MODELS AND METHODS FOR WLAN / WIMAX- NETWORK DESIGN

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Abstract - Parallel to the traditional cabled solutions for the enterprise communication networks (CN) based on Ethernet/ ATM LANs the ***WLAN /WiMAX networks (Worldwide Interoperability for Microwave Access)*** became more significant as the wireless routes. Therefore wireless network design is closely tied to the traditional design problems for infrastructure CN. Certain models and design methods are examined below [3].

I. Wireless routes deployment

The typical deployment scenario is as it follows: those wireless routes partially substitute the building cabling sub-system and at mid-term can also be used instead of the campus subsystem or as an efficient backbone solution (Fig.1). The constellation of AP / BS for wireless networks is a complex multi-criteria/parameter optimization problem. The generalized formula for this mini-max-optimization process is given below [1-6]:

$$MinK(N, L, DR)(1)$$
$$MinN_{ap} \vert \mathrm{Max}\ \mathrm{S_{rf}}(S,d)(1a')$$
$$MinN_{ap} \vert \mathrm{Max}\ \mathrm{DR}(\mathrm{N_{user}}, d),\ \mathrm{DR} \geq \mathrm{DR_{i\,min}}(1a'')$$
$$MinN_{bs} \vert \mathrm{Max}\ \mathrm{S_{rf}}(S,d), H_{bs} \geq h(x,y) + \beta \bullet r(1b')$$
$$H_{bs} \geq h(x,y) + d^2/8 + \beta \bullet r(1b'')$$
$$(x, y_{gps})_{lower} \leq (x,y) \leq (x, y_{gps})_{upper}$$
$$\beta = 0{,}8..1$$

where K – overall cost function for enterprise CN, N_{user} – number of corresponding users, Nap – number of AP, N_{bs} – number of BS, N – number of used network devices, L – common cabling system length, DR – data rate, d(x,y) – distance Tx-Rx for AP/BS, $DRmin_i$, i=1,N_{user} – DR constraints, H_{bs} – accepted antenna mast height for BS, S_{rf}(S, d) – RF illumination surface as a function of signal power S(x,y), r – minimal radius for 1st Fresnel zone, h(x,y) – height of geometrical/geographical point (x,y), { $(X,Ygps)_{upper}$, $(X,Ygps)_{lower}$ } – absolute GPS – coordinates.

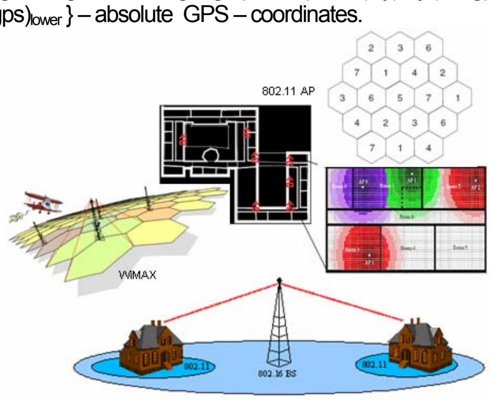

Fig.1. Up-to-date and mid-term wireless deployment integrated scenario

Among the important requirements to the used design models and algorithms for wireless networks act the following features: accuracy, complexity, relevance for defined frequency bands and propagation effects (like e.g. reflection and multi-path propagation) as well as the requirements to LOS, indoor/outdoor, used frequencies and maximal range Tx-Rx, certain environmental limitations (used materials, types of walls, roofs, streets, hills etc.) [7-16]. Generally RF signal strength is weakened [9] via the following EM-wave propagation effects (fig.2):

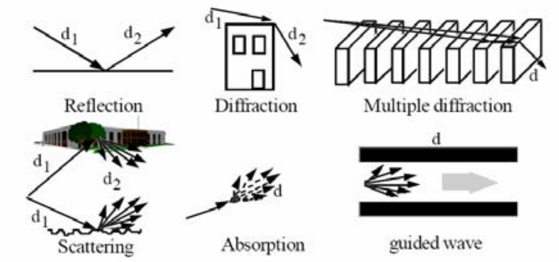

Fig.2. Modeled propagation effects for wireless communication

II. Visualization and positioning methods for wireless design

The classification of existing models and in CANDY used visualization-positioning algorithms is given in Fig.3. Empirical and semi-empirical models are not satisfying accurate; sometimes they do not work well with higher frequencies or locality/ environment types. The ray-optical models combine acceptable complexity degree (***O***(***n***^{2})) and accuracy; they are relevant practically for each frequency bands or environmental types [11,3].

