DESIGN PARTICULARITIES FOR WIRELESS NETWORKS

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Particularities of design for innovative wireless networks – WLAN and WiMAX – are examined. Models and methods for wireless networks design are investigated. Main requirements as well as integration way into a XML-based network design environment is shown.

1. Particularities of WLAN/WiMAX-design

Particularities of WLAN/WiMAX-design. WLAN/WiMAX [3,4] design is very complicated via multiple influence factors. A distinguished feature of CN design is the fact that a lot of special experiences are required from the specialist, indeed:

1. The first aspect is strength considering of geometry due to limited reach (100m – 10Km), moreover considering of mobility for some standards is necessary (up to max. 250Km/h). All software decisions need 2D/3D- map of coverage area
2. Use of simplified approximating formula for performance/load models in combination with picture processing techniques like
   - ***Propagation model*** (free space, LOS/NLOS) – loss via attenuation at distance
   - ***Link Budget model*** (Last Mile Access) – attenuation at receiver site with considering of distance, properties of transmitter and receiver and data rate (DR)
   - ***Path Clearance model*** (NLOS) – heights of antennas of transmitter and receiver at basis stations (fig.1)

in combination with simplified approximating graphical algorithms for WLAN-design, for instance, ***Multicolor Ink Spot Model and Algorithm*** [5] is the second aspect***.***

3. Furthermore, it is estimation of obstacles' influence under condition that sources of interferences are "black boxes". The generalized parameters are the signal attenuation coefficients
4. Full monitoring or simulation (calculation) of transmitted signal quality ***S*** and ***DR*** at each coordinate pair ***[X,Y]*** is the next aspect. Very important is availability of visualization tools for monitored/simulated parameters: ***{S, DR, X, Y}*** in combination with the required map materials or building layouts, i.e. output of calculated areas as tables and pictures in different data formats (HTML, NDML as well as graphical formats).

There are some good software decisions for monitoring or simulation but only for WLAN 802.11 [3-5]. Partially these software decisions are tied to hardware purchase.

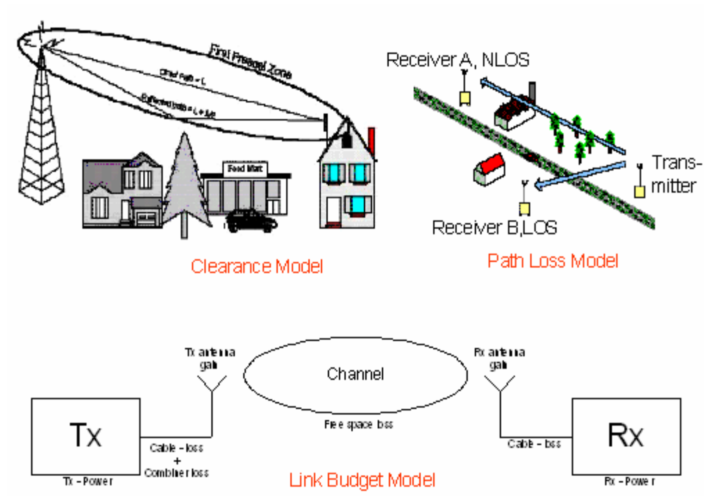
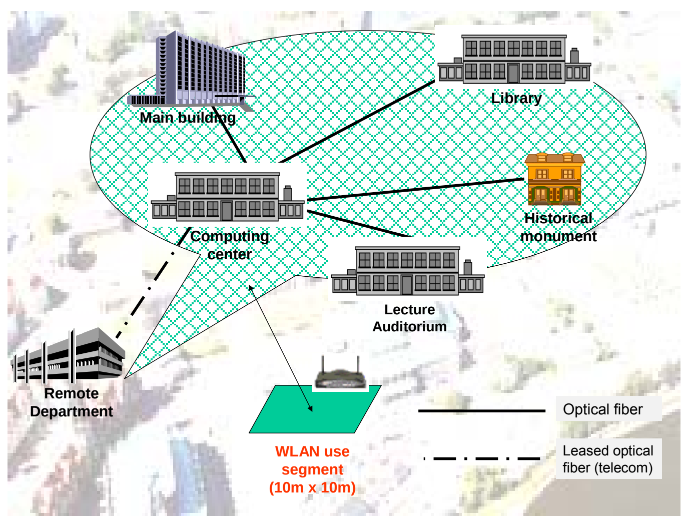


Fig.1. Propagation and Link Budget models (Olexa-Smyth).

