Buletinul Ştiinţific al Universităţii Politehnica Timişoara

TRANSACTIONS on ELECTRONICS and COMMUNICATIONS

Volume 60(74), Issue 1, 2015

The study of radio coverage and service quality of a Campus-Wide Wireless Network

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Abstract – The appearance and development of mobile equipment led to a growth in the usage of Wi-Fi networks. At present, in order to access the Internet, the most used networks are the ones based on the IEEE 802.11 standard. These networks were conceived to service a limited number of customers with a symmetric traffic for uplink and downlink and concurrently with a limited coverage area dependent by the access point (AP) radio transmission power. The herein paper describes the tools and the steps followed to increase the radio coverage and to improve the quality of the services provided by a campus network made of 200 interior and exterior Wi-Fi hot-spots managed by one Alcatel-Lucent OmniAccess dedicated controller.

Keywords: Wi-Fi networks, radio analysis, radio coverage, optimization, QoS, radio map

I. INTRODUCTION

The contemporary society is more and more based on mobile equipment and wireless communication allowing mobile users to access information anywhere, anytime in a timely and cost-effective ways. According to ITU statistics the number of mobile (cellular) subscriptions worldwide at the end of 2014 is more than 6.95 billion, close to the size of worldwide population [1]. Smartphone ownership in developed markets surpassed featured phones ownership in 2013 [2]. Smartphone penetration rate on developing markets follows also and increasing trend [2]. It seems that in every aspect of our live, the ability to communicate becomes more and more important, with people using mobile terminals on a daily basis for phone calls, email, to access the Internet and applications of social networks. For most employees, the phone or the tablet has become a compulsory instrument that accompanies them everywhere, including at their workplace [3].

The term "Wi-Fi" refers to local wireless networks which use the specifications of the IEEE 802.11 standard versions. A new version of the IEEE 802.11 family of standards, IEEE 802.11ac, has recently been defined with the promise of delivering significant increases in bandwidth while improving the overall reliability of a wireless connection [3]. The main goal of this standard is to provide wireless data rates compared to common wired LAN infrastructures, over 1 Gbps bandwidth. Wi-Fi networks are used in schools, campuses, companies and homes, as an alternative to LAN wired networks. Usually, hotels, cafes, airports and, generally, public places offer public access to Internet by Wi-Fi, these locations being called "hotspots" [4]. Despite their spread, wireless networks are still lacking the performance and quality of wired networks. The recognized problems of WLAN still remain the radio coverage and variable transfer rates, both resulting in poor quality of services.

The present paper represents a starting point in the improving of the radio coverage capacity, as well as in the quality of the services provided by EduRoam network of the Politehnica University of Timisoara. The first step in the making of this project was finding the software and hardware instruments, needed for determining the present state of functioning of the network and its evaluation from the point of view of the radio coverage and transfer rates. The second step was generating a radio coverage map by using dedicated software for measuring the radio signal power strength of the AP's. The measuring was made within the premises of the campus, inside the main university buildings and outdoor, in the nearby park. The next step implied the correlation of the radio coverage with the transmission rates of the AP's in different locations, beginning with the area with the best signal quality and ending with the area with worst signal quality, within the measured areas. The last aspect of this study is the interpretation of the results and the offer of a solution based on coverage, quality and cost for a maximum exploitation of the network.

The following sections will cover a part of the most important scientific contributions to this subject.

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Section II provides the description of previous related work on radio signal mapping and wireless optimization. Section III presents the existing environment under analysis. Section IV describes the methodology used to do the analysis and monitoring. The results and optimizing recommendations are presented in section V. The last section concludes the paper

II. RELATED WORKS

Up to this time there have been carried out several studies on the analysis and optimization of Wi-Fi networks, studies based on generating coverage radio maps that use RSSI (received signal strength indicator) or analysis of the traffic generated by users (number of customers, type of data, broadband). [5][6]

The study conducted by Pechac, Klepal and Martinez led to an optimization algorithm based on evolution strategies, being implemented in a web application of planning radio resources. The algorithm allows automatic projection of some wireless LAN heterogeneous models with a minimum of data gathered on field [7]. The authors use the Architect/One software for planning WLAN network and APs placing for the optimal layout and quantity to achieve the required network parameters. This method is used before WLAN implementation providing no monitoring support for network parameters' validation at runtime.

Connelly, Liu, Bulwinkle, Miller and Bobbit produced a set of tools for automatic generation of radio maps outside the buildings. The set of tools could collect data with the help of the personnel of the campus or the security of the campus during their normal work (the set being put in a simple backpack). The collected data were integrated in a merging algorithm in order to obtain a complete image, used afterwards as a radio map [8]. The achieved radio maps, based on RSSI interpolation, are used to implement an outdoor wireless positioning system, but no optimization decision are taken.

