A WLAN planning tool with a practical approach

Ricardo Tomé[1], Pedro Lourenço[2], António Grilo[3], Francisco Cercas[4], António Rodrigues[4], Fernando Velez[4] and Pedro Sebastião[4]

[1]IC R&D WON - Siemens, Rua Irmãos Siemens 1, 2720-093 Amadora, Portugal
Phone: +351 214242000, Fax: +351 214178044, e-mail: Ricardo.Tome@siemens.com
[2]Business Intelligence - PARAREDE TI, S.A., R. Laura Alves, N.º 12, 3º, 1050-138 Lisboa, Portugal
Phone: + 351 217235000, Fax: + 351 217235001, e-mail: pedro.lourenco@pararede.com
[3]INESC/IST, R. Alves Redol, Nº9, 1000-029 Lisboa, Portugal
Phone: +351-213100226, Fax: +351-213100226, e-mail: antonio.grilo@inov.pt
[4]Instituto de Telecomunicações, IST, Av. Rovisco Pais 1, Torre Norte, 1049-001 Lisboa, Portugal
Phone: +351-218418485/7/9, Fax: +351-218418472, e-mail: francisco.cercas@lx.it.pt; antonio.rodrigues@lx.it.pt; fjv@ubi.pt; pedro.sebastiao@lx.it.pt

Abstract — **This paper presents a new planning tool that facilitates the design and implementation of a WLAN (wireless local area network) which not only provides an accurate solution, but it also gives practical and useful information for the professional planner towards a quick implementation, such as the number and position of the access points (AP) or an estimation of the total cost of implementation based on data provided by different equipment manufacturers.**

The novelty of this tool is a new algorithm for calculating the best position of each AP was used, which is based on the user's applications and their most probable positions. This tool is user friendly and it interactively helps WLAN designers to properly define all the necessary equipment so as to provide a given coverage, i.e. with a given quality of service, for a given floor plant without to make a site survey in the places where this networks will be implemented.

Key words: wireless LAN planning tool, propagation model, capacity models, Wi-Fi.

1. INTRODUCTION

This tool helps to plan a wireless local area network (WLAN), - technologies IEEE 802.11a, 802.11b and 802.11g [1]-, for a determined floor of a building. It optimizes the number of access points (AP) and its position, as well as the total cost of the equipment according to the choice of WLAN technology suppliers. It is user friendly and it allows the development of the project in two different modes, automatic (the position of APs is defined by the tool) and manual (the designer decides the position of APs).

The tool only needs as input the file with the plant where the installation of WLAN will be made, the position and the type of material of the obstacles and the most probable location of the personal computer (PC).

The wireless local area network (LAN) planning tool (WLPT) can distinguish two main scopes:

Technical: - it defines the position of AP using one of the following options: The distribution of signal power in accordance with propagation models; the capacity of the applications used by each user and their most probable position.

Economic: - generate a budget according to the quantity and type of equipment provided by the supplier.

In indoor environments the propagation of radio frequencies is strongly influenced by the building's layout and its materials so the adopted propagation model takes into account several obstacles (doors, walls, closets, machines, etc.) and their attenuation coefficients [2] [3]. We also refer to some related work for the indoor propagation model, e. g., [4], [5], [6].

Concerning the total capacity needed for each AP, we defined the capacity according to the application (Voice over internet protocol (IP), Video over IP, file transfer protocol (FTP) e-mail, world wide web (WWW), files transfer (FT), etc.) using transmission rate results obtained in an experimental work developed at Instituto de Engenharia de Sistemas e Computadores (INESC), that were compared with [7]. The total capacity supported by each AP is obtained as a function of the number of users assigned to it and the time spent in a given application.

This tool only needs the following inputs: Digital format of the floor plant; position and obstacle's type; total covered areas; user's position and user's applications.

The manual distribution mode was implemented to allow the user to try and test different possibilities of the received signal distribution. Among the options given to the user, we can distinguish manipulation of APs, obstacles, covered areas (CA) and PC location. This mode is very attractive when the designers want to develop and configure the area to be covered.

The automatic distribution differs from the manual one by the fact that AP positioning is automatic. Depending on obstacles, the user's position and their capacity, the tool defines the quantity and positioning of the AP to reach an optimized coverage and/or the associated capacity.

