A System Approach in a WiFi Network Design

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***Abstract*—The article presents a systematic approach to WiFi network design, how to solve WiFi connection problems at the Department of Information Networks, Faculty of Management and Informatics at University of Zilina in Zilina under specific conditions that arise here. For example, an enormous increase in connected devices at the same time and in the same area. On the other hand, it is a removal of access points from places where employees refuse their presence.**

I. Introduction

Demands on the functionality and expandability of wireless networks are constantly increasing, as more and more users use more frequently and at the same time multiple devices that use the wireless service. Such a rising trend must be taken into account already when planning the WiFi network, so that it can then be ensured that it runs smoothly in operation.

With the growing number of users and devices, administrators face another challenge, namely to provide an ever-increasing level of service.

The aim of the contribution is to solve the problem of WiFi connection for Department of information networks, Faculty of management science and informatics, University of Žilina (KIS FRI UNIZA), as there are currently several problems. The first is an enormous increase in the number of devices connected to one access point (AP) at the same time, and the second problem results from the demands of some employees who do not want to have the AP located near them, and therefore, when the AP is relocated, signal coverage is not ensured for those who they demand it.

The addition of more APs will not solve our situation and will not improve the services provided, and therefore it is necessary to find another way to eliminate the emerging problems.

II. International organizations for health protection against non-ionizing radiation

The issue of the impact of electromagnetic radiation on the human body is worldwide and is dealt with by various international organizations and administrative bodies, which, based on a number of expert analyses, issue guidelines on the effects of non-ionizing radiation [1].

The most famous are:

- World Health Organization (WHO).
- International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Some states adopted these guidelines as standards in their legislation in the form of laws, others adopted them as recommendations, respectively some countries have adopted stricter standards than recommended.

A. Legislative in Slovakia

When planning a new WiFi network and its subsequent use, it is necessary to pay attention to the limitations regarding WiFi radiation. The level of the transmitted signal at the output of the antenna must not exceed a certain maximum value defined in the legislative regulation. Based on the recommendations of ICNIRP and WHO, the Slovak government adopted the law No. 355/2007 in the field of health protection [2].

The implementing regulation in the field of electromagnetic radiation is the Decree of the Ministry of Health of the Slovak Republic No. 534/2007, which establishes:

- Minimal requirements for sources of electromagnetic radiation in order to ensure the protection of the health of residents in the environment and in the work environment in connection with exposure to an electromagnetic field with a frequency from 0 Hz to 300 GHz and to prevent risks.
- Frequency range of the electromagnetic field.
- Action values of electromagnetic field exposure [3].

III. Work methodology

When designing the WiFi network, we took a systemic approach to the solution. We used the first three phases of the development life cycle – planning, analysis and design.

First of all, the goal of the work was set: **To design a WiFi network for the department of KIS FRI UNIZA, which will meet the technical requirements and at the same time take into account the requirements of individual employees.**

Subsequently, a sequence of activities leading to the fulfillment of this goal was drawn up:

- Conducting a questionnaire survey on the current state of the WiFi network at KIS FRI UNIZA (collecting and analyzing the information obtained).
- Choosing a program for network planning and design.
- Implementation of passive research.
- Establishing recommendations for better operation.

IV. Questionnaire survey

The goal of the questionnaire survey was to find out among the employees what their opinion is about the current WiFi network in the premises of the KIS FRI UNIZA department and what they expect from the new WiFi network.

All 14 employees of the department were involved in the survey. The survey was conducted in the form of a questionnaire created in Google Form and contained 27 closed and 2 open questions. The questionnaire was distributed via MS Teams in December 2022.

A. Survey results

As part of the survey, a questionnaire was sent to 14 employees of KIS FRI UNIZA, of which 93 % of respondents answered and their answers represent the following results.

84.6 % of respondents consider the WiFi connection at the department important and use it, and the remaining 15.4 % do not consider the connection important and do not use it at the same time.

69.2 % of the respondents have no problem with the placement of the AP in the office, but on the other hand, 30.8 % of the respondents said that the presence of the AP in their office bothers them. Respondents who do not use a WiFi connection did not answer the questions related to quality, reliability, connectivity to the network and did not add a comment about the WiFi network, therefore the remaining answers relate exclusively to respondents using a WiFi connection.

