Signal Power Loss Prediction in a Micro-cellular LTE Network Employing an Enhanced Adaptive Combined Vector Order Statistics and Muti-Layer Perceptron Artificial Neural Network Model

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ABSTRACT

This work presents a resourceful predictive model, built on multi-layer perceptron (MLP) network with vector order statistic filter based pre-processing technique for an enhanced prediction of measured signal power loss in a microcellular LTE network environment. The predictive model is termed Vector statistic filters multilayer perceptron (VMF-MLP). The predictive abilities of the models are measured in terms of performance indices: correlation coefficient, root-mean-square error, standard deviation, mean absolute error and coefficient of efficiency, results show that VMF-MLP model prediction performs considerably better than the standard MLP model prediction approach on signal power data collected from different study locations in typical urban terrain.

Keywords

Signal power loss prediction, artificial neural network models, multi-layer Perceptron network, noisy data, vector order filtering.

Introduction

Path loss models are employed to estimate and predict the signal attenuation loss in any cellular radio communication environment for planning network and optimization purposes through prediction error reduction. Some of the basic available traditional models in literature for path loss prediction includes: Free space, Lee, COST 234 Hata, Hata, Walficsh- Bertoni, Walficsh-Ikegami, dominant path and ITU models. However, as a result of poor accuracy in prediction and lack of computational efficiency of these traditional models [1-3], many researchers have shifted their focus to the domain of artificial neural networks (ANN) models.

In this work, a combination of non-linear data filtering-based denoising method and MLP neural network model is proposed for improved prediction signal power loss using measured microcellular signal power dataset from LTE cellular network.

Mathematical Models used

Vector Median filters (VMF):

$$f(x) = \sum_{i}^{N} \left| x_i - x \right| \qquad (1)$$

$$f(x_{med}) \le f(x_i) \vee x_i, x_{med} \in \{x_i, i = 1, \ldots N\}$$

Where x_i defines the k dimensional vectors $\left[x_i, x_{i2}, x_{i3}, \ldots x_{ik}\right]^T$.

Vector L filters (VLF):

$$Tn = \sum_{i}^{N} a_i x_{(i)}, \text{ where } \sum_{i}^{N} a_i = 1 \qquad (2)$$

a_i's expresses the set of weights which describes the performance of the estimators.

Multilayer Perception Neural Networks:

$$y_i = f_o\left(\sum_{j=0}^{N} w_{jq}\left(f_h\left(\sum_{i=0}^{N} w_{iq} x_i\right)\right)\right)$$

for q=1, 2, ... (3)

$$E(w) = \frac{1}{2}\sum\left(y_q - y_q\right)^2 = \frac{1}{2}\sum_{q=1}^{N} e_q^2 \qquad (4)$$

where: $e_q = y_q - y_q$, with y_q and y_q indicating the desired target output value and the actual network value, respectively.

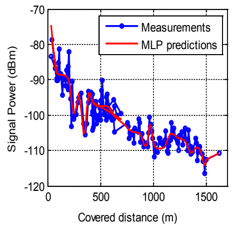
Methodology: Neural Network Training with MLP, VMF-MLP and VLF-MLP Models.

A 2013a MATLAB software platform was employed to implement the models. For optimal neural networks learning and training with the three investigated models, the measured signal dataset was shared into three subsets as follows: a training set (75% of the data), testing set (15% of the data) and validation set (15% of the data). The early stopping method was employed to cater for over-fitting during training. The training embroils the connection weights adjustments such that the network is able to predict the assigned value from the member training set. Levenberg–Marquardt training algorithm was utilized to ascertain the training capabilities of the investigated MLP, VMF-MLP and VLF-MLP schemes.