Two optimization methods were developed in order to minimize the number of APs in a given area which define its location on the plant. One of the methods was implemented considering the existing propagation models.

The other method considers the most probable localization of each user and its capacity according to the applications used.

The WLPT was developed in Visual Basic 6.0 language [8], using its graphic methods and interacts with a SQL Server 2000 Data Base [9]. Other tools with higher complexity and costs exist [10], [11], [12], [13], [14], but this WLPT has the advantage to be a fast simplified technical budget planning tool that can easily be used by network designers in industrial environment, as well as students in their academic studies.

The paper has three more sections. Section 2 describes the adopted models, - propagation and capacity. Section 3 presents the algorithms related with signal power coverage and the required capacity for the users. The characteristics of the tool are presented in section 4. Finally, the main conclusions and some guidelines to future work are outlined.

2. MODELS

The WLPT tool is mainly focused in the propagation and capacity models. The next subsections give a brief introduction to these models.

2.1. Propagation models

For obtaining the average received power in a given point we need to know the average attenuation factor, $\overline{PL}(d)$ as a function of the distance d, between the AP and that point.

Eq. (1) represents the $\overline{PL}(d)$ expressed in dB [2],

$$\overline{PL}(d) = \overline{PL}(d_0)[\text{dB}] + 10 n_{SF} \log\left(\frac{d}{d_0}\right) + \\ + FAF[\text{dB}] + \sum_i PAF[\text{dB}] \quad (1)$$

where, $\overline{PL}(d_0)[\text{dB}]$ is the path loss attenuation for a 1 meter distance d_0, n_{SF} represents the exponent value (for the same floor equals 3.5 dB), $FAF[\text{dB}]$ is the floor attenuation factor (for the same floor equals 12.9 dB).

For some materials the obstacle attenuation factor, $PAF[\text{dB}]$, can be derived from [2]. The average path loss attenuation, considering the reference distance, is given by,

$$\overline{PL}(d_0)[\text{dB}] = 10\log\left(\frac{\lambda^2}{(4\pi)^2 (d_0)^2}\right) \quad (2)$$

where $\lambda = c/f$, $c = 3\times10^8\,\text{ms}^{-1}$ and f is the carrier frequency accordingly to the IEEE 802.11 standard [1]. The threshold received power was obtained from [15]. The average received power is given by $\overline{PR}(d) = \overline{PE} - \overline{PL}(d)$, where $\overline{PE}$ is the average emitted power. The threshold received and emitted powers, respectively, can be observed in [15].

2.2. Capacity models

The planning of a WLAN is mainly focused in the coverage of all PCs. Usually, the suppliers of wireless equipment visit the local and make a site survey with a laptop, verifying if all locations have sufficient power to establish the link between the AP and the PC. Unfortunately, some times, this strategy it is not enough to make the correct planning in terms of economic aspects. Thus, it is necessary to define the number of APs and its position, taking also into account the capacity used by each user. This capacity is obtained according to the used applications.

Table 1 presents the average transmission rate corresponding to each group of applications considering packets with an average size obtained by experimental work.

According to the threshold of the received power and its correspondence with the maximum transmission rate, for each standard [15], the WLPT defines the total APs and their corresponding positions assuming a given user's simultaneous factor (USF) for each application. The choice of USF depends of the type of department (the percentage of users that use the same application simultaneously).

Table 1:Average transmission rate for each application.

Applications	Transmission rate IEEE 802.11b [kbps]	Transmission rate IEEE 802.11a/g [kbps]
Voice over IP (G.711)	230	274
Video over IP (MPEG 4)	1042	1053
FTP+WWW+e-mail+FT	500	500

