A FIELD-VALIDATED LOCATION CONSCIOUS QOS PREDITION TOOL FOR WLL NETWORKS

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Abstract: Wireless Local Loop (WLL) has become a viable alternative for the last mile problem, especially for emerging countries. However the success of a large scale deployment of such a technology relies on careful network planning taking into account existing building layout to achieve predictable quality of service (QoS) for each customer. This paper proposes an approach where actual geographical layout of the area to be covered is taken into account to distinguish line-of-sight (LOS), Obstructed Line-of-sight (OLOS) and non-LOS (NLOS) regions and uses adequate propagation models for each case. By doing so a more accurate prediction on achievable QoS is possible for each point of the area. The output of the tool is a point-by-point quantitative measure of received average signal strength prediction and an optimized overall coverage quality. Finally, field measurements and benchmarking were used to validate the approach adopted.

1 INTRODUCTION

In a net savvy world, broadband internet is as important as having access to the power grid. Large areas of the developing world still lack today the wired infrastructure on which xDSL can run. Given the prohibitive cost of running such installations, a WLL solution is really the only viable alternative. But unlike a twisted pair channel, which offers a dedicated channel with highly predictable bandwidth for a given distance from the local office, a WLL operates over a channel which depends not only on distance but also on actual obstacles between transmitter and receiver. In order for an operator to guarantee a QoS for its customers, an accurate prediction of achievable performance for each customer is required taking into account actual position of base transceiver station BTS, customer premises equipment (CPE) as well as landscape. This paper proposes a field validated, benchmarked, Geographic Information System (GIS) based tool providing point by point received signal strength prediction and a simulation-based BTS placement optimization algorithm. Next, Section II discusses the system model. Section III covers the propagation models and tool description. Section IV presents validation methodology and results, before the last section draws some conclusions and proposes future work directions.

2 SYSTEM DESCRIPTION

In order to accomplish the goals set for this research, an awareness of the exact layout of propagation environment between transmitter and receiver had to be harnessed. This feat was accomplished in a two stage process: first, natural elevation of the area had to be taken into account and for the purposes of our work the Digital Terrain Elevation Data (DTED) files made available by National Imagery and Mapping Agency (NIMA) were used. Second, actual buildings laying in between transmitter and receiver needed also to be taken into account, we made use of a GIS map (in the publicly available ESRI shapefile format; (ESRI shapefile 2008) of the desired area. This map provides not only delimiting points of each building in the area of interest but also their height.

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The height information is not complicated to get as cities obey strict zoning regulations that determine for every zone building heights. By combining this information we are able to accurately distinguish LOS, OLOS and NLOS areas. The combination of elevation information and GIS map gives the system a complete knowledge of the propagation environment as Figure1 shows.

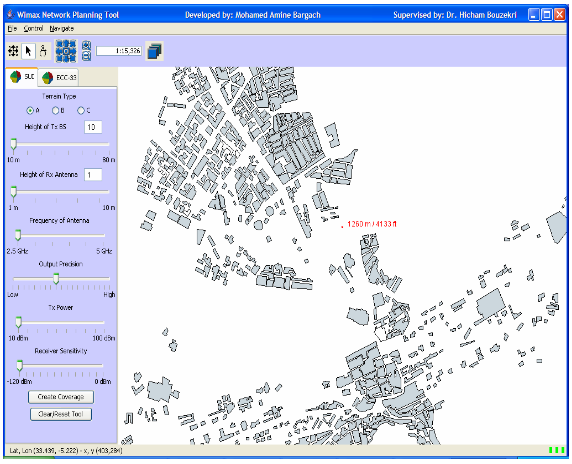

Figure 1: Tool display of a Map of the Azrou Region (Morocco).