Kotz and Essein studied in 2001 the wireless network of a campus, year in which it was implemented [5]. Henderson, Kotz and Abyzov came back to the campus network when it reached maturity in 2003-2004 [9]. Another example of university whose wireless network was studied was North Carolina University [10]. These studies are very important for those who develop, deploy and manage WLAN infrastructure, as well as those who develop applications for wireless networks. However, these studies consider nomadic computing traffic coming from laptop users. Similar studies are therefore needed for more recent kind of traffic, those who is coming from mobile users.

Guillet assembled a typical environment of home network in order to evaluate and optimize the design of Wi-Fi antennas for residential gateways. His paper describes the measuring process and the illustration of the interactions between different antennas and their working environment [11]. The examples provided illustrating the interactions of WiFi antennas of monitoring equipment with indoor multipath channel have been used to establish the measurement approach and its implementation.

A large scale WLAN monitoring system deployed at Dartmouth College, covering 210 campus locations and 5000 users, is presented in [6]. In this paper the authors describe the monitoring approach, designs and solutions addressing the technical challenges that have resulted from efficiency, scalability, security, and management perspectives of the campus WLAN network. The proposed WiFi monitoring system is made of three components: (1) a high-performance sniffing system, (2) an online network trace sanitization and distribution system, and (3) a tool for configuring, launching, monitoring, and terminating an experiment. The main goal of our work is similar to the monitoring system presented in [6]. However, first measurements and deployment radio and transfer rates were achieved manually.

Similar studies have been carried on in diverse home environments. The authors of [12] present a measurement study of wireless experience in such environments by deploying an infrastructure composed of OpenWRT based APs. They are configured with a dedicated measurement and monitoring software that communicates with a measurement controller through an open API.

Although in the field of research, the subject of Wi-Fi is popular, there are few studies on the area of analysis of radio coverage. This is why with this paper we will bring a contribution to this field by exemplifying the methods that can be used for analyzing and optimizing a wireless network, the work tools used and, also, our conclusions and recommendations in Wi-Fi optimization with direct application on the campus network under study.

III. WORKING ENVIROMENT

The UPT network EduRoam was developed with the purpose of improving the Internet communication infrastructure within an extensive project of cooperation between the Politehnica University of Timisoara and Debrecen University. The project implied installing 200 specific equipment (Access Points) for Wi-Fi communications, connected to a monitoring and managing equipment called controller (Fig. 1). The AP's assure coverage for the faculty buildings, as well as for the University dormitories. Coverage inside and outside the buildings was assured. In the interior, the communal spaces have been mostly considered (halls, corridors, study rooms), and in the exterior the coverage of parks and alleys around the building has been deployed.

OmniAccess APs are produced by the Alcatel-Lucent and operate exclusively with OAW 6000 WLAN controller to provide network access to wireless customers. The equipment support IEEE

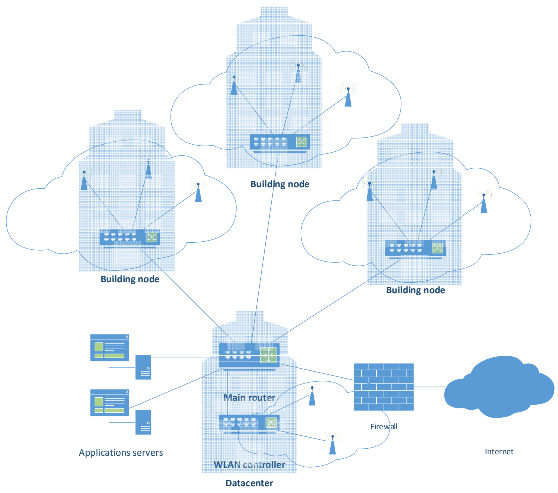

Fig. 1 Controller managed wireless network

802.11a/b/g/n standards for wireless systems and adaptive radio management (ARM). ARM is a radio frequency resource allocation algorithm enabling each AP to select the optimum radio channel and transmission power setting to minimize interference and maximize coverage and throughput. The AP's have the capacity of radio adaptation to surrounding interferences, increasing or decreasing their transmitting power as appropriate and switching channels based on the level of engagement of the channel. The APs scan for better channels at periodic intervals and report information to the WLAN controller to set-up the APs' configuration parameters [13].