The most common device through which the respondents connect to the WiFi network is a mobile phone and 90.9 % laptop and 9.1 % respondents connect via a PC.

Respondents most often use the WiFi network in classroom RB302 72.7 %, followed by the corridor where WiFi is used by 63.6 % of respondents, classrooms RB301 and RB303 each 54.5 % and classroom RB304 36.4 % . In other offices, the number of respondents using WiFi varies depending on how many are sitting in that office.

Less than half of the respondents using the WiFi network 45.5 % use it during teaching and the remaining 54.4 % do not use it during teaching.

Teachers do not use WiFi during teaching, because when 90 students connect to WiFi through their laptops and mobile phones at the same time, there is an overload and a network failure.

Other questions monitored the quality parameters of the WiFi network, such as **coverage** of the signal in the room, **connectivity** to the network and **reliability** of the established connection.

In terms of **signal coverage** of the room, classrooms RB301, RB302 and RB303 are the best performers, with coverage of 100 % and offices and the corridor are covered at around 73 %. 28 % of the respondents said that in their offices and in the corridor it is possible to connect only in some places.

From the point of view of **connectivity** to the WiFi network, 83.3 % of the respondents indicate that there is always a problem-free connection in classrooms RB302 and RB303, 75 % in classroom RB301. 42.9 % of the respondents indicate worse connectivity in the corridor and 36.4 % in the offices.

From the **reliability** point of view of the established connection, the WiFi connection is the most reliable 100 % in rooms RB302 and RB303, in offices 63.6 %, in the corridor 57.1 % and the least reliable for respondents in room RB301 50 %. The current connection to the KIS FRI UNIZA WiFi network is considered by 90.9 % of respondents to be sufficient and 9.1 % to be insufficient, and these respondents said that they would expect from the network:

- Higher throughput – 100 Mbps and more.
- Better WiFi access in the labs.
- Better WiFi access in the offices.

B. Survey conclusions

Almost 30.8 % of the respondents said that they are bothered by the presence of an AP in their office. The solution to this problem is as follows:

- Moving the AP from the office to the corridor.
- Relocating employees so that employees who want WiFi in their office can access it and those employees who don't want WiFi are out of the WiFi coverage area.

There is an unreliable WiFi connection in room RB301. It has been found:

- The AP located in the RB301 has an antenna that is not compatible with the AP.
- There is signal absorption due to the presence of many metal devices (devices in the rack).
- The influence of the WiFi network from the adjacent laboratory.

Solution:

- Replace the antenna on the AP with a compatible one.
- Change the orientation of the antennas.
- Removing the rack from the room.
- Installation of a new AP in room RB302.

28 % of respondents reported dissatisfaction with connecting to the WiFi network in the office or in the corridor. Possible solutions are:

- Relocate APs.
- Add another APs.

The information obtained through the questionnaire survey serves as a basis for settings in predictive network design.

V. Network planning methods

Predictive design [10], passive exploration and active exploration are network planning methods that have been used in many scientific works [18], [19].

Currently, there are a large number of programs and mobile applications available that deal with predictive design, active or passive WiFi signal research. The following table provides an overview of WiFi network analysis and design software:

A. Predictive design

Based on predictive design, the positions of wireless access points in the physical existing space are determined. It is based on a model that is experimented with in order to obtain the best desired conditions (i.e. the best WiFi signal coverage,

TABLE I. SOFTWARE FOR WIFI NETWORK DESIGN AND ANALYSIS

Windows/MacOS	Android/iOS
inSSIDer [9], [4] Ekahau [10], [11] SolarWinds [12], [17] Acrylic WiFi [13], [17] VisiWave Site Survey [14] Site Survey [15] NetSpot WiFi [13] AirMagnet [16]	WiFi Analyzer [17] ManageEngine [17] Ekahau Analyzer [17] WiFi Heat Map [17]

the largest throughput, etc.). Predictive design significantly reduces the effort, cost and time spent in placing an Access Point (AP) in the space, since the position and installation of the AP can be determined based on the information from the program [5].