3 PROPAGATION MODELS AND TOOL DESCRIPTION

3.1 Propagation Models

Given that interest in this study is average received signal strength in an urban environment, a deterministic channel model approach (such as ray tracing) is clearly unusable. Although Ray tracing is very popular among researcher in this area, we think that given the high number of reflections arriving at the receiver and their dynamic nature, it would be unreasonable to exhaustively enumerate and track them. The assumption of a few dominant paths is also inaccurate in the case of NLOS. The only valid approach for a dynamic urban layout is to use empirical propagation models (Rappaport, T, 1996). However the models for LOS, OLOS and NLOS environment are vastly different. In our approach, for every point in the map, a line-of-sight assessment is applied between the location of the BTS and each potential receiver antenna position. The tool uses an OpenMap API to import ESRI shapefile of the area augmented by DTED.

In case of a Line of Sight (LOS) environment, the Free Space Loss (FSL) (Rappaport, T, 1996) model is used, provided the first Fresnel zone is clear. This is a reasonable assumption as although transmitted signal reflected replicas do arrive at the receiver in the case of an urban environment, the receiver will lock on the highest-power first arriving path.

The second possible case is that of OLOS. In case an obstruction is within the First Fresnel zone, whose width depends on the transmission frequency, neither the LOS nor the NLOS models are appropriate. After a careful review of appropriate models to be used for this case, the choice was made to adjust the LOS path loss with an Excess Path Loss (EPL). The most appropriate method for calculating EPL was found to be the Deygout method (Saunders, 2006). As Figure 2 shows all edges (obstructions) in the Fresnel zone are taken into account. In this illustration the main edge (closest to the LOS path) defines two sub-paths. The method is then recursively applied to these sub-paths

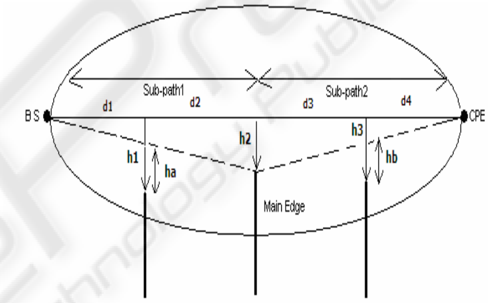

Figure 2: Edges inside Fresnel zone.

For a single edge in the Fresnel zone, the EPL is given by the following formulas:

$Gd = 0$ for $v < -1$

$$Gd = 20 * \text{Log}_{10} (0.5 - 0.62 * v) , -1 < v < 0 \qquad (1)$$

$v = h/r \, \text{sqrt}(2)$ & $r = \text{sqrt} (2(d1+d2)/(c/f)(d1.d2)$

h being the negative height of the main edge compared to the LOS path; d1 is the linear distance from BS to the edge and d2 the distance from the main edge to the CPE. f is the carrier frequency and c the speed of light.

Naturally, in an urban deployment of a Wireless Local Loop (WLL), some of the CPEs, if not most, lack the privilege of having this clear, unobstructed line of sight to the BTS. Consequently, empirical propagation models have to be used in (Abhayawardhana, 2005), three models were evaluated, namely the Stanford University Interim (SUI) model, the COST-231 Hata model and the ECC-33 model which showed the closest agreement with the measurement results. In our paper both models (ECC-33 and SUI), (IEEE 802.16 standards, 2008) will be simulated to validate against measured results.

