Identification algorithm of NLOS

——review & analysis

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Outline

- Channel models
- Identification algorithm
  - The kurtosis
  - Mean excess delay
  - RMS delay
- Likelyhood- ratio test
- Mitigation
- Future work

Channel model

- Identification and mitigation of non-line-of-sight (NLOS) effects
  - One of the major challenges for localization systems
  - Happened when a fixed terminal(FT) is obstructed from the mobile terminal(MT)
  - Different characteristics between LOS/NLOS
    - Amplitude
    - Multipath
    - Delay spread

Channel model

- Channel impulse response (CIR) of the received signal

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

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

- Here, the IEEE 802.15.4a standard ultrawideband(UWB) channel models are used as examples.
- There are 8 channel models in this standard. Representing different situations.

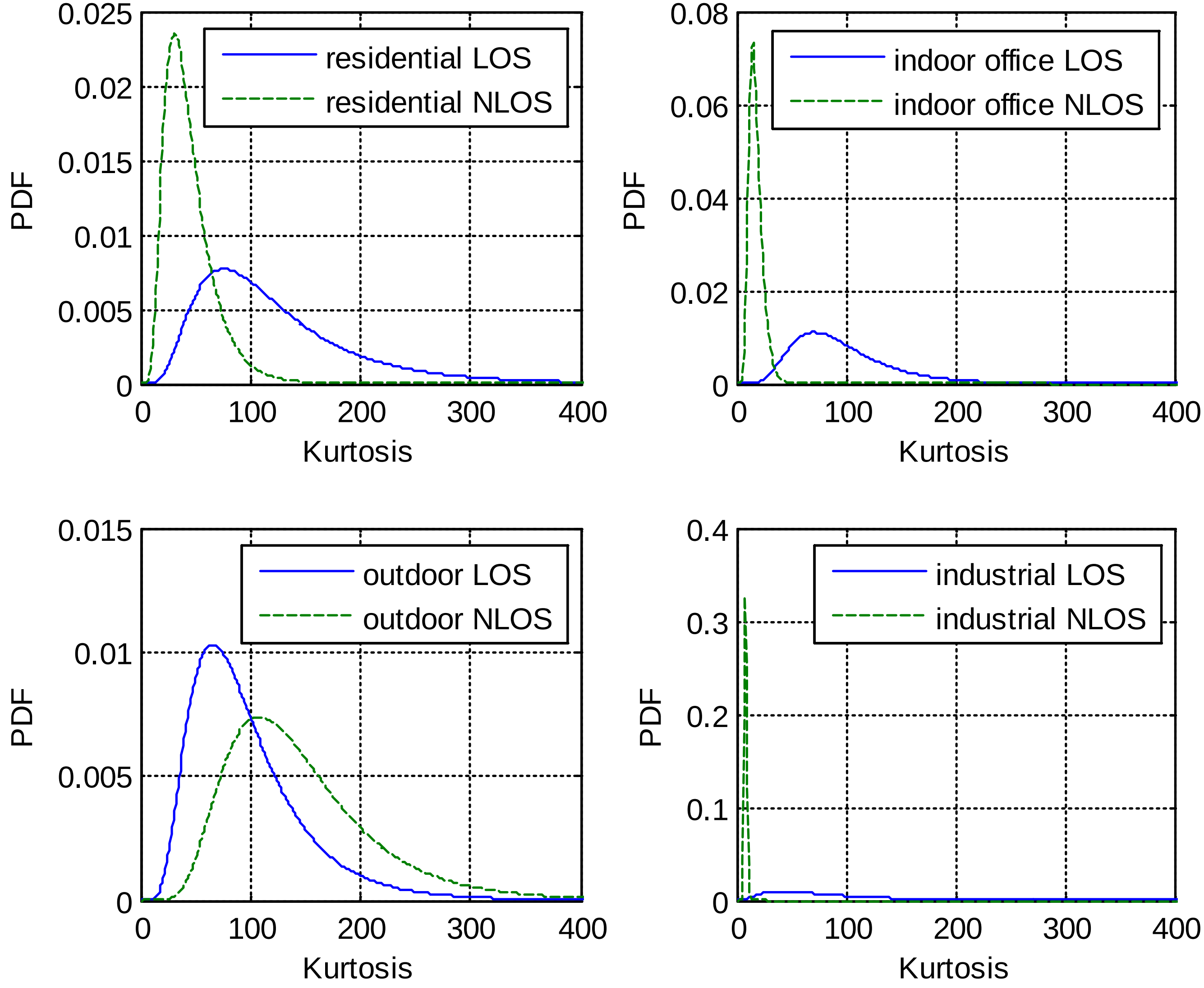
The kurtosis

- The ratio of the fourth-order moment of the data to the square of the second-order moment (variance).
  a) Characterize how peaky a sample data is
  b) A CIR with higher kurtosis, more likely is LOS
  c) Only amplitude statistics, no delay properties