On the fig.2 a case study "university campus"for use of wireless links is shown:



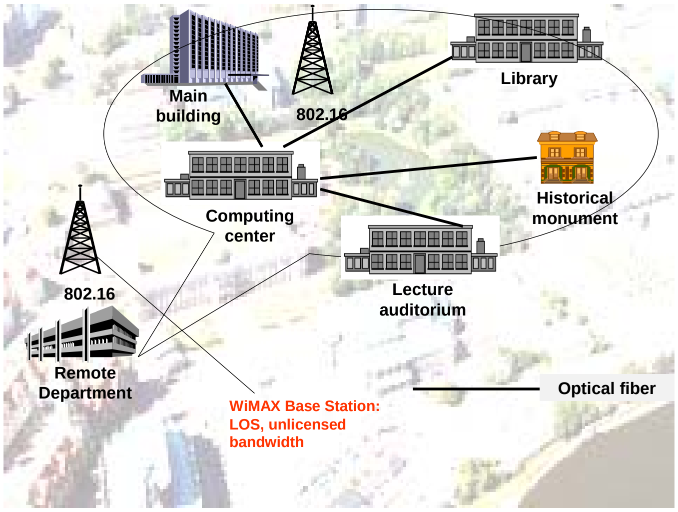


Fig.2. Methodic of wireless network design with considering of existing cabling system and splitting of campus onto service sectors

2. Typical models for wireless networks design

In this work design tools for WLAN(802.11)- and WiMAX(802.16)-networks are examined. Standard tools like ***Ekahau Positioning Engine, Site Survey, Wi-Fi Tag, Radio Mobile Deluxe***) can be integrated into ***CANDY*** with some new developed design applications for calculation under use of the following models:

Propagation Model (1)
PL= φ(R, F);
"Last Mile" Link Budget Model
L = φ1(Power, Gain, Sensitivity, F, R)
DR = φ2(L, R, Sensitivity);
Path Clearance Model
H = φ(R, F)
Multicolor Ink Spot Model And Algorithm
DR = φ(N, AP, x, y),

where ***PL***– path loss coefficient, ***R***– distance (reach), ***F***– carrier frequency, ***L***– loss coefficient, ***[Power, Gain, Sensitivity, H]***– transfer power, gain, sensibility and antenna height, ***N*** and ***AP***– user and Access Point number, (***x,y***)– AP coordinates, ***DR***– data rate. The following propagation models [3,4] are relevant for WLAN/WiMAX (the bandwidth F = approx. 2 up to 6GHz):

- Free Space Model – calculation for LOS-links
- Street Canyon Model
  - relevant for NLOS-links with external antennas
  - used for urban areas
- Walfish – Ikegami Model
  - empirical model, relevant for macro-cells up to 5 km
  - able to calculation path loss coefficients in strong tilled areas (metropolitan areas)
  - considering of secondary radio waves paths created via inflection of rooftops into the streets
  - provider antennas must be installed inside of buildings
- Okumura – Hata Model (1968)
  - for suburbs and rural areas, forests, hills
  - relevant for frequencies under 1000MHz up to 20krm and antenna heights up to 30m
- COST 231 – Hata Model (1996)
  - similar to Okumura – Hata Model
  - propagation model for in-door-installations with considering of wall attenuation
  - but indeed relevant for frequencies up to 1800MHz
- Lee Model (1982)
  - developed for analog mobile radio networks
  - relevant for frequencies over 450 MHz and receiver antennas heights under 3,5m at distance up to 10km.

The distance ***R*** as a parameter is influenced also via modulation method (QPSK, 16QAM, 64QAM). Some propagation models characteristics are given at Tables 1,2 [3,4]:

Table 1. Relevant propagation model for different mobile/wireless standards

Standards	Link Type LOS/NLOS	Relevant propagation model
2,5G/3G	NLOS	Hata / COST 231
802.11b,g	Hybrid	COST 231
802.16a	Hybrid	COST 231
802.16	LOS	Free space
802.20	NLOS	COST 231

Table 2. Cell sizes for frequencies F=3,5GHz and 5 GHz

Modulation type F=3,5GHz	DR, Mbps	Distance R, m			
		Free Space	Street Canyon	COST 231	Walfish-Ikegama
QPSK	30	12100	2740	230	90
16QAM	60	6800	1775	175	75
64QAM	90	3850	1140	110	50
Modulation type F=5GHz	**DR, Mbps**	**Distance R, m**			
		Free Space	**Street Canyon**	**COST 231**	**Walfish-Ikegama**
QPSK	30	8470	2100	160	65
16QAM	60	4750	1350	120	50
64QAM	90	2680	870	75	30

Such empirical models correspond more to reality: ***{R=0,6-0,9km, DR=20Mbps}***, than the published theoretical parameters: ***{R=50km, DR=70Mbps}.***
Characteristics of HATA-Model. Model ***COST-231/ HATA*** is a combination of ***path propagation and clearance models*** and is applied for loss coefficient on the basis of the following parameters [3,4]:

$$PL[dB] = 46.3 + 33.9lg(F) - 13.82lg(H) + (44.9 - 6.55lg(H))\cdot lg(D) + C, \quad (2)$$

where:
A – Path Loss;
F – Frequency in MHz (between 700 and 2000 MHz);
D – Distance between base station and terminal in km;
H – Effective height of base station antenna in m;
C – Environmental correction factors:

- 2dBfor dense urban environment: high buildings, medium and wide streets

- 5dBfor medium urban environment: modern cities with small parks
- 8dBfor dense suburban environment: high residential buildings and wide streets
- 10dB for medium suburban environment: industrial area and small homes
- 15dB for rolling hills and forest with residential construction penetration margin
- 26dB for rural with dense forests and quasi no hills.