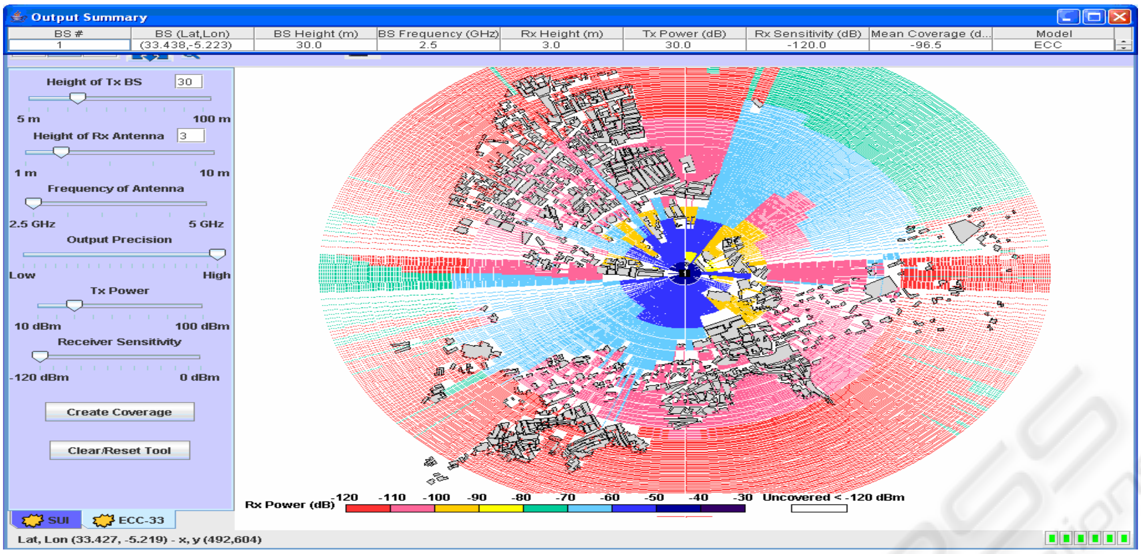

Figure 3: Predicted Coverage of the Azrou region (Normal Mode).

3.2 Tool Description

The Graphical User Interface (GUI) of the tool allows the operator to enter all relevant information for the simulation such as carrier frequency, height of BTS and CPE, transmitter power and sensitivity of the receiver as well as desired precision of the output map. This last parameter directly impacts the run time. The operator can then either pinpoint the position of the BTS or make use of an optimization algorithm for positioning the BTS.

Theoretically the algorithm would attempt all possible locations for the BTS, however network planning obeys business constraints. The tool expects from the operator axes (typically along major avenues) along which to search for optimum positions. In the case of multiple BTSs, the exponentially complex algorithm of finding joint optimum positions can be replaced with disjoint local optimum positions. This trade-off allows for faster convergence of the algorithm at the expense of the precision for the proposed placements.

QoS has taken various meanings depending on the context it is being used in. For the work presented in this paper, we are interested in the average received signal strength as an indicator for QoS, either the area average for the optimization algorithm or individual for each point in the map. For example the 802.16 standards (Wimax Forum, 2008.) tie the signal strength received to different modulation formats used (from 64 QAM to QPSK) translating into different data rates and different error rates and hence different QoS.

4 SIMULATIONS AND TOOL VALIDATION

This section presents results obtained: the first subsection displays graphically the point-by-point received signal strength prediction while the second subsection details the approach and the results of the tool validation.

4.1 Simulations

Figure 3 shows the output of the tool for the Azrou region in Morocco. The different colors highlight different received signal strengths with a scale displayed in the bottom and a summary table on top displaying BTS number, position (latitude and longitude), height, frequency and overall area average received signal strength.Figure. 4 shows the output of the optimization algorithm for three BTS. Each BTS position is optimized along a separate axis to achieve overall best average Rx power.

4.2 Tool Validation

In order to validate the estimates provided by the tool, field measurement campaigns had to be conducted. This section details the approach used and the results obtained.

Through a university-operator partnership a street signal strength measurement campaign was held in the city of Rabat during summer 2007. The area of the city where measurements were conducted