The WLAN controller is the central equipment which manages the configurations of the APs and, at the same time, functions as a switch for wireless traffic. The controller is an equipment of enterprise class which functions as a connection between the traffic of wireless customers from/ to traditional wired networks. It has many functions, such as:

- The management of the entire wireless network is concentrated to a single point
- It behaves as a firewall between the cabled part and the wireless part of the network
- VPN connectivity
- Mechanism of detection and prevention of intrusions
- Central handover mechanism
- Analysis and monitoring of the radio spectrum

The authentication of users to the UPT network EduRoam is based on a user name and a password (e-mail account of students) by an AAA server (Authentication, Authorization and Accounting) using Active Directory services and Radius protocol.

Starting with the existing specifications and the capabilities of the previously presented network, we decided to carry out an extensive radio analysis of the coverage area and the data transfer speed rates which will be described in the following section.

IV. MEASUREMENT METHODOLOGY

In the making of this study, we tried to gather as much information as possible about the way the Wi-Fi network EduRoam functions, its specifications, as well as the exact positioning of the APs. In the measurement process we identify every AP by name (configured in the WLAN controller), MAC address (hardwired), IPv4 address (allocated statically by the controller) and location. At each testing location there are several APs to be take in consideration.

The next step was finding a way of measuring (quantifying) the coverage area beginning from using the Chanalyzer software, together with the hard equipment Wi-Spy DBx [14]. The results obtained after processing were not used in the making of the radio map, because, physically, the location of the measurements could not be determined.

After a thorough documentation we used two software applications, the purpose of this choice being checking the accuracy of the measurements data. In the first app, called Ekahau Heat Mapper, a plan of the area or the building where the measurements will take place is necessary. The software generates a radio map by repeated measurements of the signal power in different points, in the end being capable to recognize the surrounding AP's, as well as their coverage [15].

The second tool used, Wi-Fi Speed Test offers information on the quality of the radio connection from the point of view of the transfer speed to and from the user. A notebook featuring two network interfaces (one internal and one external connected to USB port) have been used to measure and monitor the radio interface and transfer rates, respectively.

Once established the measuring instruments, we decided to choose two relevant areas in which to make the preliminary analysis, more precisely the 4th floor of building B and the 3rd floor of building A due to their specific constraints and problems occurred: (1) building B has many small laboratories and separating walls and (2) building A long corridor with variable transfer rates and often disconnections in some locations because of ARM. We began our analysis by carrying out repeated measurements at the same floor in order to test two aspects:

- the first step was confirming the hypothesis that says: the more the distance between the sampled points increases, the more the results are more inaccurate;
- the second step was about modifying the emission strength of the AP's when these are in each other's proximity.

After carrying out the measurements and generating multiple radio maps in the specified locations, we passed to the stage of wanting to know the upload/download speed in different locations. We began from the most concentrated areas in which the radio signal had the highest values and went to the periphery of the coverage area of the AP's in order to see how the degrading of the radio signal influences the data transmission speed in the network.

At the end of the process of measuring and testing of the UPT network EduRoam, we gathered several results about coverage and transmission speed, results which are presented in the next sections.

V. RESULTS AND OPTIMIZATION RECOMMENDATION

We collected a large amount of data and we extended our research to several buildings over the course of six weeks, but the herein paper will present only a small amount of what we considered relevant.

At the 4th floor of the building B we carried out four repeated tests to know if the number of samples influences the way in which the radio coverage is disposed. After the measurements, we arrived at the conclusion that an increased sampling is necessary (it is necessary we take into account as many points of the building as possible) in order to obtain precise results, as it can be observed in Fig. 2 and 3.

At the same time, to confirm the credibility of the results, we decided to increase the measuring area.

Therefore, besides the communal spaces from the 4th floor, we extended our measurements to the laboratories at the same floor in order to consider the separating walls (Fig. 4). As it can be seen, there is no significant change in the radio coverage, which led us to believe that it is sufficient to follow a measuring track only in the communal spaces and Ekahau Heat Mapper will generate a radio assessment extended to laboratories and class rooms. However, this assumption is true only for the case of building B due to the internal walls surrounding the main lobby where the APs have been installed.

Once the 4th floor radio map was realized for one active AP, we activated the APs in the neighborhood. The APs nearby have been turned off to observe the signal strength of one single radio equipment. In the second scenario we analyze how nearby APs could influence each other. Cumulative radio map of APs belonging to our network which emits in that area is presented in Fig. 5. Analyzing the radio coverage map we confirm the zones of B building (labs at every floor) that do not have WLAN access – labs in the left and bottom right. Furthermore, foreign an unofficial hotspots interfering the EduRoam ones are identified. These APs limit the radio coverage of our APs overcrowding the radio spectrum in the area.

