International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:7, No:2, 2013

Analysis of Wi-Fi Access Networks Situation in the City Area

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***Abstract*—**With increasing number of wireless devices like laptops, Wi-Fi Web Cams, network extenders, etc., a new kind of problems appeared, mostly related to poor Wi-Fi throughput or communication problems. In this paper an investigation on wireless networks and it's saturation in Vilnius City and its surrounding is presented, covering the main problems of wireless saturation and network load during day. Also an investigation on wireless channel selection and noise levels were made, showing the impact of neighbor AP to signal and noise levels and how it changes during the day.

***Keywords*—**IEEE 802.11b/g/n, wireless saturation, client activity, channel selection.

I. 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 when 360 million standalone Wi-Fi units were shipped, and it is a 135 % increase from 2009 year. During 2012 the Wi-Fi chip-sets shipment should exceed 1 billion units. 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, 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 wireless access point (AP) The problems mostly arise in urban areas with overloaded Wi-Fi environment [2], [3].

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

In the first part of the paper, a closer look into Vilnius city Wi-Fi network environment will be done to show the Wi-Fi network situation, load, users activities and habits during 16 days monitoring period. Afterwards, main problems that influents performance of Wi-Fi networks will be stated and their solutions will be discussed.

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II. Related Works

During last ten years a large number of studies and analyzes on IEEE 802.11 wireless communications and saturations were done [2]–[10]. 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 [3], [7]. Other investigations are concentrated on large Wi-Fi installations, in campus or office buildings [4]–[6],[9]. 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 big load [2]–[3], [5].

In other type of investigations some models were proposed for Wireless traffic utilization using modeling tools like ns-2 or Opnet [10], [11], which allowed of simulating more distinctive environments, but without accounting the real client habits and activities.

It is need to mention that in some studies were made to understand the client activities [4]–[6], [12] 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 wireless network situation in Vilnius city and also to find out habits of Wi-Fi clients, an investigation on home wireless networks situation and their user's activities was performed.

III. 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 (Fig. 1). The system periodically, during 16 days, from 11th until 27th of January, 2012, collected statistical and client activity information from 39940 number of Wi-Fi AP. Data collection automation was made by TCL scripts that periodically connected to wireless AP to request and download the statistical data. 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 [4]–[6] 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' wireless networks were used not only during work hours, but also at evening and weekends.

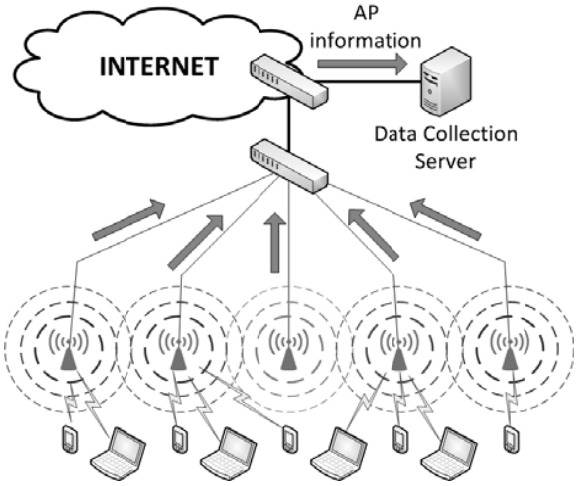

Fig. 1 Structure of wireless monitoring system

During the information collection TCL script gathered information about connected Wi-Fi client, wireless networks saturation and used wireless channel.

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 number and lost or 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.

IV. Measurements Results and their Analysis

After the data collection was done, the primary analysis and filtering were made using Python scripts. The obtained results were imported to MySQL database for future examination.

A. Wireless Networks Situation

For the first investigation a time function of average successive measurement during the day was made, (Fig. 2). It was done to know the average deviation of measurements throughout the day, because most of monitored Wi-Fi AP are installed in private householders and could be turned off during at night or working hours.

From the obtained results it can be seen that the difference between the maximum and minimum amount of measurements does not exceed 20 %. Based on this it can be stated that the deviation of measurements (number of active AP around and wireless client 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.