Advantages of predictive design:

- A map of the researched area is sufficient for creation.
- Can take place anytime and anywhere using the design tool.
- The error rate of predictive design tools is estimated to be 10 %.
- Does not require physical access to researched area.
- Does not interfere with the operation of the organization.

Disadvantages of predictive design:

- Inaccurate results with an incorrect map.
- A physical survey should be performed to confirm the location, number and configuration of installed access points.

The following input data to the simulation program are required for predictive designing:

- Map.
- The material from which the walls and doors are made.
- The number of users of the WiFi network.
- Required signal coverage.

There are many places such as schools and hospitals where the concentration of wireless devices is much higher compared to the average building. Therefore, it is important to map how many wireless clients will simultaneously access the WiFi network and thus ensure sufficient access point capacity. It is common that within the covered area of the "Heat map" there are places with increased demands on WiFi network capacity and, conversely, places where this signal is unnecessary [7].

B. Tools for WiFi network design and analysis

Currently, the market offers a large number of software and mobile applications that allow performing predictive design, active or passive exploration together [8].

For our purposes of our work, we were looking for software that would best suit our requirements. Several software had time or functional limitations. Finally, we chose the Ekhau Site Survey program, which is often used by other authors of articles, where they monitor the behavior of WiFi networks during simulations. In the article [20], where the authors focused on WiFi network planning, they simulated the number of necessary APs necessary for operation in order to ensure the specified requirements. In another research [21], the Ekhau Site Survey software was used to create a pattern of signal propagation and analyze the obtained data, while the goal of the work was the degradation of WiFi signal intensity depending on external influences.

1) Active research: Active research is performed after a wireless connection is deployed and gathers information from specific APs by running various test metrics. The advantage of this survey is obtaining detailed information from each tested AP. It is time-consuming to perform, so it is not performed as often as passive research.

2) Passive research: Passive research is carried out after predictive designing and serves to check whether the result of predictive designing corresponds to reality. The research is done during operation or before the WiFi network is put into full operation.

We conducted a passive research through the Ekahou Site Survey program. Through the program, we obtained basic information about all available networks. After surveying the entire object, the software will display the acquired data.

The graphic representation of the WiFi network signal is done through a Heat map. The software creates this map as a colored overlay of the survey area. According to the color spectrum of the map, it is possible to determine the intensity of the signal in the network.

The coverage map can be created with the help of simulation or as a result of a passive survey.

VI. IMPLEMENTATION AND RESULTS OF SOFTWARE SIMULATION

The simulations were realized for the University of Zilina, Faculty of Management and Informatics, Department of Information Networks and were done by using the Ekahau Site Survey software. In the beginning, a project was created, into which the plan of the department was imported together with the data of the thickness of the walls and the elevator shaft.

The Fig. 1 shows the plan with the location of the APs (marked in green), from which we started. This plan is part of the department's documentation and shows the laboratories (RB301, RB302 and RB303), offices a nd c orridor o f the research area.

Fig. 1. Plan of KIS FRI UNIZA with the original location of AP We

implemented simulations for:

- Coverage of WiFi signal.
- Signal to noise ratio (SNR).
- Throughput.

WiFi signal coverage: We performed the simulation in the 2.4 GHz band on channel no. 1. The signal intensity value -50 dBm was used for visualization. This value was chosen because it almost guarantees trouble-free signal strength for connecting to a WiFi network. The direction of the antennas of specific APs is indicated by arrows in the figure. The color shades indicate the intensity of signal coverage (dark green - best signal coverage to gray color - area without signal coverage). Objects that affect the transmitted signal, such as furniture, electronic devices and metal objects are not in the simulation.

