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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 estimation is degraded due to the complicated indoor environment, particularly non-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

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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 least-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.

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### 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)

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

where \( L \) is the total number of multipath components (MPCs), and \( \alpha_l \) and \( \tau_l \) are the amplitude and delay of the \( l^{th} \) 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.

\[
\kappa = \frac{E \left[ \left( |h(t)| - \mu_4 \right)^4 \right]}{E \left[ \left( |h(t)| - \mu_2 \right)^2 \right]^2} = \frac{\sigma_4^2}{\sigma_2^4}
\]

where \( \mu_4 \) and \( \sigma_4 \) 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

\[
\mathbf{R} = E \{ \text{vec}(H) \text{vec}(H)^H \}
\]

\[
= \begin{pmatrix}
1 & \rho_{1,2} & \cdots & \rho_{1,N}
\rho_{2,1} & 1 & \cdots & \rho_{2,N}
\vdots & \vdots & \ddots & \vdots
\rho_{MN,1} & \rho_{MN,2} & \cdots & 1
\end{pmatrix}
\]

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

\[
\Phi(\mathbf{R}) = \sqrt{\frac{1}{MN(MN-1)} \sum_{i=1}^{MN} \sum_{j=i+1}^{MN} \left| \rho_{i,j} \right|^2}
\]

Equation (4) indicates that the MIMO correlation measure is a root mean square of the magnitude of all cross correlation coefficients of the matrix \( \mathbf{R} \). For the full correlated case, all cross correlation coefficients of the matrix \( \mathbf{R} \) 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

\[
PL = -10 \log_{10} \left( \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left| H_{i,j}(f) \right|^2 \right)
\]

where \( H_{i,j}(f) \) 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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