A Floor Description Language as a Tool in the Process of Wireless Network Design

Remigiusz Olejnik*

West Pomeranian University of Technology, Szczecin,
Faculty of Computer Science and Information Systems,
ul. Zolnierska 49, 71-210 Szczecin, Poland
r.olejnik@ieee.org

Abstract. The paper describes a Floor Description Language (FDL) which could be used as a key chain in the process of wireless network design. Traditional ways of designing wireless networks are also presented. Numerical results and comparison with commercial systems summarizes the paper and proves FDL's usability.

1 Introduction

Currently density of modern wireless networks grows very fast. Many of the deployments are not sufficiently prepared – most of home and small office wireless networks have never been designed by a designer or network engineer – just users bought network equipment, turned it on, connected to the rest of their network and used it "as is". Such approach is very inefficient in terms of the quality indices such as overall network set-up costs, maximal network range and throuhput. This paper presents a novel Floor Description Language (FDL) which along with well known propagation model makes designing of the wireless networks much easier with ready map of the floor.

The paper consists of three parts. First part describes known ways of wireless network designing and propagation models. Second part presents novel Floor Description Language used in the process of network design. Third part shows numerical results and comparison with commercial systems. Summary containing possible future works ends the paper.

2 Wireless Network Design Process

Traditional process of network design is composed of four main steps:

1. gathering necessary data on actual state of infrastructure and desired future functionality;

* I would like to thank my graduate student, Grzegorz Bera, who undertook deep research of the above mentioned FDL in his master dissertation [11]. His hard work proved that it is not only my general idea, but it really works and is comparable with commercial systems.

A. Kwiecień, P. Gaj, and P. Stera (Eds.): CN 2009, CCIS 39, pp. 135–142, 2009.

2. preparing project of future network that meets requirements set in first step;
3. modelling of projected networks;
4. physical building of the network.

The process can be also extended with fifth step that covers possible measurements of the network after its deployment.

There are many known approaches used when designing wireless networks. Among them are:

- user deployment – users do not have any network related knowledge or experience; it is based on basic installation of the network components without any analysis or planning; it is simple and it could lead to inefficient coverage [1,2];
- grid installation – an area is divided into K triangles or rectangles, where K is number of available access points; access points are installed in the center of triangles (rectangles); there is no need to know anything on propagation models but this approach is often more expensive than first one and less efficient than next one [2];
- coverage optimization – it is more expensive and complex approach that engages propagation analysis and optimization algorithms when searching for the best access points locations; "best" is understood as providing adequate coverage with minimal infrastructure density [2,3];
- site survey – it is based on the analysis of signal strength's measurements conveyed in the future network area.

2.1 Propagation Models

Wireless network design based on the software aids that have built-in propagation models is much cheaper and easier than 'site survey' approach which is time consuming and relativly expensive. It could help to predict signal strength level anywhere in the future network environment [4]. Propagation models could be classified as follows [5]:

- Empirical
  - Free Space Loss
  - One Slope Model
  - Linear Attenuation Model
  - COST 231 HATA
- Semi-empirical
  - Multi Wall Model
  - COST WI
- Optical
  - Ray Traycing
  - Ray Launching
  - Dominant Path Prediction
- Theoretical
  - based on the field theory

Propagation models that have been verified [6] and found to be most prospective during current and future research on wireless network design methods are One Slope Model and Multi Wall Model. Both of them use simple Free Space Loss formula for calculating fundamental loss over the distance in free space.

Free Space Loss. Free Space Loss (FSL) model is derived from the Friis Equation [7] which describes signal loss over the distance between the transmitter and the receiver:

$$\frac{P_\mathrm{r}}{P_\mathrm{t}} = G_\mathrm{t} G_\mathrm{r} \left(\frac{\lambda}{4\pi R} \right) \ , \tag{1}$$

where P_r is power received by the receiving antenna, P_t is power output to the transmitting antenna, G_t and G_r are the antenna gain of the transmitting and receiving antennas, λ is the wavelength and R is the distance between the transmitter and the receiver.

Equation (1) transformed and simplified with the assumption that gain of the antennas $G_\mathrm{t} = G_\mathrm{r} = 0\,\mathrm{dBi}$ has the form:

$$PL(R) = 20 \log \left(\frac{4\pi}{\lambda} \right) + 20 \log R \ , \tag{2}$$

where $PL(R)$ is path loss over distance R.

After further transformations we get formula:

$$L_\mathrm{FSL}(d) = 32.44 + 20 \log f + 20 \log d \ , \tag{3}$$

where L_FSL is free space loss [dB], f is the frequency [MHz] and d is the distance [km].

