# Evaluation of Geostatistical Analysis Capability in Wireless Signal Propagation Modeling

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## 1. Introduction

Radio signal path loss is a particularly important element in the design of any radio communication system or wireless system, and it is necessary to be able to determine the levels of the signal loss for a give radio path. The more accurate model the better decision making will occur for the network rollout, planning and optimization. The radio signal path loss could be estimated by many elements of the radio communications system in particular the transmitter power, and the antennas, especially their gain pattern, height, azimuth and also are highly influenced by clutters (land use), terrain height and morphology, spatially related parameters. Okumura-Hata empirical model, which has many parameters, is the most common model for prediction and estimation of this complicated phenomenon.

On the other hand, geostatistical techniques offer interpolation methods for describing the continuity of spatially/temporarily variable data which is essential feature of many natural phenomena. Over the last decades, this theoretical framework has been successfully applied in other type of spatial problems (Konak, 2010). As it is mentioned above signal path loss is highly influenced by spatial parameters, therefore geostatistics has high potential to be implemented for such purpose (Arpee J. et al., 2000).

There are few researches conducted using geostatistical techniques for modelling wireless propagation models. In a recent paper, Konak (2009) reports that ordinary kriging is competitive with radial basis ANNs to estimate the signal-to-noise ratio in cellular wireless networks. Konak in 2010 extends the ordinary kriging approach proposed in 2009 by considering path loss due to obstacles and other factors in indoor environments. In this paper we have compared the result of different spatial and non-spatial interpolation techniques with Okumura-Hata empirical model to evaluate geostatistical analysis capability to find a way of having more accurate mobile coverage models. As the result, this research will help us to have RF path loss trend estimation which is extracted from sampled data to describe data variability across the entire cellular system areas.

The area of interest is a city in west of Iran. Okumura-Hata, Inverse Distance Weighting (IDW- a non-spatial interpolation technique) with different power and number of neighbour and different type of kriging (ordinary & universal) with different semi-variogram model and number of neighbours are used to model RF propagation in study area. Finally, the result of all interpolation methods are compared using the check points of real data.

# 2. Research background

In this section, a brief description of Okumura-Hata empirical model and also geostatiscal interpolation technique, kriging, are presented.

## 2.1. Okumura-Hata empirical model

Path Loss (L) is a measure of the reduction in power density of an electromagnetic wave as it propagates through space (Konak, 2010). The method analyzes raw RF power data that is collected by drive testing a sample of roads in a cellular system. Radio Propagation predictions are mainly used to demonstrate how the mobile signals are scattered in the environment as well as how strong the signals are in different places. however, there are various factors influencing the radio propagation prediction accuracy such as reflection, diffraction, scattering, transmission, refraction, etc.

This method is used for cellular system planning and management, the one which is used is the standard macrocell model which is based upon the Okumura-Hata empirical model with a number of additional features to enhance its flexibility. The model has a number of features that enhance its flexibility and accuracy such as the inclusion of clutter offsets and heights and the use of diffraction. The Okumura-Hata model has the following validity range:

- The distance from the site between 500 m and 30 Km
- Antennas height in the range of 15-200m
- Receiver heights in the range of 1-10m
- Frequency: 150…1000 MHz and 1500…2000 MHz
- MS height**:** 1 m…10 m

The data needed for computation using this data are in two categories, (a) data related to the antenna such as antenna gain, pattern, height, azimuth, power, etc (b) mapping data including terrain DTM and terrain clutter (land use).