Theoretically, each AP can guarantee the maximal transmission rate in each ring, according to the received power showed in [15]. Therefore the AP positions depend on the PC positions and the applications used by them. Figure 1 depicts the AP position and the associated data rate threshold for each ring. The transmission rate (TR) in each ring, TR_r must obey the following equation:

$$TR_r \leq TR_{rth} \quad (3)$$

where TR_{rth} defines the transmission rate threshold in a given ring. TR_r is given by

$$TR_r = NU_r \sum_{a=0}^{A} TR_a \, USF_a \quad (4)$$

Where NU_r is the number of users by ring, A is the total number of applications and TR_a is the data rate of each application. On the other hand, the total TR supplied by each AP must verify,

$$TR_{TOTAL} \leq TR_{thTOTAL} \quad (5)$$

where,

$$TR_{TOTAL} = \sum_{r=0}^{R} NU_r \sum_{a=0}^{A} TR_a \, USF_a \quad (6)$$

The total number of rings is represented by R. Thus, a given position of an AP is accepted if eq. (7) is verified, that is,

$$\begin{aligned}&\left(TR_0 \leq TR_{th0}\right) \cap \cdots \cap \left(TR_r \leq TR_{thr}\right) \cap \cdots \\ &\cdots \cap \left(TR_R \leq TR_{thR}\right) \cap \left(TR_{TOTAL} \leq TR_{thTOTAL}\right)\end{aligned} \quad (7)$$

otherwise the AP have to move its position to the anterior and a new AP close to the last PC has to be allocated. The same process is then repeated to this new AP.

Section 3 presents a detailed algorithm to position each AP, minimizing its number.

3. ALGORITHMS

As we already mentioned there are two types of signal distribution, manual and automatic. Manual distribution allows the designer to try and test different possibilities of the received signal distribution. Among these options we distinguish manipulation of AP, obstacles, CA and PC.

In the automatic distribution the application achieves AP positioning automatically. Depending on the obstacles, the user's position and their capacity, the application achieves the quantity and positioning of the AP, to reach the optimized coverage and/or the necessary capacity.

The automatic distribution can also be made by two different methods: coverage and capacity.

The purpose of the coverage algorithm is to properly cover the area(s) defined by the designer. This algorithm sets an AP in the center of the defined area and splits the area in four quadrants. The coverage is verified for each quadrant. If the coverage is not enough in a given quadrant, also this area is splitted in four quadrants and a new AP is placed in the center of this new splitted area. This process is repeated until all the defined area is covered. For each AP placed in a quadrant, the algorithm will check if the previous APs are still needed. In Figure 2 is depicted a plant delimited by the points 1 to 4 and the AP are placed in accordance with algorithm.

The capacity algorithm takes into account the position of each PC and the applications they use. The algorithm starts placing an AP nearest to the PC position (0,0). Then, the AP is moved to the next PC. If the first PC is covered by the demanding TR, the algorithm keeps checking the remaining PCs, based on their proximity from the previous ones, verifying if the AP can supply the total TR of the precedent PCs. The process stops when the AP can't cover the previous PCs with the necessary TR. In this case, and if there are more PCs, the AP will be positioned in the previous PC position and another AP will be placed in the current PC. The position of the new AP will be closer to the next PC and the same process is repeated until the necessary TR is guaranteed for all PCs. This algorithm uses eq. (7) mentioned in the capacity model section. This algorithm is depicted in Figure 1.

4. CHARACTERISTICS OF TOOL

This section presents the main characteristics of the developed tool, its functioning and potentialities. It was developed having in mind its user friendly use and also to help network designers with a fast, technical and economic planning tool. This tool supports all the IEEE 802.11 (a/b/g) standards, it estimates the TR needed by the network according to the capacity model. Items such as the obstacles, APs and network cards types can also be updated directly in the tool. Different propagation models, both indoor and outdoor, can also be introduced and tested.

Figure 3 shows an example of the actual layout of the WLPT tool (received power distribution and economic plan).

The possibility of upgrading the tool to support future standards that allow high capacities and different frequency bands was also foreseen and can be easily implemented.

The WLPT tool has several menus that enable the user to insert the appropriate parameters according to several options. This tool can make a complete plan for coverage of a given area based solely on a plant file, the obstacles, their material and position and the several locations of the PCs. As the output, the program generates a layout showing the received power-capacity and the APs position. The tool allows the designer to introduce some equipment manufacturers simply introducing the characteristics of the equipment in a database, as showed in Figure 4. After the technical planning, the WLPT tool can estimate the total cost of the equipment involved, as well as its required quantities.

As we can see, by properly running this tool it is possible to optimize the planning for a given area in a very simple and efficient way.