Results, Performance Evaluation Criteria and Discussion

Figures 1(a,b,c) to 3(a,b,c) show the measured signal power and their predictions in locations 1 to III, using MLP, VLF-MLP and VMF-MLP models. Table 1 shows the summarized performance results of the three neural network models employed to predict the measured signal power, using MAE, RSME, STD, COE (%) and R indices. A closer value of R and COE (%) to 1 and 100, respectively, indicates better performance in predicting or fitting the actual data. On the other hand, the lower the values of MAE, STD and RMSE are, the better the neural network model prediction performance. From Table 1, it is established that VMF-MLP and VLF-MLP models attained the lowest MAE, RSME, STD values in the three study locations, when compared to MLP model. Similarly, VMF-MLP and VLF-MLP models also attained the highest prediction accuracy in terms of R and

COE, as compared to other models in the three study locations.



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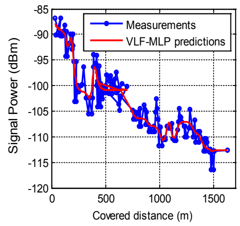

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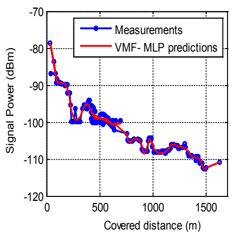

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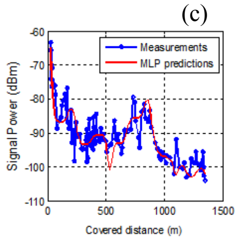
Figure 1: Signal power predictions with (a) MLP, (b) VLF-MLP, (c) VMF-MLP models versus covered distance in BS site I



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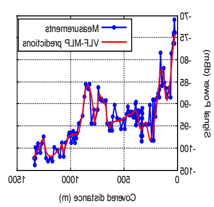

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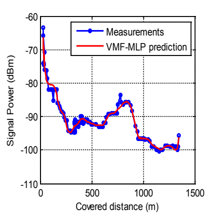

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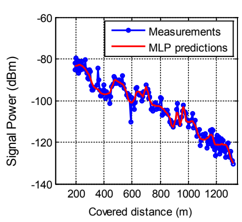
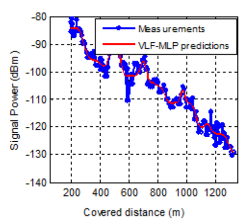
Figure 2: Signal power loss predictions with (a) MLP, (b) VLF-MLP, (c) VMF-MLP models versus covered distance in BS site II



(a)



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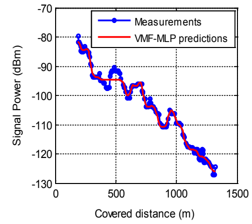

(c)

Figure 3: Signal power loss predictions with (a) MLP, (b) VLP-MLP, (c) VMF-MLP model versus covered distance in BS site III

Table 1: Computed first order statistics with MAE, RSME, STD and R for Locations 1- 3

	MLP Model Prediction				
Location	**MAE**	**RMSE**	**STD**	**R**	**COE (%)**
.0 I	2.071	2.777	1.849	0.931	86.83
II	1.992	2.529	1.557	0.982	96.49
III	2.677	2.642	2.642	0.872	76.16
	VMF-MLP Model Prediction				
I	0.696	1.079	0.825	0.988	97.61
II	0.867	1.229	0.870	0.995	99.14
III	0.784	1.271	1.001	0.982	96.59
	VLF-MLP Model Prediction				
I	1.464	1.947	1.284	0.957	91.64
II	1.587	2.129	1.459	0.987	97.42
III	1.663	2.285	1.567	0.941	88.62

Conclusion

The vector order statistics filters based pre-processing technique have been exploited in this work to improve adaptive trend prediction of stochastic noisy signal power data using ANN model. The proposed predictive approach is termed Vector statistic filters multi-layer perceptron (VMF-MLP). By means of different performance indices such as coefficient of efficiency, correlation coefficient, standard deviation, root mean squared error, and mean absolute error, the adaptive prediction results on LTE signal power data collected from three different study locations in urban terrain demonstrated that VMF-MLP model performs considerably better compared to standard MLP prediction approach. This rightly implies that the pre-processing of the information content in datasets enhances its training and prediction accuracy with neural network models.

References

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