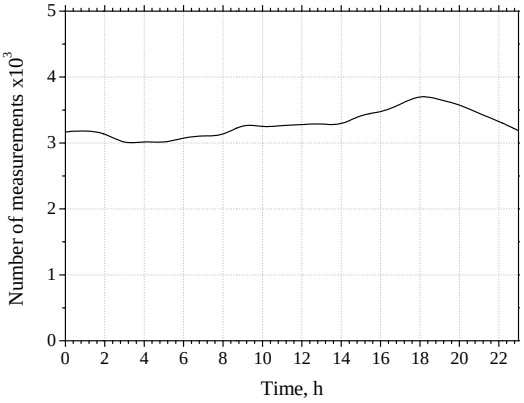

Fig. 2 Average measurement count during the day

Further, in order to find more about client 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 39421 unique devices were seen. In average it is one client on every monitored Wi-Fi AP.In addition, a time graph of connected clients during the day was made and presented in Fig. 3.

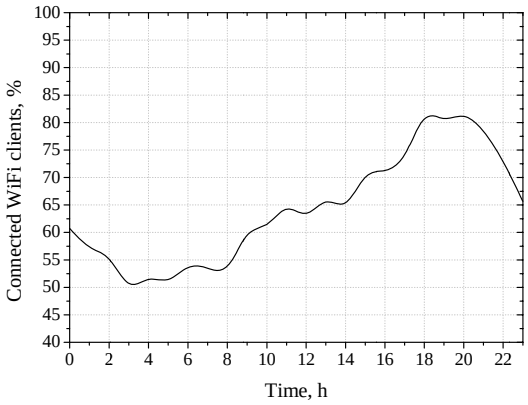

Fig. 3 Average number of connected client during the day

From results shown in Fig. 3 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. After wards 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 quite small, approximately 30 %, and its only shows that most of the clients are not used to turn off their wireless devices at night time or working hours.

Further more detailed investigation of per day analysis of associated client showed that at 12 PM and 5 PM a small degradation of number of active clients is observed.

It can be explained that some of clients are used to take mobile wireless devices (smart phone, tablets,and notebooks) out with them thus reduce the associated Wi-Fi AP client count.

In order to find out what vendor equipment the Wi-Fi clients are mostly using, an analysis of obtained MAC addresses was made. It was done by comparing the first six characters of MAC address, which represents the device manufacture, with IEEE vendor database in Internet. The obtained results are show in Table I.

TABLE I
MOST POPULAR VENDOR DEVICES SEEN ON WIRELESS AP

VENDOR	COUNT	PERCENT
INTEL CORPORATION	10360	26,3
HON HAI PRECISION IND CO LTD	6622	16,8
AZUREWAVE TECHNOLOGIES INC	3870	9,8
APPLE COMPUTER INC	3832	9,7
GEMTEK TECHNOLOGY CO LTD	2922	7,4
LITE-ON COMMUNICATIONS INC	2363	6,0
ASKEY COMPUTER CORP	1490	3,8
NOKIA DANMARK A/S	1086	2,8
D-LINK CORPORATION	936	2,4
HTC CORPORATION	704	1,8
Other manufactures	5236	13,3

B. 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 wireless channel. 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.

To investigate the wireless network saturation in Vilnius city, show current situation and try to detect possible problematic areas due to overloaded wireless environment.

For this a periodical “active” wireless scan (Broadcast request) was performed every time the TCL script connected to wireless AP. An Active scanning mode was preferred instead the passive, because of shorter data collection time, and not effecting connected Wi-Fi clients

Fig. 4 represents the average number of active Wi-Fi AP devices during the day hours. It is observed that deviation of active wireless AP during the day is very 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 wireless AP are not seen if the wireless AP is very busy (loaded) or working in invisible (hidden) mode. So the actual number of active wireless AP could be bigger.

Again, by filtering obtained results based on Basic Service Set Identification (BSSID), the total number of 79096 unique wireless AP were found, in average every monitored device could see two additional Wi-Fi AP in its surrounding.

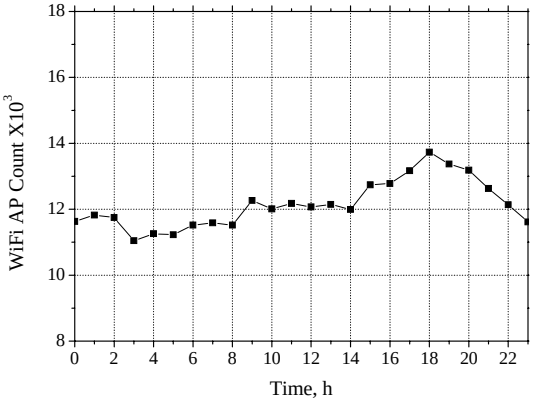

Fig. 4. Average number of wireless client during the day

Fig. 5 represents the worst case scenario of wireless environment; this is a reflection of Wireless network saturation in peak hours, from 6 PM to 8 PM.