5. CONCLUSIONS

In this paper was presented a tool that allows a planning designer to dimension a WLAN topology, for any standard of the IEEE 802.11 family, with a practical approach. Basically, it is possible to obtain the signal coverage and TR maps from the plant of a given place; The cost of implementation of a communication wireless network can then be easily estimated also based on the necessary TR (used applications) foreseen.. These are some aspects that make this tool a simple and complete way to implement the more recent WLAN solutions.

The WLPT tool can generally be described as a simple and quick tool to get both the technical and budget planning and that can be used by network designers in industrial environments as well as a helpful simulator that can help students in their academic studies.

Some improvements were made in this tool. One of them is to planning an outdoor Wi-Fi network. By other hand, some additional work will be developed, namely the use of intelligent models for the capacity algorithms, as a way to model the simultaneous use of several applications.

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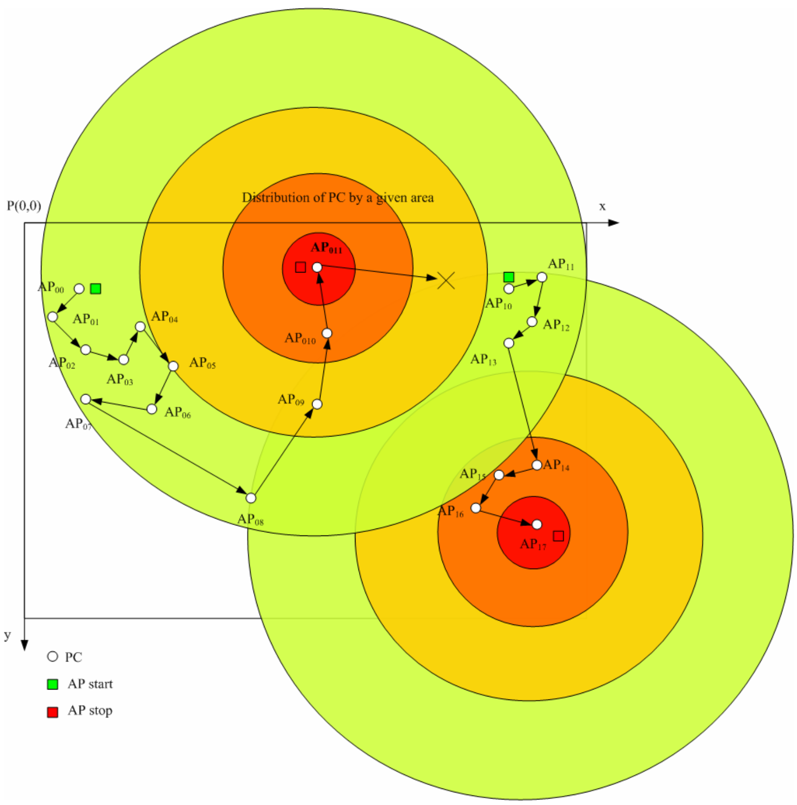

Figure 1: Transmission data rate rings, according to the IEEE 802.11b standard.

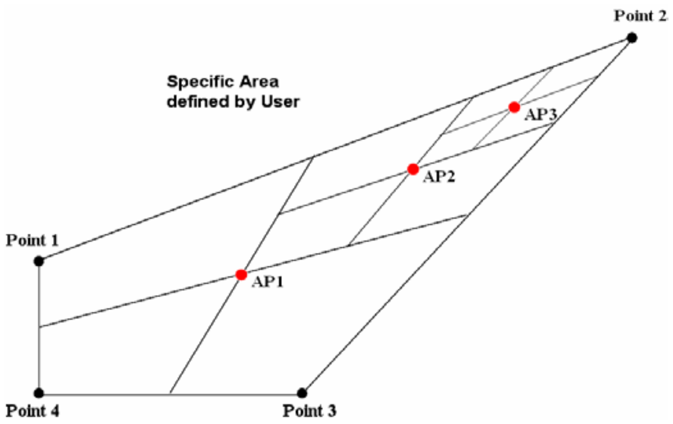

Figure 2: The Algorithm used for place the AP.