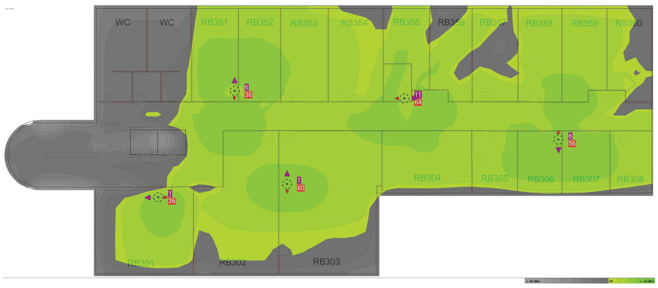

Fig. 2. Visualization of the signal coverage simulation at the -50 dBm limit

To validate the simulation, we then conducted a passive survey (we went through all the rooms and the Ekahau Site Survey software recorded data at the points marked with a dot in the image number 3) and created a visualization from the measured data. The signal intensity limit was again -50 dBm.

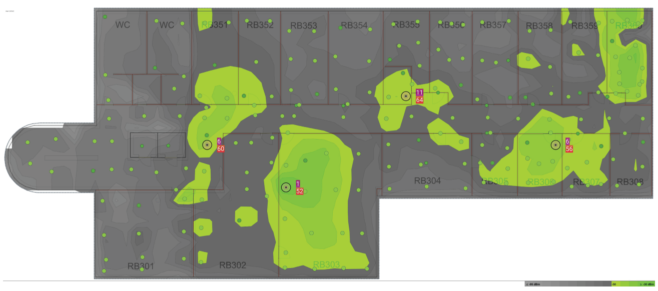

Fig. 3. Visualization of signal coverage from passive survey at -50 dBm limit

From the visualization of the passive survey, it emerged that there is a problem with the WiFi signal in almost all areas of the department.

It can be seen from the plan that the location of the AP does not match the plans of the department. During the passive survey, the location of the AP is not entered into the program, the program itself plots the location of the AP based on the best signal, which indicates inaccuracies. In addition, the AP in room RB301 is not recorded at all, because AP was not functional at the time of the passive survey and therefore the software did not even place this AP in the plan.

The generated visualization from predictive design and the visualization from passive exploration are different, which points to the fact that software simulation alone is not sufficient for WiFi network planning.

Signal to noise ratio (SNR) While noise can be the cause of an unstable WiFi connection, the visualization from the simulation and the visualization from the passive survey were made again.

During the simulation, APs were preserved as they are in the department's plans. On the other hand, in the case of the simulations, any other devices that may contribute to signal interference have been neglected.

The result of the SNR visualization from the simulation is shown in Fig. 4. The gray color indicates the places where the SNR value was less than 20 dB (falling below this limit causes a problem with the stability of the WiFi connection). The simulation shows that SNR does not cause a problem in the entire monitored area.

Subsequently, a passive survey was conducted, the results of which are recorded in the Fig. 5.

Fig. 4. Visualization of the SNR from the simulation

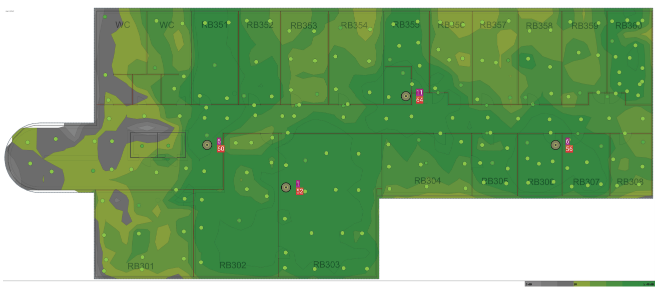

Fig. 5. Visualization of SNR from passive survey

By comparing the simulation and the passive survey, it was found that the passive survey more realistically describes the current situation, as the real conditions in the given premises were recorded during data collection (the influence of other devices participating in interference).

Throughput Before starting of the visualization, it was necessary to establish the initial parameters, such as:

- Number of WiFi network users = 90.
- Number of devices using WiFi network simultaneously = 180.

The result of visualization of the simulation is shown in the Fig. 6.

Fig. 6. Throughput visualization from simulation

The simulation shows that there should be no problems in terms of throughput. Dark green color shows the highest throughput.

Subsequently, a passive survey was carried out and the visualization of the permeability is shown in the Fig. 7.