The model has a large number of parameters and options which may be selected or calibrated by the user in order to obtain a close representation to measured propagation data. Since network simulations are very time consuming, the choice of the macrocell propagation model is a trade off between prediction accuracy and computational efficiency. For this reason the standard Okumura-Hata macrocell model has been chosen. The basic equation used in the path loss calculation is given as follows (Equation 1, Table 1) (Aircom Tech Doc, 1999):

$$PL(d) = K1 + K2.\log(d) + K3.Hms + K4.\log(Hms) + K5.\log(Heff) + K6.\log(Heff).\log(d) + K7.Ldiff\_Losses + Lclutter\_Losses \quad \text{(Equation 1)}$$

Where:

| | |
|---|---|
| **k1 & k2** | Intercept and Slope. These factors correspond to a constant offset (in dBm) and a multiplying factor for the log of the distance between the base station and mobile. |
| **k3** | Mobile Antenna Height Factor. Correction factor used to take into account the effective mobile antenna height. |
| **k4** | Okumura-Hata multiplying factor for Hms. |

| | |
|---|---|
| **k5** | Effective Antenna Height Gain. This is the multiplying factor for the log of the effective antenna height. |
| **k6** | Log (Heff)Log(d). This is the Okumura-Hata type multiplying factor for log(Heff)log(d). |
| **k7** | Diffraction. This is a multiplying factor for diffraction calculations. A choice of diffraction methods is available. |
| $\mathbf{P_L}$ | the path-loss in dB |
| **d** | the distance between the BS and the MS in meters |
| $\mathbf{h_{MS}}$ | the height of the MS in meters |
| $\mathbf{h_{eff}}$ | the BS effective antenna height in meters |
| **Diff_Losses** | the diffraction losses and Clutter_Losses are the losses associated with the clutter types. |

*Table 1 - Model Parameters*

### 2.2. Geostatistics

Kriging is a geostatistical technique to interpolate the values of a random spatially/temporarily field value in an unobserved location from observed nearby locations. It was developed by Krige (1951) and Matheron (1963) to accurately predict ore reserves from the samples taken over a mining field. There are different types of kriging such as ordinary, universal, indicator, disjunctive kriging [Krivoruchko K., 2001]. In Kriging, the prediction is based on semivariogram which is function of distance and is highly dependent of researcher's experience (Yoo S., 1994). There are different models which are used for modeling semivariogram such as spherical, gaussian, exponential and circular (Zimmerman DL et al., 1991)

## 3. Method

This paper is a part of an ongoing research to test and use the capability of geostatistical analysis for coverage predicting, simulating and tuning. The goal of this research is to test different interpolation techniques in coverage prediction. Method presented here, analyzes raw data that is collected by drive testing a sample of roads in study area (Figure 1). First this data were processed to eliminate gross errors and duplicate values. Here 58029 point data are collected.

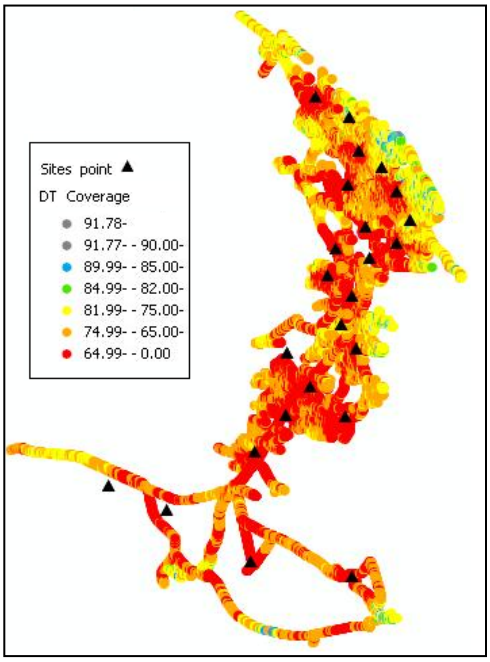


**Figure 1- raw data that is collected by drive testing a sample of roads in study area**

Different continuous surface are created using different interpolation methods. To compare the interpolation methods used here, we have selected 15417 as check points, to be able to compare the predicting values of different type of techniques. Although kriging, could be evaluated by error prediction analysis which is one of the advantage of this technique but we used check points to be able to compare the result of this technique with non-spatial interpolation technique. To have check points in different locations, they are selected by creating a grid network (Figure 2). So 42612 points are used for prediction and 15417 points are used as check points.