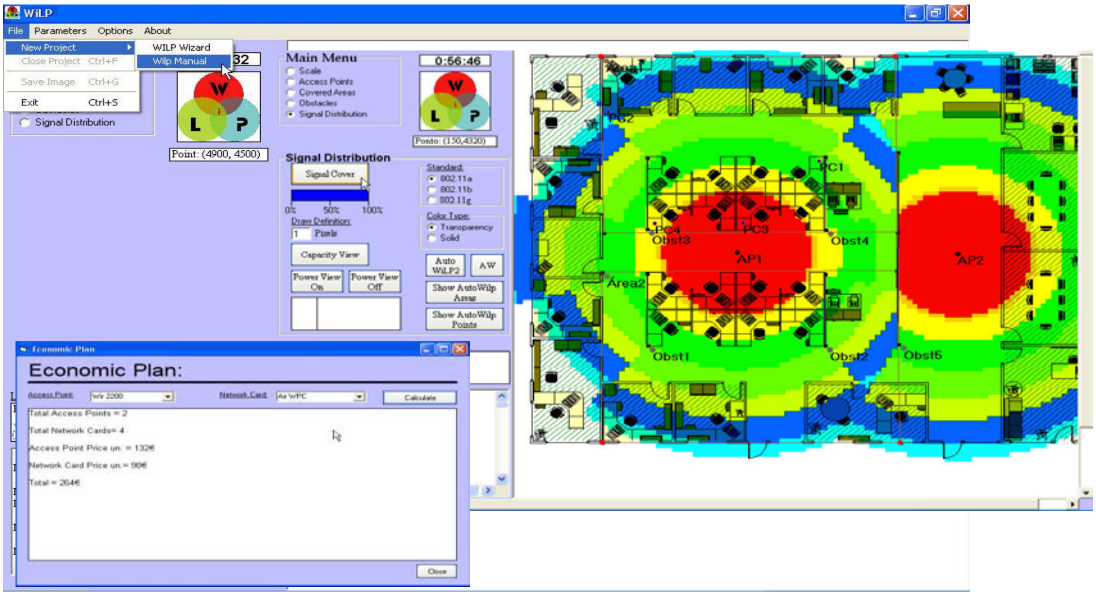

Figure 3: Tool's planning layout.

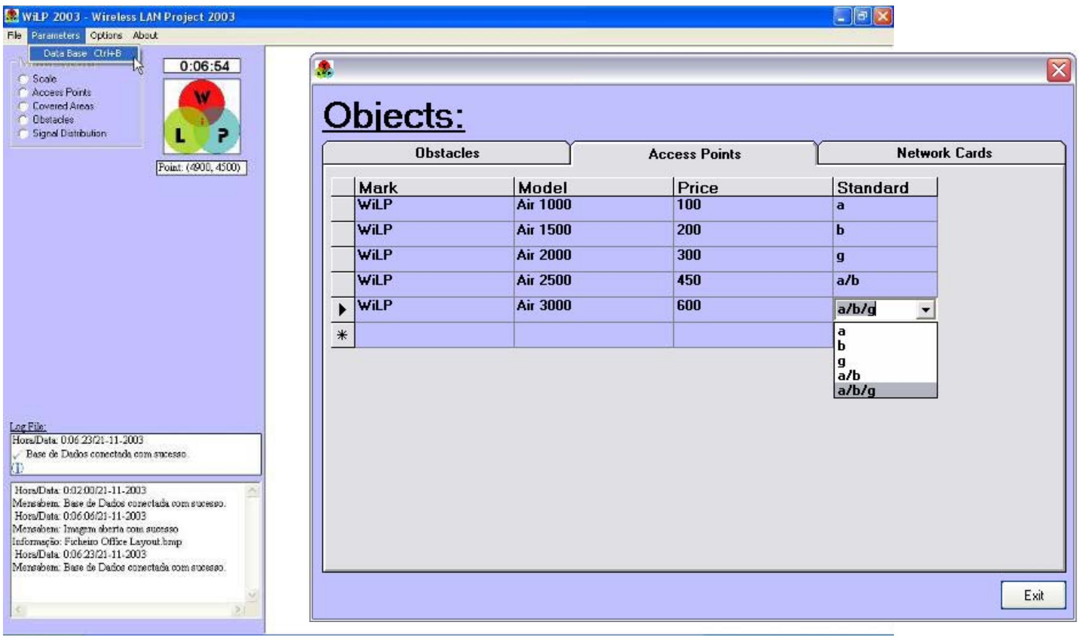

Figure 4: Tool's data base for IEEE 802.11a/b/g standard.