The next step was monitoring the transmission speed in the coverage area of the AP in the same time. The speeds were of minimum 4.35 Mbit/s and maximum 12.7 Mbit/s, as it can be seen in Fig. 6. Transfer rates are decreasing with the received radio signal strength of the APs.

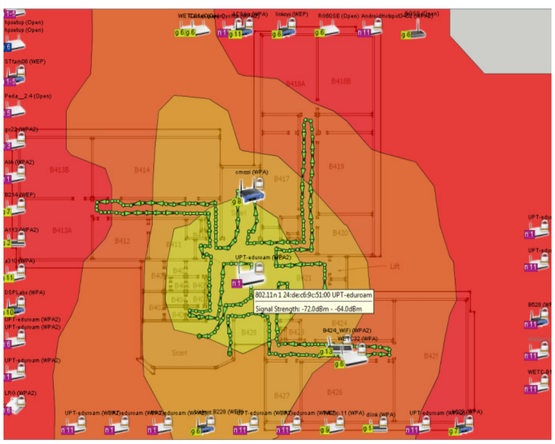

Fig. 2 Radio coverage with a reduced number of samples

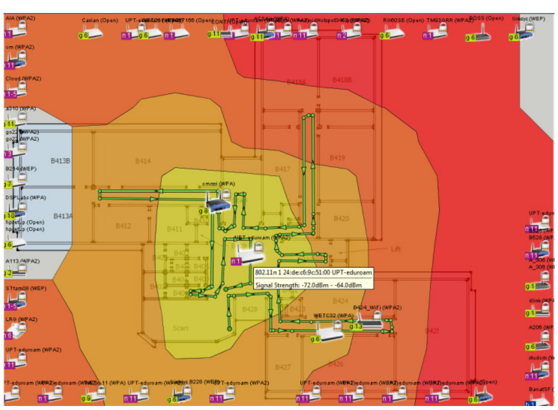

Fig. 3 Radio coverage with an increased number of samples

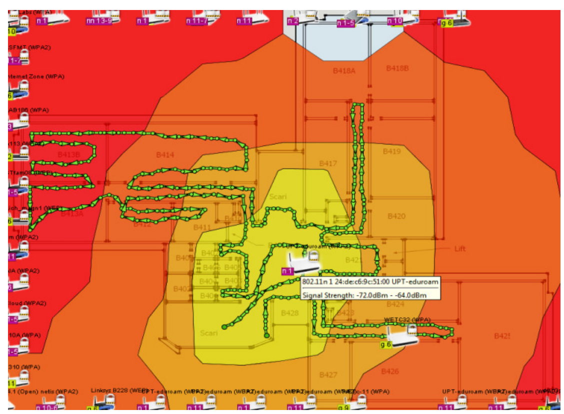

Fig. 4 Radio coverage of the extended measurement area

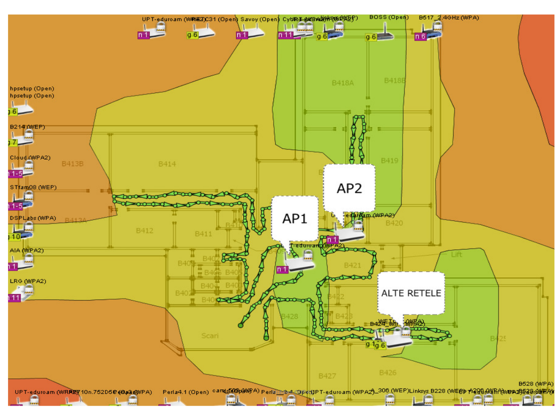

Fig. 5 Radio coverage of the extended measurement area

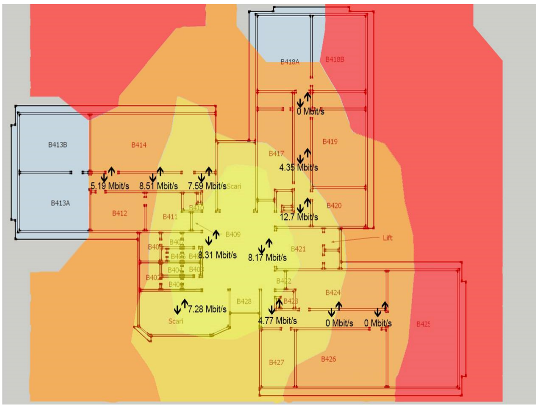

Fig. 6 Transmission speeds in the 4th floor coverage area

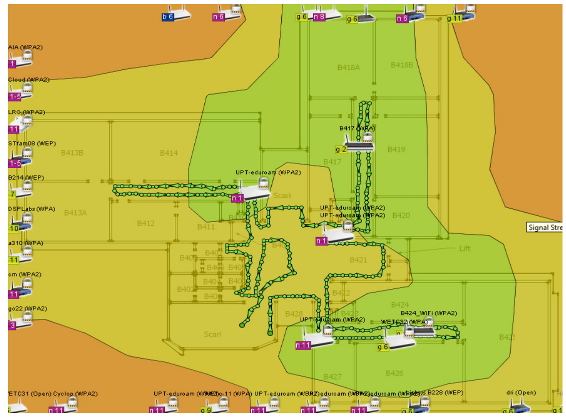

Fig. 8 Radio coverage after optimization

The proposed optimization solution for increasing the radio coverage of the network, considering the previous results, is the following: bringing in 2 additional new AP's and fixing them on each classroom access hall, more precisely at the centre of the hall and relocating the AP which is currently at the centre of one of the halls of the 6th floor, as it can be seen in Fig. 7.

After validating the optimization hypothesis, the result was an increased radio coverage at the 4th floor in building B, in the classrooms as well as in the common space mostly used by students. Figure 8 presents the radio coverage after applying the optimization process.

After measurements being taken, at the 3rd floor of building A, there were identified 2 AP's of the EduRoam network which have the radio coverage presented in Figure 9. Also, after tests conducted to establish the transmission speed in the coverage area, we obtained a maximum transfer of 10.24 Mbit/s and a minimum of 5.25 Mbit/s. A problem observed during the transfer speed test was connection loss at the border of the two AP's, due to the transmission power adaptation mechanism of the two APs (ARM).