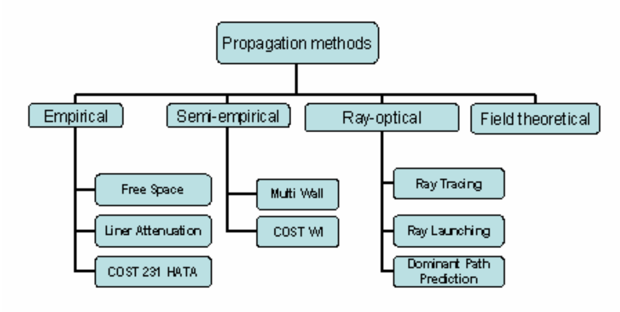

Fig.3. Visualization and positioning algorithms for WLAN/WiMAX

Some important methods are relevant for WLAN/WiMAX indoor/outdoor and CANDY framework implementation are discussed below (Table 1):

Table 1. Visualization and positioning algorithms for WLAN/WiMAX

Nr.	Method/ Model	Network deployment	Description	Implementation in CANDY
1.	Free Space [9]	All types (in/outdoor)	empirical, path loss $L = \alpha /(RF)^2$, sometimes 2-tier	+
2.	MWM, Multi-Wall Model [11]	WLAN 802.11 indoor	Ray-optical, loss coefficients L_i via interaction with walls (without dispersion) calculated, considering of material type γ and distance R	+
3.	Multi-Color Ink Spot Alg., MCISA [16]	cellular WLAN 802.11 indoor	empirical; DR and signal quality S are calculated with considering of room geometry, used frequency and cell reuse pattern $D / R = \sqrt{3Ncluster}$, user quantity N and profiles QoS	+
4.	COST WI Model [15]	GSM+, WiMAX 802.16 outdoor	semi-empirical, n-tier path loss coefficients considering in dependence on R, roof heights and streets widths w; based on COST 231 and Walfisch-Bertoni: $L = L(HTx, Hroof, HRx, w)$, ***F=0,8-2GHz, d<5km***	+
5.	Digital Height Maps/Clearance Model [9,14]	WiMAX 802.16 outdoor	calculation of Tx/ Rx heights, antenna downtilt angles on given digital maps with considering of clearance and Fresnel zones	+
6.	Ray Tracing [15]	WiMAX 802.16 outdoor	ray-optical, path loss coefficients calculation via ray tracing with considering of environment interaction (walls, hills, roofs) and primary and secondary sources, NP-complexity problem	not implemented due to high computational complexity
7.	Ray Launching [15]	WiMAX 802.16 outdoor	ray-optical, path loss coefficients calculation via ray launching from primary and secondary sources; fusion of all rays into bundles with considering of environment interaction (walls, hills, roofs), NP-complexity problem	not implemented due to high computational complexity
8.	Dominant Path Prediction, DPP Model [12]	WLAN 802.11/ WiMAX 802.16 indoor/outdoor	ray-optical, path loss coefficients calculation via considering of 2-3 the most important rays with their interaction with environment (walls, hills, roofs); computational complexity reduced	planed in 2006

III. Design examples

Due to consequent optimization routines deployment a suboptimal by Bellman constellation (Tx, Rx) for WLAN802.11 AP/WiMAX 802.16 BS can be obtained.

Design example for WLAN 802.11. In the most cases for design of WLAN 802.11 a cellular structure is recommended. Let us consider indoor WLAN combined with Ethernet 802.3 for on a example of a university building (with lecture halls, laboratories, computing center). The mini-max problem has to be solved:

$$MinN_{ap} \mid \mathrm{Max}\ S_{rf}(S,d) \quad (2)$$

$$MinN_{ap} \mid \mathrm{Max}\ DR(N_{user}, d),\ DR \geq DR_{i\,min} \quad (2a),$$

$$i = 1, N_{user}$$

An optimized AP constellation obtained via CANDY Site Finder is given in Fig.5.