One Slope Model. One Slope Model (OSM) is one of the simplest models for calculating of signal strength level without considering structure of the bulding:

$$L_\mathrm{OSM}(d) = L_0 + 10n \log(d) \ . \tag{4}$$

Signal strength level L_OSM depends mainly on the distance d between the transmitter and the receiver [8]. The enviroment-dependent values L_0 (signal loss on 1 meter distance) and n (emprical value representing degree of signal loss) are fixed for specified environment. Values of L_0 and n are given in the literature, e.g. for the office environment at frequency $f = 2.45\,\mathrm{GHz}$ variables L_0 and n have values: $L_0 = 40.2$ and $n = 4.2$ [8].

OSM is not precise model because it does not incorporate structure of the environment. Sometimes the structure is not known so the model OSM could be useful in such cases.

Multi Wall Model. Multi Wall Model (MWM) uses FSL for basic calculation of the loss over the distance and more sophisticated sum of the losses on the obstacles, mainly walls [8]:

$$L_\mathrm{MWM}(d) = L_\mathrm{FSL} + \sum_{i=1}^{N} k_{\mathrm{w}_i} L_{\mathrm{w}_i} + k_\mathrm{f} L_\mathrm{f} \ , \tag{5}$$

where L_{FSL} is signal loss in free space (Eq. 3), d is the distance [m], N is number of types of the walls, k_{w_i} is number of the i-type walls with L_{w_i} loss [dB], k_f is number of the ceilings with L_f loss [dB]. Similar to OSM we need some measured values of variables (L_{w_i} and L_f) that are characteristic for modelled environment.

3 Floor Description Language

FDL is an aid used in the process of planning of the wireless network. It simply describes environment that is provided to the designer on the map of the floor. Along with the map it is necessary to provide the values of the loss of every type of the walls and ceilings. FDL does not use any propagation model, however one of them is necessary in futher step to find appropriate network components locations. MWM model has been chosen because it seems to be suitable and most reliable in typical applications of home and office designs [6].

3.1 FDL Specification

The FDL itself consists of a few markup-like statements that describes the environment as it appears on the floor's map. So the only input data for FDL is map of the floor and specification of loss coefficients for the walls and ceilings.

Types of the walls are represented by different colors: type 1 – red, type 2 – green, type 3 – blue, type 4 – black, type 5 (no wall) – white.

FDL desribes a floor in the building. The structure of the floor is divided into three parallel parts, as shown on Fig. 1. Every part contains at least one room. Parts are declared as follows:

```
number_rooms_A = 5;
number_rooms_B = 3;
number_rooms_C = 4;
```

Rooms could be of different types and adequate identifiers are responsible for their description: stairs (1), corridor (2), office (3), conference room (4), social room (5), toilet (6). For part A on the Fig. 1 we have:

```
id_rooms_A = [1:number_rooms_A; 3 4 3 3 6];
```

Dimensions of the room are declared in next row. First lengths of the rooms are specified and then widths of them.

```
id_dim_A = [1:number_rooms_A; 30 7 8 10 5; 10 10 10 10 10];
```

Key element of the FDL describes all of the rooms' walls. It is done with declarations:

```
walls_A = [1 1 3 2; 3 1 3 2; 3 1 3 2; 3 1 3 2; 3 1 1 2];
```

For all of the specified types of the walls we need to specify losses of them:

```
loss_dB = [15 12 10 40 0];
```

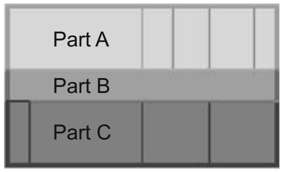

Fig. 1. Floor's map

Additional element used only at visualisation stage is thickness of the walls:

```
walls_th = [0.25 0.15 0.1 0.13 0];
```

3.2 Modelling Procedures Parameters

FDL needs also some more additional parameters for the modelling procedures. Input data for them are:

- signal level required at the workstation locations [dBm],
- percentage of the coverage [%],
- output power of the transmitters [dBm].

Output data are:

- the best combination of the access points localizations that met all of the requirements.

Propagation procedures are used in the following way:

- signal strength level is computed using MWM formula for every workstation and combination of the access points,
- percentage of the workstations that achieve required level of signal strength is then computed,
- loop is repeated for next combination of the access points, for all of their possible localization,
- the best solution is then chosen – the best means that all of the criteria has been met and number of the access points is the lowest.

Output has also visualisation of the best combination of the access points that assure required parameters.

4 Numerical Results

The computations were undertaken in MATLAB environment using aforementioned FDL implementation for sample map of the floor (Fig. 1). Results were compared with output from commercial products – Ekahau Site Survey [9] and RF3D WifiPlanner [10].