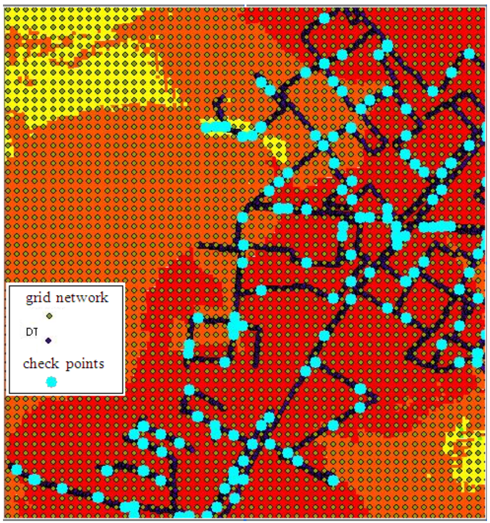


**Figure 2- Check points selection using grid network**

After the steps of data preparation, different surface using Okumura-Hata model with optimum factors and different interpolation methods are created. The interpolation methods used here are Inverse Distance Weighting (IDW) with different power and number of neighbours, ordinary kriging and also universal kriging with gaussian, spherical, circular and exponential models for semivariogram with differnt number of neighbors. In following figure (Figure۳ ) surfaces created by some of used methods are depicted.