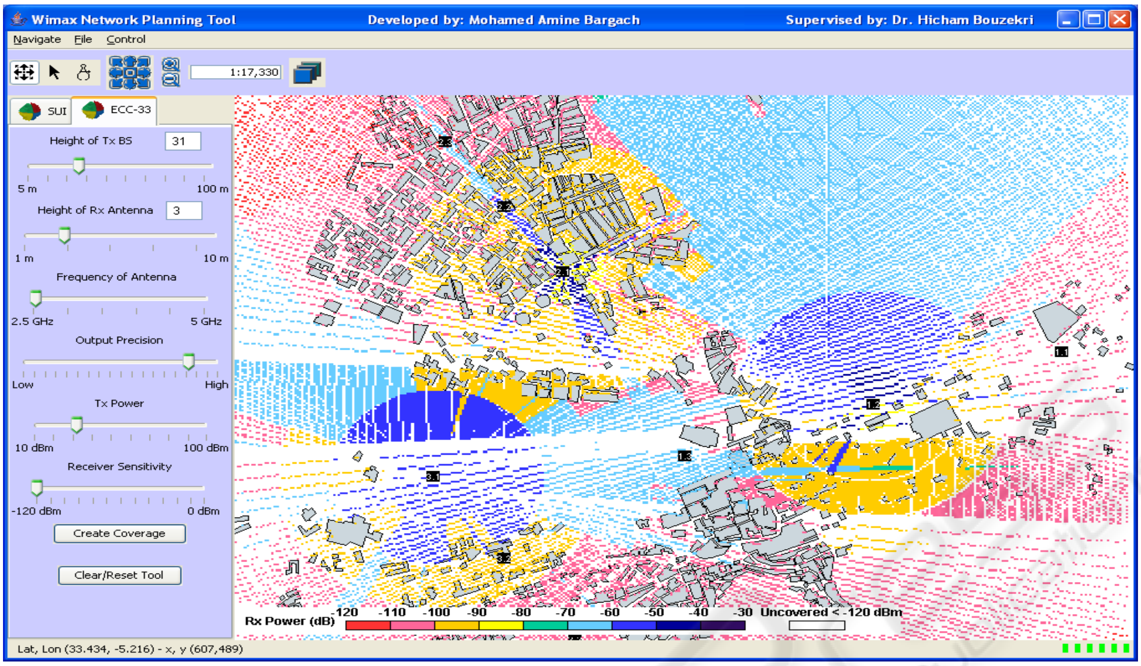

Figure 4: Optimized positions for 3 BTS.

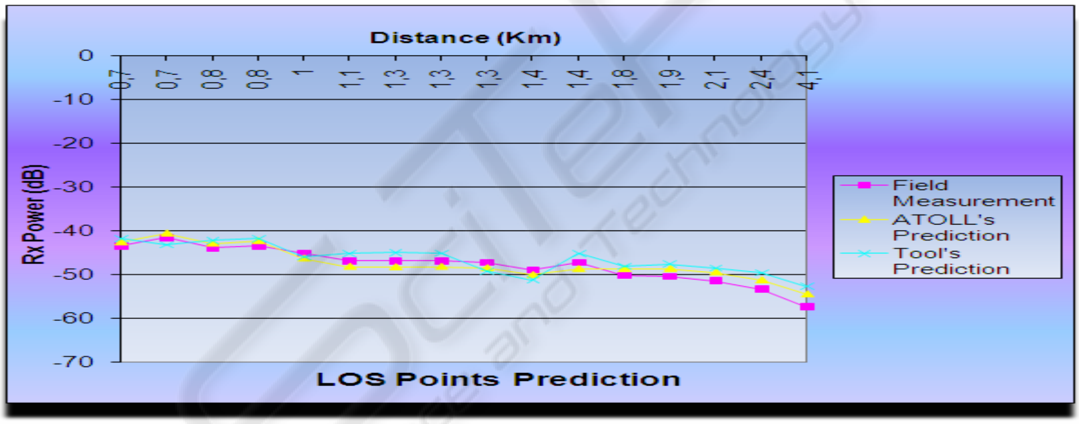

Figure 5: Comparison with measured values LOS areas.

is a medium density city with up to 5-floors buildings. The interest was not in determining instantaneous signal strength but rather time average signal strength as these were influencing the QoS the operator was able to provide.

The operator had several CPEs deployed around the city and a centralized control and monitoring system collected regularly signal strength signals received at CPEs. Most of the installed CPEs were in a LOS configuration, and the collected measurements were used to validate the estimates obtained by the tool. To complete this study a field measurement campaign was conducted using a spectrum analyzer and an omni-directional antenna mounted on a vehicle. In addition to LOS areas, the campaign targeted OLOS and NLOS areas in increasing distances from the BS.

As the operator was using a commercial RF planning tool (ATOLL), we have run a simulation to obtain a commercial tool benchmark for our tool. In order to validate each propagation model separately the results were categorized as either LOS, OLOS or NLOS.