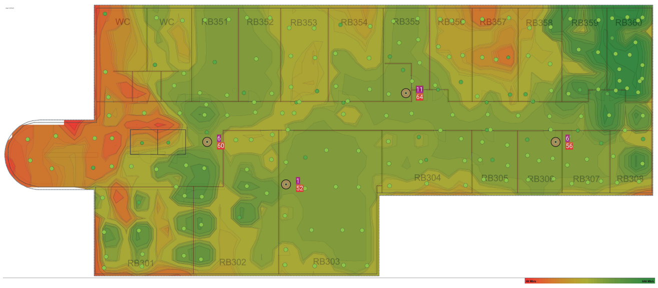

Fig. 7. Throughput visualization from passive survey

By comparing visualizations of the simulation and the passive survey, it can be seen that the passive survey shows a worse signal throughput than in the case of the simulation.

A. *Location and number of APs*

Finally, 3 more simulations were carried out, which show if the bandwidth and signal coverage of the WiFi network changes when:

- Keeping the same number of APs.
- Decreasing number of APs.
- Increasing number of APs.

During the simulations, we also took into account the user requirements resulting from the questionnaire survey, for example APs have been relocated as far as possible from the rooms of employees who are disturbed by APs in their rooms or close to them.

Keeping the same number of AP. In this case, simulations were made in which APs were moved within the rooms, but also outside the rooms. The situation that most meets the requirements to ensure a WiFi signal for a larger number of users at the same time in the laboratories and at the same time the WiFi signal is accessible in the offices of employees who require it, is shown in the Fig. 8.

Fig. 8. AP position design with the same number of APs

Decreasing the number of AP. During the simulations, we reduced the number of APs by 1 AP (4 APs remained). With a lower number of APs it was no longer possible to cover the required area with a WiFi signal. When placing them, emphasis was placed on covering the classrooms (the left side of the figure). 1 AP remained to cover the offices. From the repeated simulations, the best AP location is shown in the Fig. 9.

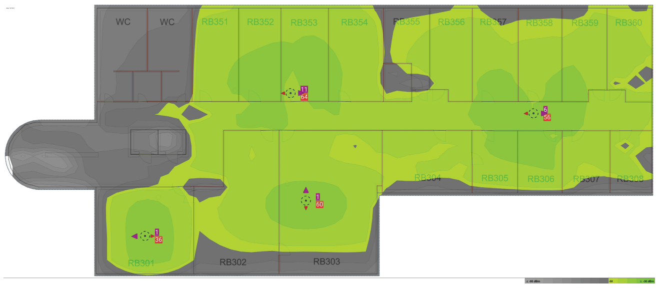

Fig. 9. Design of the AP position with a reduced number of APs

Increasing the number of AP. The goal was to cover all required areas with a signal strength of more than -50 dBm. The channels that were used on individual APs were configured automatically by the controller software. The best simulated AP placement solution is shown in Fig. 10.

Fig. 10. Design of the AP position with an increased number of APs

VII. Conclusion

The article shows how to use a systems approach when designing a WiFi network. The need for a proposal arose from the real situation at KIS FRI UNIZA. At the beginning, a questionnaire survey was carried out, which on the one hand pointed to the insufficient WiFi connection in certain areas of the department, but on the other hand also pointed to the disagreement of the employees to have APs located near them.

Subsequently, a survey was conducted among predictive design programs. We chose the Ekahau Site Survey program. Through the program, simulations and passive surveys were carried out, the results of which are detailed in chapter VI.

From the results of the simulations, it is possible to claim that the current situation at KIS FRI UNIZA from the point of view of AP placement is not ideal. Signal outages occur mainly in classrooms when the WiFi network is overloaded. And on the other hand, there is not enough coverage even for the other areas of the department.

From the performed simulations, it can be concluded that they are a good initial tool when planning a WiFi network, but they cannot be the only tool, as the disadvantage of predictive design is manifested in the form of inaccurate results, which was also shown in our case, namely the bad marking of the location of the AP on the plans of the department, which formed the input for the simulation.

Therefore, after the initial simulations, it is always necessary to do a physical survey to confirm the location and number of APs used.

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