Further assumptions and parameters were:

- constant width and length of the area (floor's dimensions: 60 x 25 m),

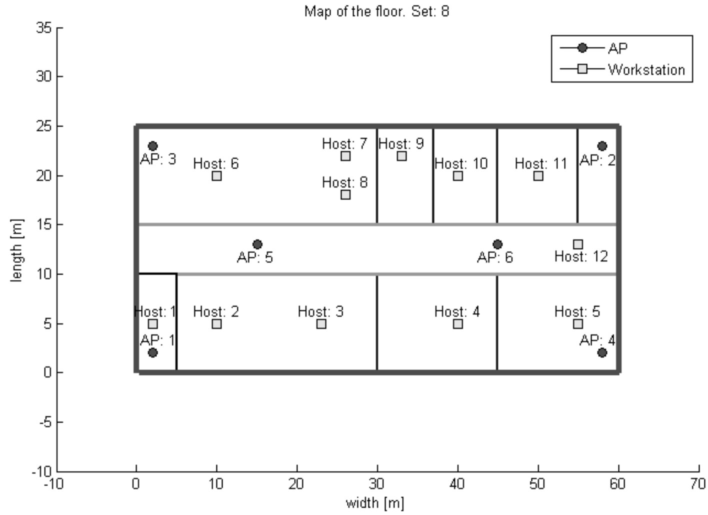

Fig. 2. Map of the floor with workstations' and the access points' localizations

Table 1. Loss coefficients [dB] and the colors used by the FDL and commercial systems

Wall type	FDL	Ekahau	RF3D
type 1	15/red	15/orange	15/red
type 2	12/green	15/gray	12/green
type 3	12/blue	15/gray	10/blue
type 4	40/black	45/black	30/black

Table 2. Coverage percentage [%] results

Set	No. of AP	FDL	RF3D	Ekahau
No. 1	1	50	42	42
No. 2	1	25	0	17
No. 3	1	25	17	17
No. 4	2	75	50	67
No. 5	2	25	17	17
No. 6	2	58	50	58
No. 7	4	75	67	75
No. 8	6	100	83	92

- nine rooms and a corridor,
- four types of the walls (as specified before),
- constant number of workstations and power of the transmitters (15 dBm),
- required percentage of coverage (70%),
- required signal strength level (−63 dBm).

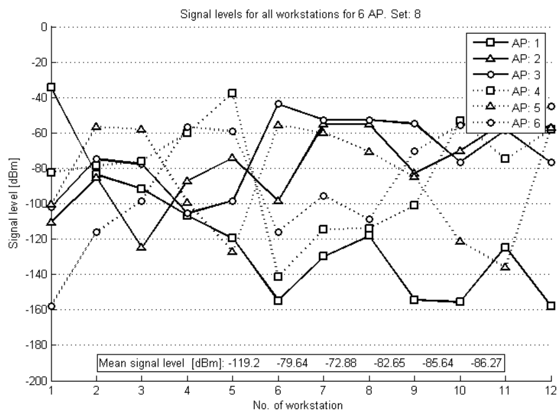

Fig. 3. Signal levels' comparison for selected access points combinations

The differences between colors and the loss coefficients used by FDL and commercial systems are summarized in the Table 1.

Sample results given by the FDL implemenation with MWM propagation model are presented on the Fig. 2 and Fig. 3 (map of the floor and signal strength levels comparison respectively). Output graphic results given by commercial systems are omitted.

Numerical results are summarized in the Table 2.

4.1 Results Conclusions

Data presented in the Table 2 prove that FDL with MWM can compete with commercial systems when optimization criteria is coverage range. In every case FDL seems to find set of the access points that provides the highest coverage percentage.

Detailed analysis of output data for all of the sets given by three systems (that are omitted due to their volume) lead to following conclusions:

– differences of computed signal levels are not greater than a few dB,
– at least 80% of cases where FDL with MWM is used seems to be better than commercial systems in terms of both coverage range and number of the access points used.

Another research proved that results given by the FDL with MWM are very close to those given by site survey approach. The maximal difference between measurements and FDL with MWM was 4 dB and results given by Ekahau Site Survey were worse in most cases with maximal difference of 9 dB.

5 Summary

Presented Floor Description Language although it covers simple idea gives results very close to the results of commercial-grade modelling systems. Its simple ideas that combine geometric decomposition of the floor with classic propagation models could be further developed. Possible enhancements could be done with:

- database extension (e.g. obstacles' definitions etc.),
- auto-localization of the access points procedure,
- additional network parameters,
- graphic files import and recognition of the floor's map.

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