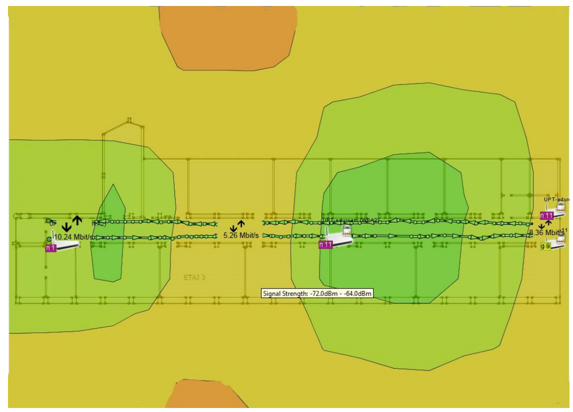

Fig. 9 Radio coverage area at the 3rd floor of building A and transmission speeds

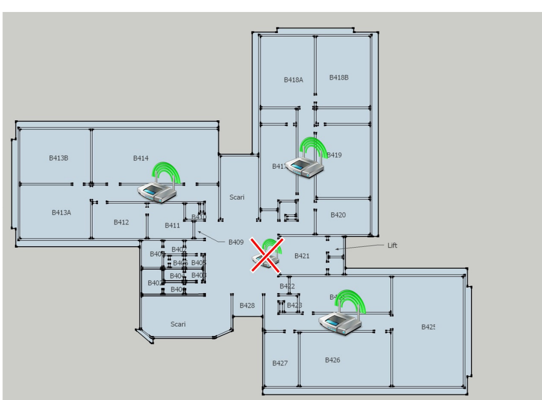

Fig. 7 Optimization solution for radio coverage at the 4th floor of building B

The optimization solution we propose in this case is establishing manually the radio coverage area of each. Once modified, the problem of connection loss at the border of the two APs will disappear.

VI. CONCLUSIONS

The herein study tried to anticipate our users' need of having unrestricted access to the UPT Wi-Fi network EduRoam on an area as large as possible, a radio connection quality as good as possible and at transfer speeds close to the actual needs of students and professors alike of the Politehnica University of Timisoara. In our study we analyzed several patterns of building structures and how WLAN behaves in these environments. We identified one design and implementation problem (building B) and one intermittent problem (building A). The first problem occurred due to the size of floor concrete. It has been solved by adding one AP each floor and reorganizing existing APs accordingly. The second problem occurred at the boundaries between two adjacent APs due to the automatic adaptation algorithms of the WLAN controller. It has been solved temporarily by limiting the transmission power of the two APs and by selecting statically the channels they are operating.

ACKNOWLEDGEMENTS

This work has been partially supported by the project HURO//1101/074/1.2.1 – JCBICS-UDUPT – "Joint Cross-Border Internet Communication System of the University of Debrecen and Politehnica University of Timisoara", 2013-2015.

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