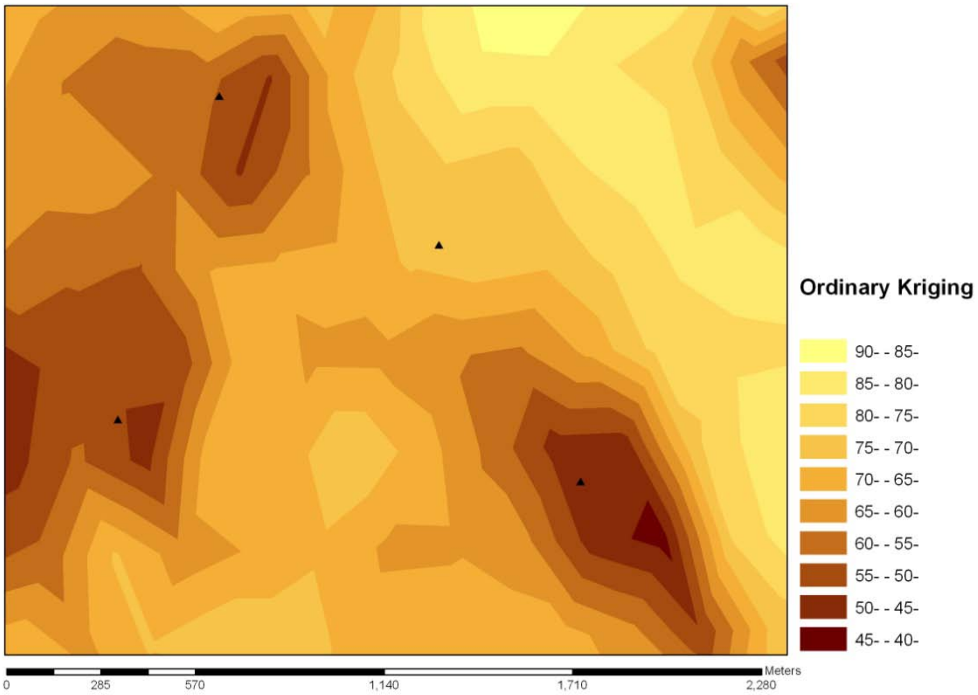


**Figure 3a- Surface Created by Ordinary Kriging**

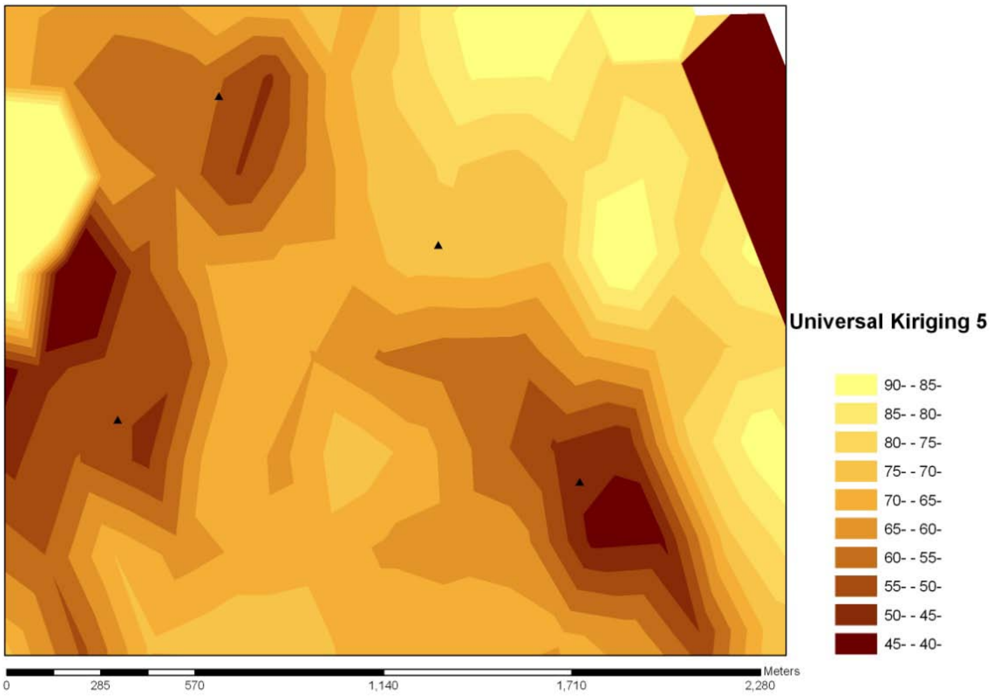


**Figure 3b- Surface Created by Universal Kriging**

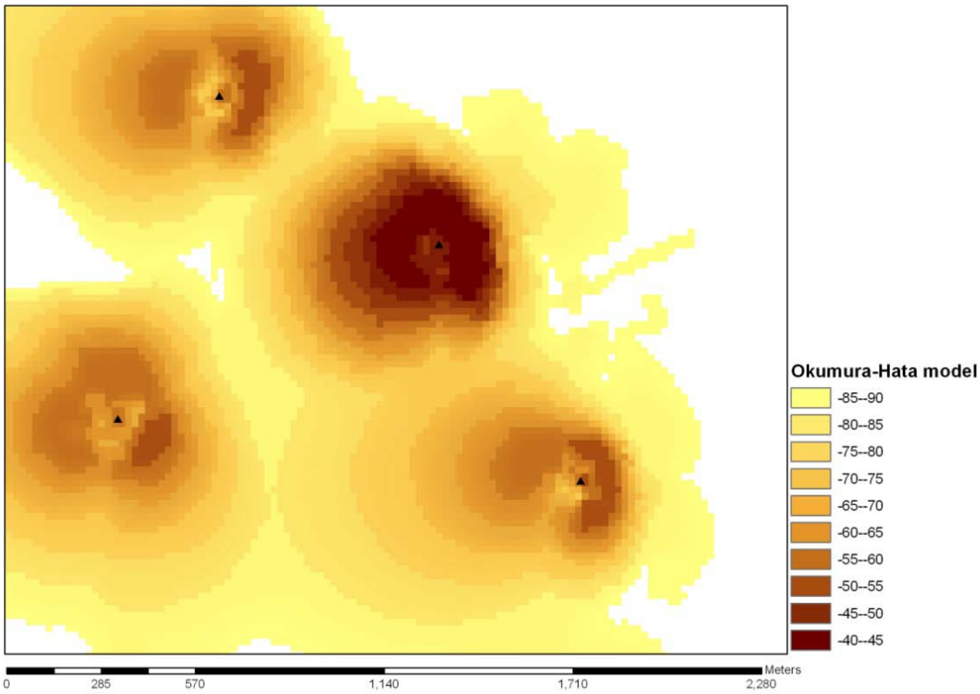


**Figure 3c- Surface Created by Okumura-Hata Model**

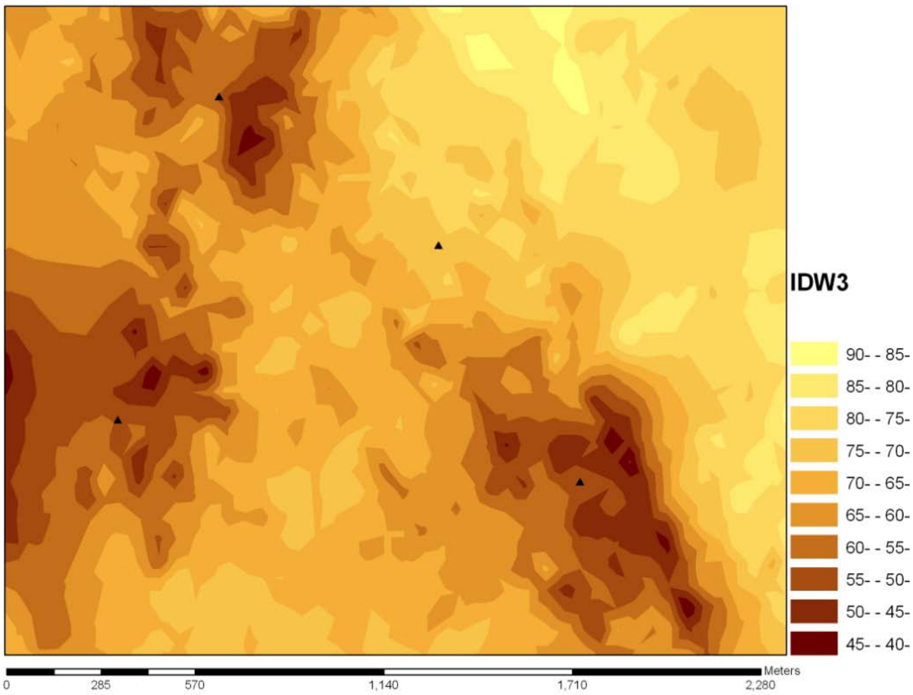


**Figure 3d- Surface Created by IDW**

For the result comparison, we have used check points. Prediction values for check points are extracted from each surface and the difference with actual value are computed. The root mean square is used to compare the methods (Table ۱ ).

**Table ۱ - numerical result for comparison of best fitted surfaces of each method**

| Surface | Model | Detail | $\sigma$ |
|---|---|---|---|
| S2 | idw_3 | Power3 | 4.684433536 |
| S9 | Okumura-Hata | | 4.450834117 |
| S6 | Univ_Kriging3 | Gaussian | 4.0973997 |
| S4 | Univ_Kriging5 | Circular | 3.706218192 |
| S7 | Univ_Kriging2 | Spherical | 3.668627883 |
| S5 | Univ_Kriging4 | Exponential | 3.351953058 |
| S8 | Ordinary_Kriging | Exponential | 3.307196376 |

## 4. Result

The outlines of the results of this study are listed as below:

- Kriging methods predict coverage having acceptable error and are even more accurate than Okumura-Hata with much less than input and computation
- Okumura-Hata methods are more accurate than IDW.
- Surfaces created by universal kriging demonstrate, exponential model for semi-variogram is best fit for coverage prediction among the tested ones. Results show the suitability of exponential and spherical for semi-variogram are almost same and place after exponential model and the last one is gaussian model
- Ordinary kriging is a little more accurate than universal kriging with exponential semi-variogram but the computational time is much more than universal kriging
- Among tested models, considering tradeoff between accuracy and computational time, universal kriging having exponential semi-variogram is best one.

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