Design example for WiMAX 802.16. For instance, an enterprise campus is illuminated via WiMAX BS 802.16a antenna (in mid-term: F=3.5 - 5.8GHz in Russia and Ukraine, Germany and other European countries). The LOS-contact for Tx-Rx is necessary. The penetration conditions for 1st Fresnel zone are proved by specified distance, heights for Tx-Rx antennas and given downtilt angles ***ang(x,y)***:

$$MinN_{bs} \mid \mathrm{Max}\ S_{rf}(S,d) \quad (3a)$$

$$ang(x,y) = arctg(3{,}28 \bullet (H_{bs} - h(x,y)) / 3274 \bullet d)$$

$$H_{bs} \geq h(x,y) + \beta \bullet r \quad (3b')$$

$$H_{bs} \geq h(x,y) + d^2/8 + \beta \bullet r \quad (3b'')$$

$$(x, y_{gps})_{lower} \leq (x,y) \leq (x, y_{gps})_{upper}$$

$$\beta = 0{,}8..1$$

where ***d*** – distance, ***r*** – minimal radius of 1[st] Fresnel zone. In Fig.6 the deployment of ***CANDY Site Finder*** [1-5], a tool for optimal constellation of WiMAX 802.16 BS, is represented. Digital height maps, building plans, input data and computation results can be described in the following well-known and proprietary formats: JPG, PDF, Python CAD XML, NDML, RadioNMDL, ifc XML.

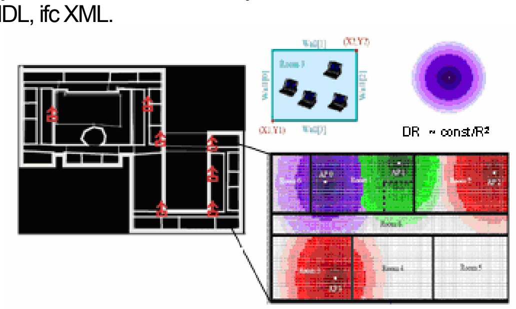

Fig.4. CANDY: 802.11 WLAN AP constellation, DR and RF distribution via MCISA

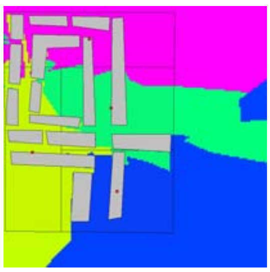

Fig.5. CANDY: 802.16 WiMAX BS constellation and RF coverage via COST WI

Conclusions

Wireless routes are widely used in the frame of integrated enterprise networks design and parallel to the wired infrastructure built via IEEE 802.3 and SCS EN50173. The wireless networks design methods and models are examined in this work. The described CANDY Site Finder tool implements certain efficient semi-empirical and ray-optical methods and can be deployed for optimization of AP/BS constellation of IEEE 802.11 AP and IEEE 802.16 BS. The digital height maps, building plans, input parameters and visualization of computation results can be described via several wide-spread graphical formats as well as via the NDML/ RadioNMDL format implemented especially for CANDY Framework.

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Glossary

AP – Access Point
BS – Base Station
CANDY – Computer-Aided Network Design utility, Java-framework for an efficient XML-based integrated network design environment developed via CANDY@TUD initiative.
CANDY Site Finder – Java/XML-based design tool for WLAN/WiMAX networks
CN – enterprise communication/computer networks
DR – data rate
GPS – Global Positioning System, international satellite-based navigation system
LOS – Line-of-Sight
NDML – Network Design Markup Language), XML-based problem-oriented language developed for representation of design data and workflow
QoS – Quality of Service
RF – radio frequency
Rx – receiver
SCS – structured cabling system
Tx – transmitter
WiMAX – Worldwide Interoperability for Microwave Access