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

where $\mu_{|h|}$ and $\sigma_{|h|}$ are the mean and standard deviation of the $\left|h(t)\right|$, respectively

PDFs of the kurtosis for CM1 to CM8



The kurtosis

- have high value for LOS comdition, due to
  a) Few peaks
  b) Distinguishable from natural noise
- have low value for NLOS condition
  a) Signal is more noise-like
- Exception: standard outdoor situation
  a) Might due to the highly dispersive characteristics of the outdoor environments
  b) The delay statistics must be taken into consideration

Mean excess delay and RMS delay

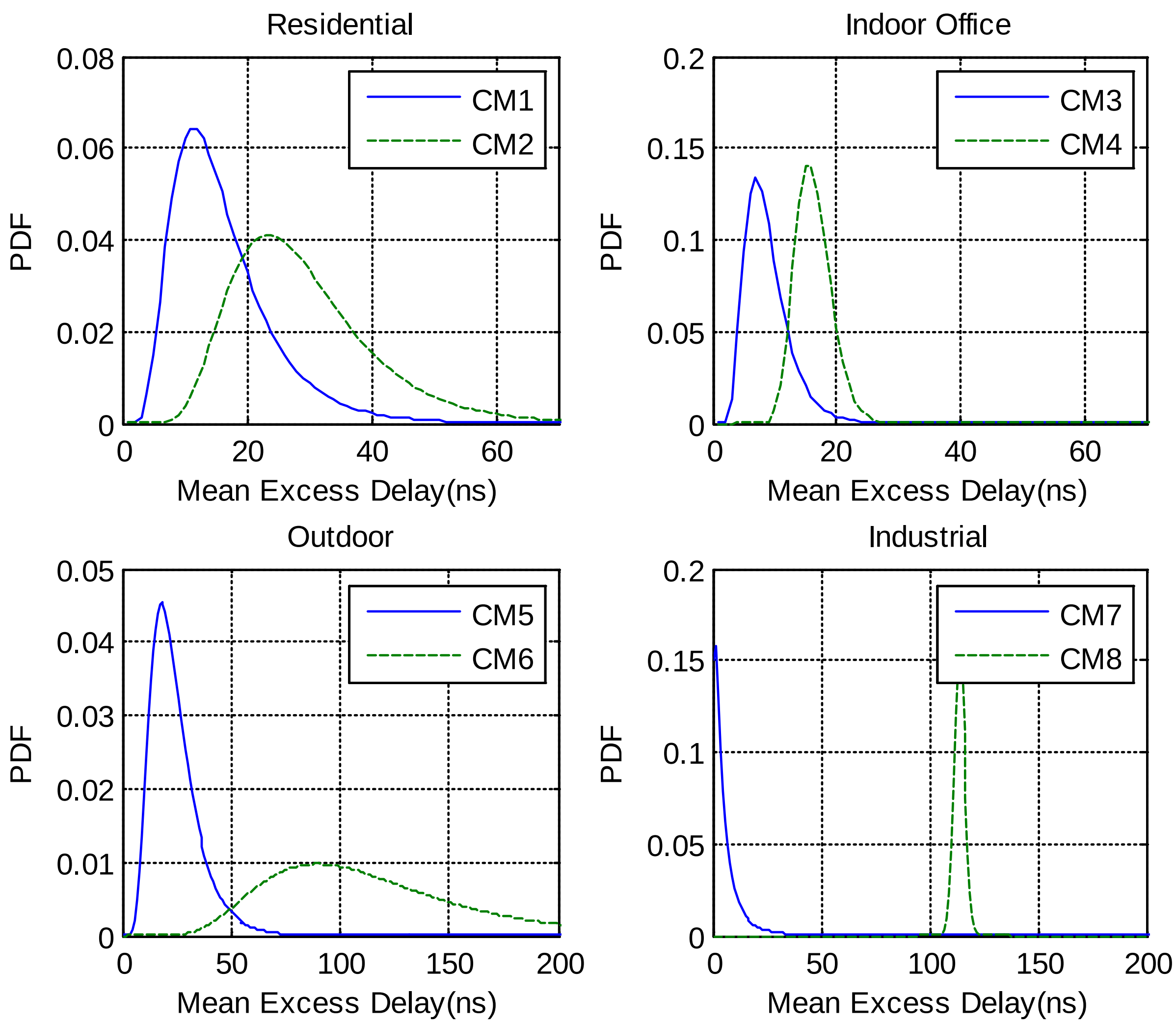
- These two statistics can provide delay information of the multipath channel
- Mean excess delay

$$\tau_m = \frac{\int_{-\infty}^{\infty} t \left| h(t) \right|^2 dt}{\int_{-\infty}^{\infty} \left| h(t) \right|^2 dt}$$

