Author(s) Zhang, Jie; Salmi, Jussi; Lohan, Elena-Simona

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Statistics Analysis for LOS/NLOS Identification based on MIMO Channel Measurements

Jie Zhang, Elena-Simona Lohan and Jussi Salmi

Abstract—**The positioning methods based on the received signal strength (RSS) measurement connect the RSS value with location of the mobile station (MS). However, the accuracy of location is degraded due to the complicated indoor environment, particularly no-line-of-sight (NLOS) propagation. In order to improve the accuracy and reliability of wireless location, the knowledge of whether the base station (BS)-MS path is line-of-sight (LOS) or NLOS is very important. In this paper, we present statistics analysis based on multiple-input and multiple-output (MIMO) channel measurement to perform NLOS identification.**

Index Terms— **indoor positioning, path, LOS, NLOS, MIMO**

I. Introduction

Over the last few years, positioning and navigation services have gradually edged into the daily life of the citizens in the world, in the most cases through applications such as route guidance. This trend will continue in the future and more people will become direct or indirect users of such services. Due to the high demand on the services and applications, wireless broadband communications are becoming more popular since the users can be provided with good location services with high availability. The IMT-Advanced [1] provides high quality mobile services and capability of interworking with other radio access system. Its unique feature especially multiple-input and multiple-output (MIMO) can be applied for improving the location estimation accuracy.

Basically, the mobile station (MS) location can be determined using various parameters, such as received signal strength (RSS), angle of arrival (AOA), time of arrival (TOA) and etc [2][3][4]. In the current WLAN-based positioning technology, the MS location can be determined based on a path-loss model, which is built from collected RSS data [5]. The path-loss model links the RSS and the MS to be located. However, the accuracy of pass-loss model depends on the wireless propagation channel. If MS and base stations (BS) path is in the line-of-sight (LOS), high path-loss modeling and location estimation accuracy can be achieved. However, due to the scattering in the complicated indoor environment, the MS-BS path is often in the non line-of-sight (NLOS). The precise of parameter estimation is degraded, which result in poor estimation of MS location. This has lead to the development of many location algorithms that concentrate on the identifying of the NLOS.

Several papers have proposed different techniques for NLOS identification. These techniques can be categorized into two main groups [6]. The first group is known as parametric techniques. It extracts some features from received waveform that varies between different channel conditions. For example, the identification is done based on the comparison of relative energy between the first path and the strongest path in [7]. In [8][9], the root mean square delay spread, mean excess delay and kurtosis parameters are used. The other group can be called non-parametric techniques, which detect obstacles without the knowledge of received waveform. As shown in [10], the probability density function (PDF) of distance is compared with the PDF of LOS propagation. The lease-square vector machines can also be used in identification [11][12]. In this paper, we present a LOS/NLOS identification method, which is based on the kurtosis and correlation measure analysis of an extensive set of MIMO channel measurement data collected at Aalto University. The measurement covers LOS, NLOS and mixed LOS and NLOS propagation conditions.

The reminder of this paper is organized as follows: Section II describes the channel measurement environment; Section III presents the definition of parameters used in the paper; Section IV shows the statistical results of the measurement data and discussion based on the analysis; finally, conclusions are drawn in Section V.

II. Measurement Description

Radio channel measurements were carried out with 60 MHz bandwidth at 5.3 GHz center frequency by using dual sounder at Aalto University, Computer Science Building. The building is a three-storey office building with a large hall in the middle. The hall occupies the whole height of the building and is surrounded by the classroom and offices. The floor plan of the measurement is shown in Fig. 1. In the measurement, the TX moved along continuous routes and the RXs were always located at fixed positions. More detail about the measurement equipment and post-processing can be found in [16]. The measurement scenarios are summarized in TABLE I.