For areas having an unobstructed LOS view of the base station of the WLL, the results obtained by the tool are very close to the benchmark commercial tool and are almost identical to the field measured values as can be seen from Figure 5.

The good match between these results can be considered a validation of the FSL model of

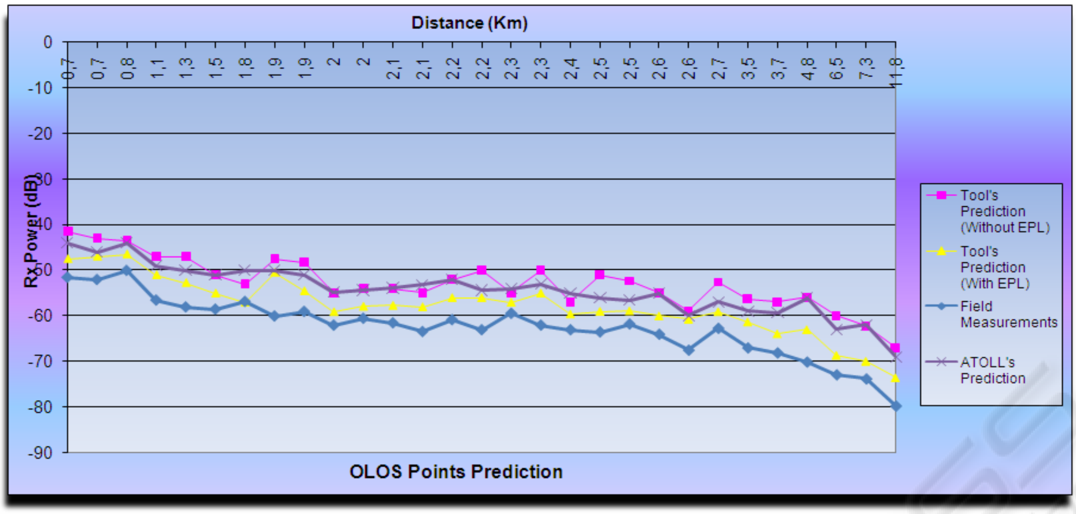

Figure 6: Comparison with measured values for OLOS areas.

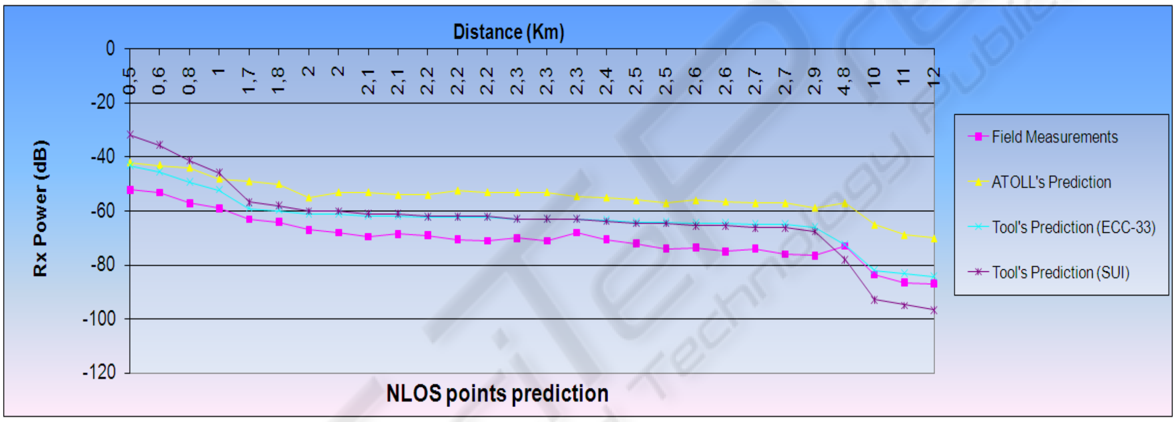

Figure 7: Comparison with measured values for NLOS areas.

propagation. One possible justification for these results is that even through reflected paths will arrive at the receiver, the synchronization loop within the receiver will lock on the first strongest path, which is the LOS path, disregarding reflected ones which will present minor interference.