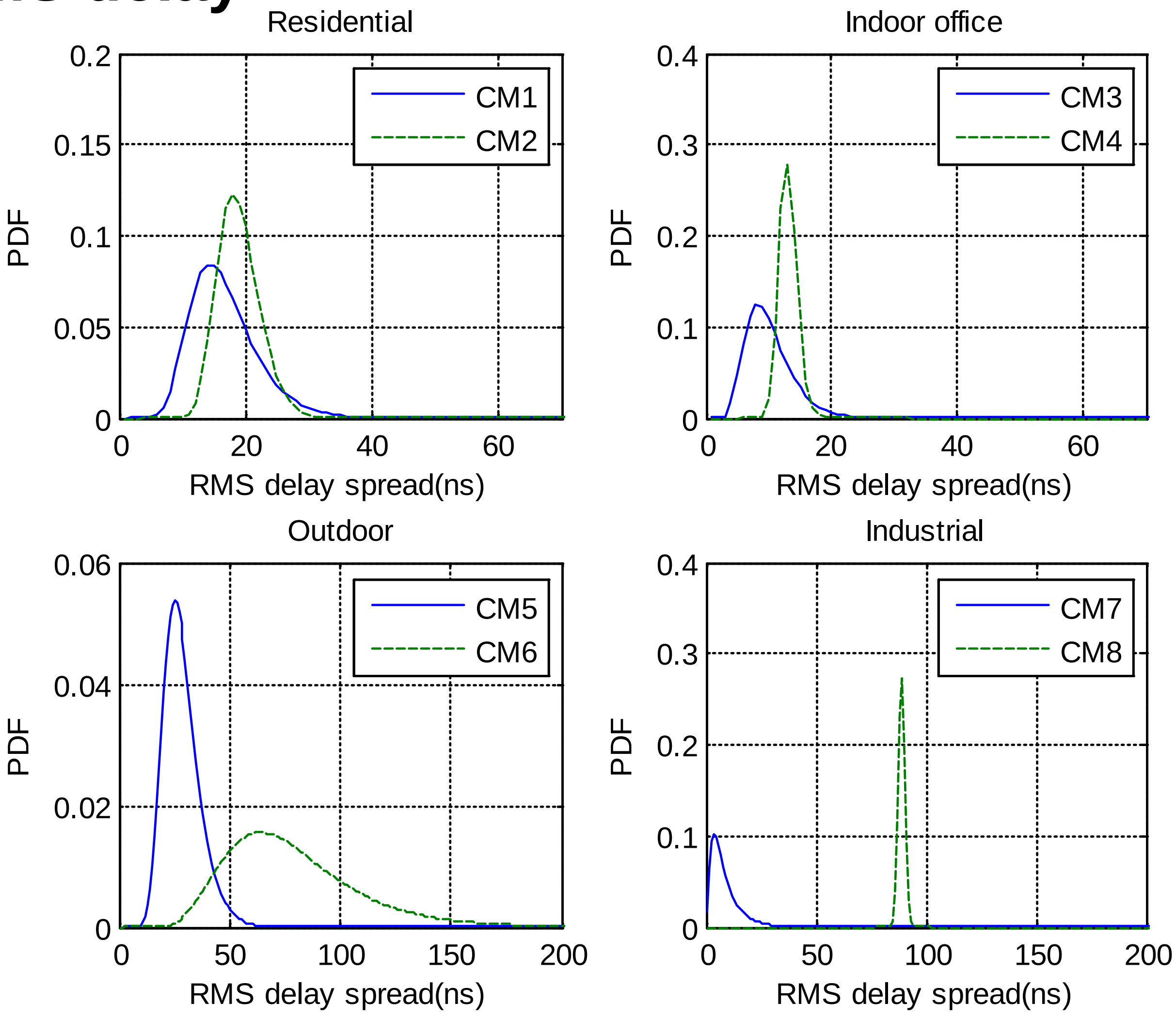
- Root mean square delay(RMS)

$$\tau_{rms} = \frac{\int_{-\infty}^{\infty} (t - \tau_m)^2 \left| h(t) \right|^2 dt}{\int_{-\infty}^{\infty} \left| h(t) \right|^2 dt}$$