Jie zhang and Elena-Simona Lohan are with the Department of Communications Engineering at Tampere University of Technology, Tampere, Finland; e-mail: jie.zhang@tut.fi, elena-simona.lohan@tut.fi
Jussi Salmi is with the Department of Signal Processing and Acoustics in School of Electrical Engineering at Aalto University, Espoo, Finland; e-mail: jussi.salmi@aalto.fi

Fig. 1: Floor plan of the measurement with the TX route (solid line) and the RX position (circle and square)

TABLE I
SUMMARY OF MEASUREMENT SCENARIOS

	Snapshots	Condition	
		TX1/RX1	TX/RX2
Route 20	1434	LOS	NLOS
Route 25	1888	NLOS	LOS → NLOS
Route 36	1553	LOS → NLOS	NLOS → LOS

III. PARAMETER DEFINITION

A. Kurtosis

Kurtosis is the ratio of the fourth-order moment of the data to the square of the second-order moment. If the Channel Impulse Response (CIR) of the received signal is defined as in (1)

$$h(t) = \sum_{l=1}^{L} \alpha_l \delta(t - \tau_l) \quad (1)$$

where L is the total number of multipath components (MPCs), and α_l and τ_l are the amplitude and delay of the lth MPC. Then kurtosis can be expressed as in (2). It characterizes the peakedness of the data samples. A CIR with higher kurtosis is more likely LOS case. However, the kurtosis only describes the amplitude statistics and there is no delay properties included.

$$\kappa = \frac{E\left[\left(|h(t)| - \mu_{|h|}\right)^4\right]}{E\left[\left(|h(t)| - \mu_{|h|}\right)^2\right]^2} = \frac{E\left[\left(|h(t)| - \mu_{|h|}\right)^4\right]}{\sigma_{|h|}^4} \quad (2)$$

where $\mu_{|h|}$ and $\sigma_{|h|}$ are the mean and standard deviation of the $|h(t)|$, respectively. For a M*N MIMO channel, there are M*N CIR for each measurement snapshot. Therefore, we take the mean of M*N kurtosis values for each snapshot.

B. Correlation Measure

For a M*N MIMO channel matrix **H**, the correlation matrix is given by

$$\begin{aligned}\mathbf{R} &= E\left\{vec(\mathbf{H})vec(\mathbf{H})^H\right\} \\ &= \begin{pmatrix} 1 & \rho_{1,2} & \cdots & \rho_{1,MN} \\ \rho_{2,1} & 1 & \cdots & \rho_{2,MN} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{MN,1} & \rho_{MN,2} & \cdots & 1 \end{pmatrix} \\ &= \mathbf{R}^H \end{aligned} \quad (3)$$

In (3), $E\{.\}$ is the expectation operation, while the super-script ^{H} denotes the complex conjugate transpose. With the correlation matrix given by (3), the correlation measure can be calculated as

$$\Phi(\mathbf{R}) = \sqrt{\frac{1}{MN(MN-1)} \sum_{i=1}^{MN} \sum_{\substack{j=1 \\ j \neq i}}^{MN} \left|\rho_{i,j}\right|^2} \quad (4)$$

Equation (4) indicates that the MIMO correlation measure is a root mean square of the magnitude of all cross correlation coefficients of the matrix **R**. For the full correlated case, all cross correlation coefficients of the matrix **R** are 1. For the uncorrelated case, all cross correlation coefficients are 0. Therefore, the value of the MIMO correlation measure varies between 0 and 1.

C. Path loss

The pass-loss can be calculated with

$$PL = -10\log_{10}\left(\frac{1}{MN} \sum_{f} \sum_{i=1}^{M} \sum_{j=1}^{N} \left|\mathbf{H}_{i,j}(f)\right|^2\right) \quad (5)$$

where $\mathbf{H}_{i,j}(f)$ is the frequency domain transfer function of the channel between the j-th transmitter to i-th receiver antennas.

IV. RESULTS

In this section, the calculations for both correlation measure and kurtosis were performed. The results are shown together with the calculated path loss with (5).