Table 1: RMS error for OLOS areas.

Model used	Error RMS
Commercial Benchmark tool	8.38
Developed Tool without EPL	9.89
Developed Tool with EPL	5.11

Areas having one or several obstructions within their First Fresnel zone were classified as OLOS areas. Figure 6 shows that the addition of the EPL considerably improves the adherence of the results compared to measured signal strengths. Quantitatively the Root Mean Square (RMS) of the error compared to measured values was assessed and is given in Table 1.

Finally for NLOS area, two models were potentially suitable: the ECC-33 and the SUI. Both simulations were run to compare the adequacy for our terrain. From Figure 7, ECC-33 seems to give the closer results to the field measurements. Quantitatively, Table 2 gives the average RMS error.

Table 2: RMS error for NLOS areas.

Model used	Error RMS
Commercial Benchmark tool	12.94
Developed Tool ECC33 model	6.8
Developed Tool SUI model	8.11

5 CONCLUSIONS AND FUTURE WORK

This paper presented the work conducted to develop and validate a WLL planning tool. The approach adopted in this paper was to use a GIS map of the area to categorize the areas to be covered depending on the presence of any obstructions between receiver and transmitter. Three categories were retained: LOS, OLOS and NLOS and appropriate propagation models were used for each. The tool developed provides a GUI based proposed BTS positions or a simulation-based algorithm to propose optimized placement. As with any QoS and prediction tool, ultimate validation comes from field measurement campaigns. Thanks to a partnership with a local operator, access to collected measurements and equipment to conduct further measurements provided an environment for validating the tool. As results showed, the tool prediction fared well and gave in certain conditions better results than benchmark commercial tools. The approach adopted is hence validated by a 40% improvement in RMS error for the OLOS case and a 47% improvement for the NLOS case compared to commercial benchmark. Another interesting observation is that SUI model tend to give excessively optimistic results for distances of less than 1 km and excessively pessimistic results for distances above 10km compared to ECC-33 model. Future work includes a larger scale validation campaign in different propagation environments and the introduction of calibration parameters to better fit different terrains and propagation environments.

REFERENCES

Stallings, W., 2005. *Wireless Communications & Networks*, Prentice Hall, New Jersey, 2nd edition

Anderson H. R., 2003. *Fixed Broadband Wireless System Design*. John Wiley & Co.

Athanasiadou G. E., Nix A. R., and McGeehan J. P. March 2000. "*A microcellular ray-tracing propagation model and evaluation of its narrowband and wideband predictions*" IEEE Journal on Selected Areas in Communications, Wireless Communications series, vol. 18, pp. 322–335.

Olexa R., 2005. *Implementing 802.11, 802.16, and 802.20 Wireless Networks. Planning, Troubleshooting, and Operations*. Elsevier Press.

Abhayawardhana V.S., Wassell I.J., Crosby D., Sellars M.P., Brown M.G., 2005. *Comparison of empirical propagation path loss models for fixed wireless access systems*, VTC 2005-Spring. IEEE 61st Volume 1, Page(s): 73 - 77 Vol. 1

Rappaport, T, 1996. *Wireless Communications Principle and Practice*, Prentice Hall.

Wimax Forum, 2008. Website, *http://www.wimax.com/*

Saunders S. R., 2006. *Antennas and Propagation for Wireless Communication Systems*, Agilent Technologies Press.

Moussaif Y., 2007 *Validating and Enhancing a WIMAX Network Planning Tool*. Master's Project Report, Al AKhawayn University, Ifrane Morocco.

Bargach, M. A. 2006. *Wimax Network Planning tool*, Master's Project Report, Al AKhawayn University, Ifrane Morocco.

Bouzekri, H., Bargarch, M. A., 2007 *QoS prediction and coverage optimization for WIMAX Networks*, Proceedings ICTIS07, Fez Morocco.

IEEE 802.16 standards, 2008. Website,, http:// *www.ieee802.org/16*

ESRI shapefile, 2008. Website,, *http://www.esri.com/*