Model predicts with a 50% statistical reliability. This can be increased to 70% by adding 6 dB fade margin, or to 90% by adding 10 dB fade margin in link budget.

Multicolor Ink Spot Model and Algorithm. There is approximated load model for calculation of real DR considering load parameters – user and AP number as well as their coordinates (fig.3):

$$DR = \varphi(N, P, x, y), \qquad (3)$$

where ***N*** and ***P***– user and Access Point number, (***x,y***)– AP coordinates, ***DR***– data rate, $R^2=x^2+y^2$ – distance[5].

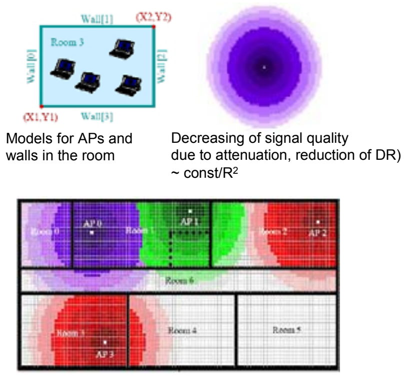


Fig.3. Multicolor Ink Spot Model and Algorithm (http://wiss.informatik.uni-rostock.de/).

The model is regularly 2D and relevant for buildings but can be scaled into 3D-model and also used under "free space" conditions. Color intensity for each of neighbor AP is decreasing by the law $1/R^2$. Frequencies number for decoupled reuse (all-round 13 by WLAN802.11) is 3 (N_{reuse}=3), that is why there are 3 the same colors. The model parameters also are:

- ***L*** – wall number, n_r – user number for the room r
- $1/n_r$ – coloration ability for the room r
- DR_{max} – max. DR for AP, for instance, for 802.11b DR=11Mbps
- DR_{min} – min. DR for DR normalized to an user, for instance, for DSL DR=1Mbps
- $C_r(x,y)$ – color intensity in the segment ***[X, Y]*** for the room r
- ***H*** – antenna height for AP, ***K*** – wall attenuation coefficient:

$$P = DRmin/DRmax \cdot \Sigma_r Nr \qquad K = \frac{1}{\prod_{0 \le l \le L} w_l} \qquad (4)$$

$D^i(x,y)^2 = x^2+y^2 = R^2$ (regular 2D-case) or $D^i(x,y)^2 = x^2+y^2+H^2$ (3D)

$C^i_r(x,y) = K \cdot DRmax / D^i(x,y)^2 \cdot 1/n^i_r$

Additionally the following variables must be defined:

- ***i,t*** – current variable for AP, iteration number
- ***l,j*** – common current variables
- ***w*** – current variable for description of wall properties (reinforced concrete, bricks, sandwich-type gypsum plaster).

Formal description of the ***Multicolor Ink Spot Algorithm*** is given below:

Step 0. ***START***
Step 1. ***FOR EACH*** (x,y) ***DEFINE*** $n_{ir}=n_r$;
Step 2. ***CALCULATE*** color intensity (according to formula ***(4)***) by $0 \le i \le P$,
$C^i_r(x,y) = \max\{C^t_r(x,y)\}$ by $0 \le t \le P$;
Step 3. ***COMPARE*** current color intensity
IF $C_r < C^i_r(x,y)$ ***AND*** $C_r > DR_{min}$
THEN $C_r = C^i_r(x,y)$;
Step 4. ***IF*** all sets ***(x,y)*** already calculated
THEN GOTO END
OTHERWEISE GOTO Step1;
Step 5. ***IF*** $C^i_r(x,y) < DR_{min}$ (i.e. color intensity isn't satisfying)
THEN $n_{ir} = C^i_r(x,y) / DR_{min}$ ***AND GOTO4;***
Step 6. ***END***

Some further features of the investigated model are:

- considering of attenuation effects of the walls
- considering of room geometry and load parameters
- considering of mutual effects from different APs and calculation of relevant user number
- calculation of limit values for distance and DR.