In Fig. 2, it shows the statistics of Route 36 TX-RX1 path. In this path, LOS and NLOS cases are mixed. It can be observed that the kurtosis and correlation are getting smaller when the TX is moving from LOS to NLOS region. In the LOS region, the kurtosis value is above 40 and correlation measure is higher than 0.8. In the NLOS region, the kurtosis

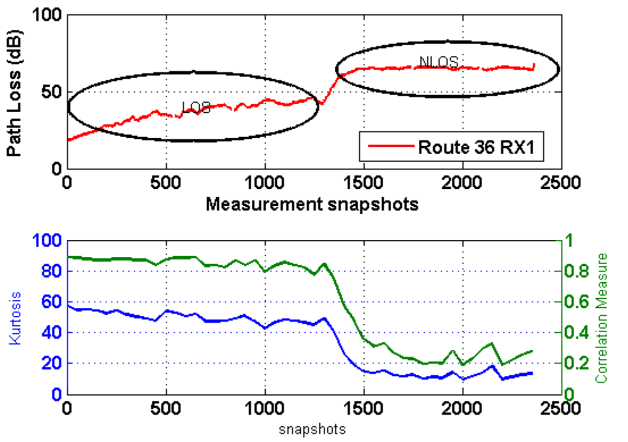

Fig. 2: Kurtosis and correlation measure of Route 36 Tx-Rx1 data

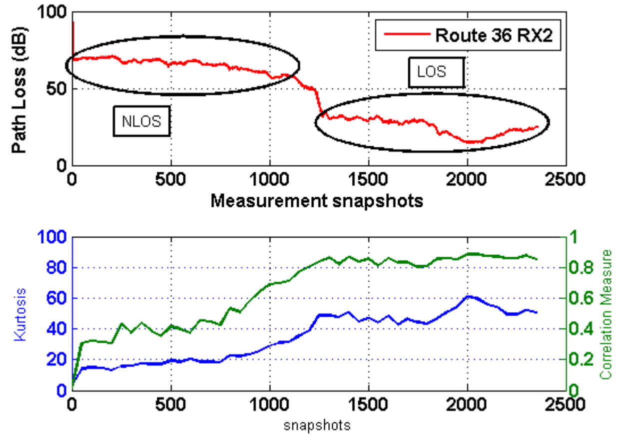

Fig. 3: kurtosis and correlation measure of Route 36 TX-RX2 data

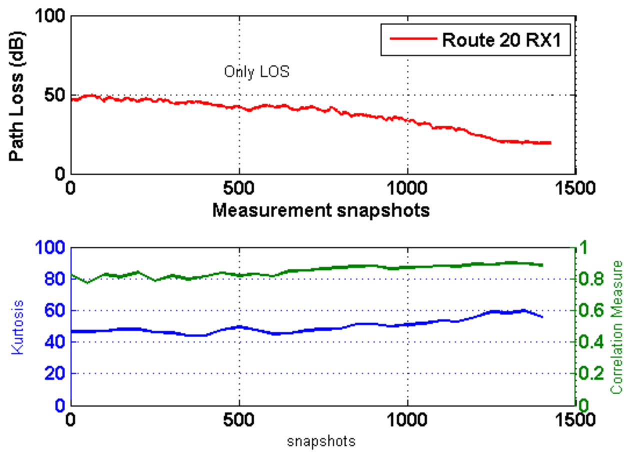

Fig. 4: kurtosis and correlation measure of Route 20 Tx-RX1 data

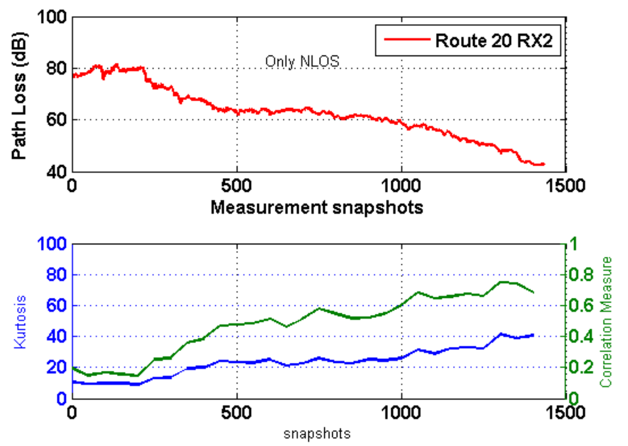

Fig. 5: kurtosis and correlation measure of Route 20 Tx-RX1 data

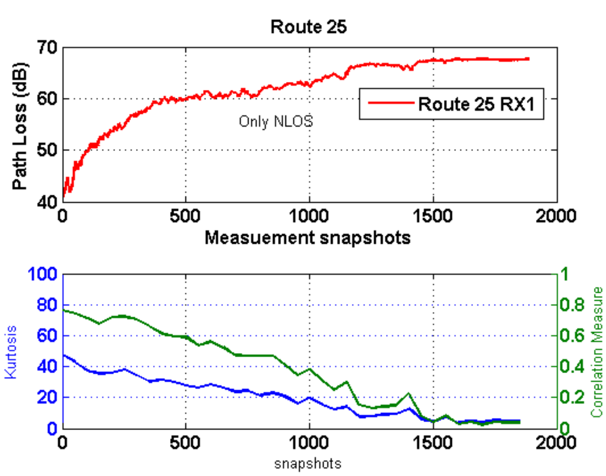

Fig. 6: kurtosis and correlation measure of Route 25 Tx-RX1 data

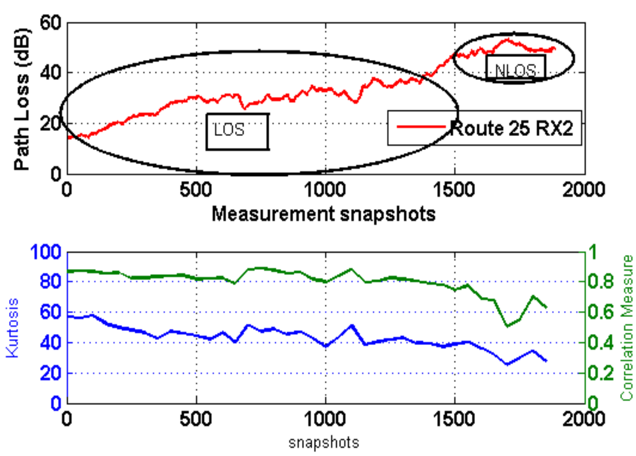

Fig. 7: kurtosis and correlation measure of Route 25 Tx-RX1 data

and correlation measure stay steadily below 20 and 0.4, respectively. . We also have the same observations on the Route 25 Tx-Rx2 path as shown in Fig. 7.

The statistics of TX-RX2 in Route 36 is shown in Fig. 3. It is the same as in Fig. 2 that the kurtosis and correlation measure is above 40 and 0.8, respectively. When path-loss is getting smaller in NLOS region (the distance between TX and RX2 is getting shorter), the correlation and kurtosis is increasing, and it goes above 0.8 and 40 in LOS, respectively

In LOS-only case as shown in Fig. 4, the kurtosis is staying above 40 and correlation is always between 0.8 and 1. The Fig. 5 and Fig. 6 show the kurtosis and correlation measure for the measurement paths, which have only NLOS case. They clearly show that the kurtosis is always below 40 and correlation measure is less than 0.8.

V. Conclusion

This paper has presented the statistics analysis based on the MIMO channel measurement in an office building at Aalto University. The correlation measure, which is one of the parameters indicating the special characteristics of a MIMO channel, has been discussed statistically in the LOS and NLOS region. Kurtosis of the CIR between each antenna pair is also studied in different conditions. The results reveal that the correlation measure and kurtosis are sufficient to identify LOS and NLOS region. Numerically, with given MIMO CIR, 40 and 0.8 can be set as threshold for kurtosis and correlation measure, respectively to separate LOS and NLOS cases.

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