 7 (anglų kalba; santraukos anglų ir lietuvių k.).