3. Software implementation within CANDY

Requirements to monitoring and design tools for wireless networks. With use of the automation tools the radiated power of ***AP, Access Points (802.11),*** or ***BS, Basic Stations (802.16),*** can be graphically represented (fig.4):

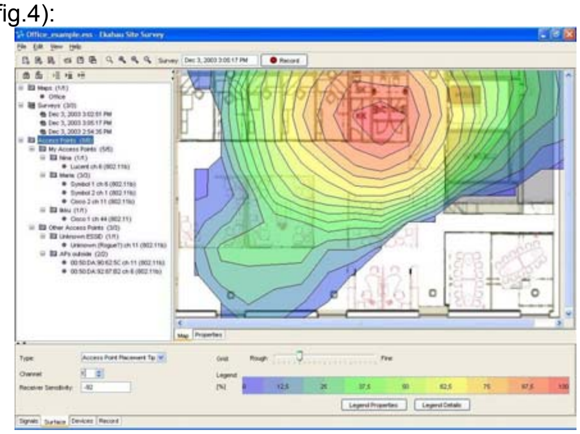


Fig.4. Visualization of WLAN design results (http://www.ekahau.de).

Parallel with manual (X,Y)-location there are also GPS-interfaces (***Global Positioning System***) frequently available to locate (X,Y) automatically. The tools for wireless networks design must satisfy to some requirements. All discussed requirements can be represented via the following table 3:

Table 3. Requirements to monitoring or simulation tools for wireless networks

Property	Monitoring and design system for WLAN/ WiMAX
Recognition of AP/ BS	+
Measurement of signal quality	+
Use of GPS–interface	Provided
Measurement analysis	+
Visualiziation of vectors (X,Y,Data)	Time diagrams of signal power, campus maps
New networks planing	2D
Modeling / Simulation	Date rate DR, radiated power S

Integration into CANDY. In this work complex models for WLAN(802.11)/ WiMAX (802.16) design are proposed. As a integrating component for design applications acts problem-oriented ***NDML - Network Design Markup Language*** [1,2], which organizes mapping of the documents for corporate networks design as well as their wireless sub-systems. A special data format ***RadioNDML for WLAN*** is used in the frame of actually created modification of the language - NDML2.0 (fig.5)**:**

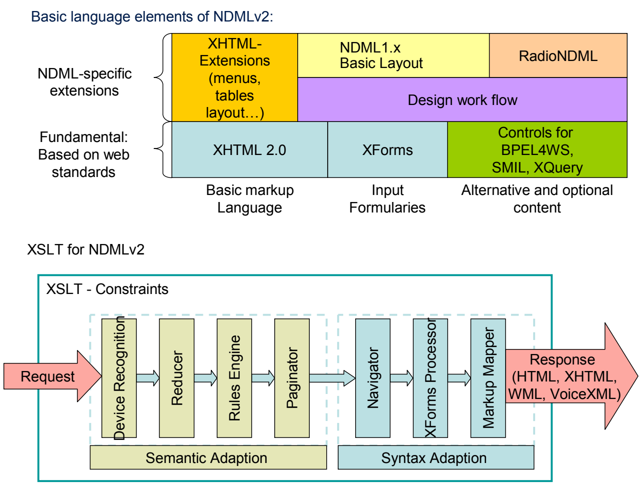


Fig.5.NDMLv2 as integration component (Orlando 2004-2005)

NDML v2 is procedural (with design workflows statements) and will be based on XHTML 2.0, XForms, SMIL, BPEL4WS and XQuery standards. Mapping into XML-DB will be optionally provided in the new NDML-Language-Profile. The XSLT-architecture for NDMLv2 transcoding is given in fig.5. XSLT-architecture elements are aimed for:

- Device Recognition – end-device supporting
- Reducer – document text reducing & normalization
- Rules Engine – document semantic checking
- Paginator/Navigator – document splitting into displayed segments and segment navigation
- XForms-Processor – forms (formulary) processing for e.g. DB-queries
- Markup Mapper – trans-coding into target formats.

NDMLv2 -content can be for design can be invariant represented on mobile end-devices with limited screen resolution and navigational abilities (PDA, mobile phone).

CONCLUSIONS

1. Well-known models and methods of WLAN/WiMAX design are examined. The above mentioned models and methods are embedded into the proposed inter-disciplinary methodology for corporate networks design, based on NDM and described via NDML, together with methods for infrastructure networks design. Those models and methods built the basic principles to implementation of software tools for WLAN/WiMAX-design.
2. ***CANDY (Computer-Aided Network Design utilitY Framework)*** possesses some evident advantages like:
   - Tools simplicity, open source freeware, free of costs
   - Use XML as main integrating component
   - Use Java as main program-technical component
   - Openness (Framework) to extension via new tools including the above mentioned
   - Orientation to Java-Tools brings possibility to manage the current versions of CANDY and to transform the framework to an Open Source Project

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