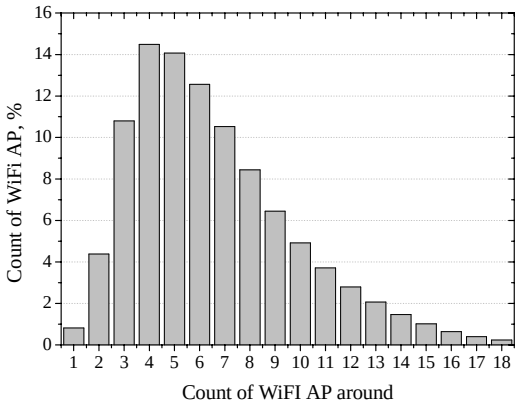

Fig. 5 Histogram of Wi-Fi AP saturation

As it can be seen in Fig. 5, the wireless network saturation is were high, and more than 80 % presents of the wireless AP can see 3 or more wireless devices around them. Of course, in some cases this number can be bigger because we monitored not only Vilnius city but also its surrounding, where 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), its performance and reliability is mostly depended from working channel condition that is influenced by near AP density and net-work load. In order to clarify the relation between wireless saturation and working channels an investigation on AP channel selection mechanisms was performed.

As it was expected most of the wireless AP were using non-overlapping channels (1, 6 or 11), and the average usage probability was almost equal. This indicates what most of the clients use the default wireless settings and don’t change the working channel (using auto mode).

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.

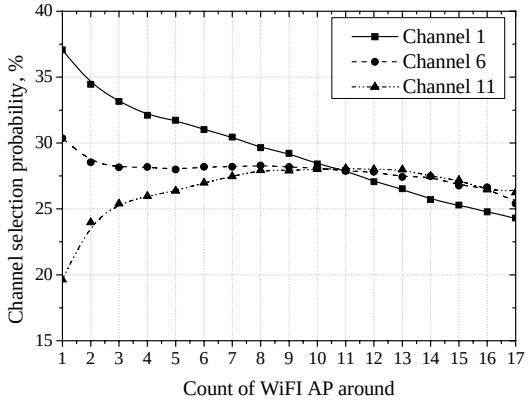

Fig. 6 Channel selection probability based on AP count

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 but when AP count increases the channel selection probability becomes almost equal.

With increasing number of Wi-Fi AP seen around most channels probably will overlap, by leading to higher noise floor and smaller SN level. In Fig. 7 the dependence between the noise floor and Wi-Fi count is represented, showing a noticeable noise level increase in heavy saturated environments of approximately 6dBm.

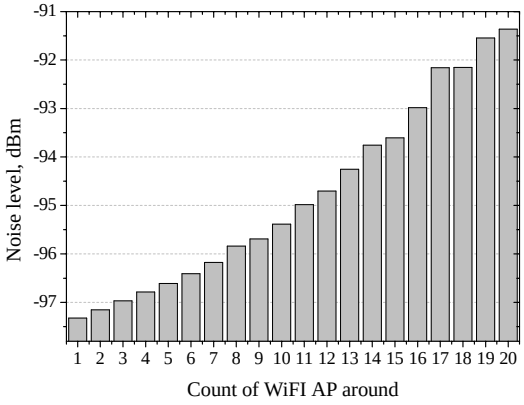

Fig. 7 Wireless noise level histogram

V. Result 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 39000 unique Wi-Fi AP located all around the Vilnius city. From obtained results the following conclusions were drawn:

1) By analyzing Wi-Fi user's habits and activities it is seen that wireless access is very popular and frequently used not only during the day but also the nighttime. During the monitoring period 39421 unique wireless clients were analyzed and were found that they 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).
2) The research on Wi-Fi device vendors shows that the smart phone count is increasing rapidly, covering approximately 14 % of all seen Wi-Fi devices.
3) The investigation on Wi-Fi network saturation in Vilnius city showed that wireless network saturation is were high, and in peak hours it reaches 87 % of the all wireless clients that can see 3 or more Wi-Fi hot spots.
4) With increase 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 some cases, especially 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.

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