Mean excess delay



RMS delay



Residential
PDF
0.2
0.15
0.1
0.05
0
0
20
40
60
RMS delay spread(ns)
CM1
CM2
Indoor office
PDF
0.4
0.3
0.2
0.1
0
0
20
40
60
RMS delay spread(ns)
CM3
CM4
Outdoor
PDF
0.06
0.04
0.02
0
0
50
100
150
200
RMS delay spread(ns)
CM5
CM6
Industrial
PDF
0.4
0.3
0.2
0.1
0
0
50
100
150
200
RMS delay spread(ns)
CM7
CM8

Likelyhood- ratio test

- Kurtosis test $$\frac{P_{los}^{kurt}(\kappa)}{P_{nlos}^{kurt}(\kappa)} \underset{H_1}{\overset{H_0}{\gtrless}} 1$$
- Mean excess delay test $$\frac{P_{los}^{med}(\tau_m)}{P_{nlos}^{med}(\tau_m)} \underset{H_1}{\overset{H_0}{\gtrless}} 1$$
- RMS delay test $$\frac{P_{los}^{rms}(\tau_{rms})}{P_{nlos}^{rms}(\tau_{rms})} \underset{H_1}{\overset{H_0}{\gtrless}} 1$$
- Where, if the likelyhood ratio is larger than 1,we choose the LOS hypothesis(H_0),otherwise choose the NLOS hypothesis(H_1).

Joint likelyhood- ratio test

- Rather than using only the PDFs of individual parameters, a better approach would be the joint PDF

$$\frac{P_{los}^{joint}\left(\kappa,\tau_m,\tau_{rms}\right)}{P_{nlos}^{joint}\left(\kappa,\tau_m,\tau_{rms}\right)} \underset{H_1}{\overset{H_0}{\gtrless}} 1$$

- Very difficult to obtain
- Sub-optimal approach

Assuming κ,τ_m and τ_{rms} as independent

$$J\left(\kappa,\tau_m,\tau_{rms}\right)=\frac{P_{los}^{kurt}\left(\kappa\right)}{P_{nlos}^{kurt}\left(\kappa\right)}\times\frac{P_{los}^{med}\left(\tau_m\right)}{P_{nlos}^{med}\left(\tau_m\right)}\times\frac{P_{los}^{rms}\left(\tau_{rms}\right)}{P_{nlos}^{rms}\left(\tau_{rms}\right)}$$

LOS/NLOS Identification Percentages

Channel Model	Kurtosis	MED	RMS	Joint
CM1	78.6%	74.3%	61.7%	81.8%
CM2	83.2%	77.9%	76.1%	84.3%
CM3	99.0%	88.5%	73.6%	97.9%
CM4	96.7%	86.3%	89.0%	95.9%
CM5	66.3%	98.2%	93.9%	98.9%
CM6	71.4%	95.2%	92.7%	97.8%
CM7	98.3%	88.3%	98.3%	88.2%
CM8	98.4%	100%	100%	99.9%

Mitigation

- Identify-and-discard

$$\beta_i^{(IAD)} = \begin{cases} 0 & if \;\; \log_{10}\left(J_i\left(\kappa, \tau_m, \tau_{rms}\right)\right) \le 0 \\ 1 & if \;\; \log_{10}\left(J_i\left(\kappa, \tau_m, \tau_{rms}\right)\right) > 0 \end{cases}$$

- The drawback
  - Misidentification
  - Insufficient number of LOS FTs, eg. two

Mitigation

- Weighted selection

$$\beta_i^{(weight)} = \begin{cases} k_1 & if \ \log_{10}\left(J_i\left(\kappa,\tau_m,\tau_{rms}\right)\right) \le 0 \\ k_2 & if \ \log_{10}\left(J_i\left(\kappa,\tau_m,\tau_{rms}\right)\right) > 0 \end{cases}$$

- Where $k_1 < k_2$, the identified NLOS has limited impact

further work

- Other methods for NLOS identification and mitigation
  - A modified biased Kalman filter and a sliding window
  - Energy-based TOA estimation(EBE) algorithm
- Compare different algorithms
  - Complexity
  - Accuracy

References

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