Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Angle of Arrival Estimation for Moving User Equipment with Application to Indoor Terahertz Communications Using a Grid Based Bayesian Filter

Date Submitted: 9 November 2015

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Abstract: The high antenna gain used for future indoor Terahertz (THz) requires a precise estimate of the direction of signal arrival. This paper presents a method for the signal arrival direction estimate in cases when the user equipment is moving in the wireless network coverage area. The method uses the grid based Bayesian filter to estimate the signal arrival direction recursively
from the previous estimate and the current

Purpose: Contribution toward future wireless systems in IG THz

Angle of Arrival Estimation for Moving User Equipment with Application to Indoor Terahertz Communications Using a Grid Based Bayesian Filter

Bile Peng, Sebastian Priebe, Sebastian Rey, Thomas Kürner

The results presented in this contribution are based on [1]

Motivation

- According to the Friis law, the path loss grows quadratically with the carrier frequency.The huge path loss due to the extremely high carrier frequency must be compensated by a high antenna gain.
- A high antenna gain is realized by a highly directive antenna and only works with a precise angle of arrival (AoA) estimation.
- The AoA estimation has been intensively studied. However, the AoA estimation in dynamic channel due to movement of transmitter/receiver is not yet exploited.
- It takes time to estimate the signal arrival direction, but in a dynamic channel, the user equipment can move faster than the estimation.
- However, we can facilitate the estimation with the Bayesian inference.

Outline

- Motivation
- **Grid Based Bayesian Filter**
- Simulation Results
- Conclusion

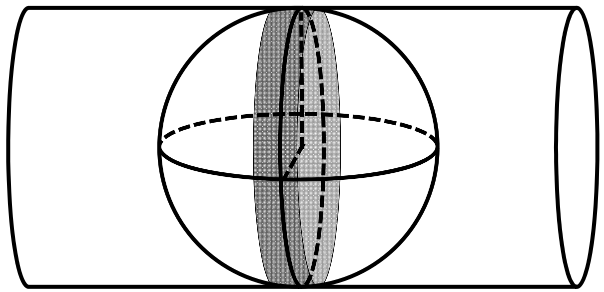
The Human Motion

- In the indoor environment, the human motion is the most important reason for the dynamic channel.
- The human motion causes displacement of user equipments and hence the angle of arrival.
- There are some certain patterns of the human motion
  - The motion speed is limited → The AoA changes continuously.
  - The motion direction changes continuously → the AoA changes smoothly too.
- The Bayesian filter is an adequate tool for the inference along time.
  - Kalman filter
  - **Grid based Bayesian filter (discrete states, estimation as a distribution)**
  - Particle filter

State Space Description

- We describe the AoA states with (2 dimensional) position and velocity.

- Because of the nonlinearity of the spherical coordinate system, we borrow the idea of the Gauss-Krüger method to project the spherical surface on a plane.



Gauss-Krüger projection

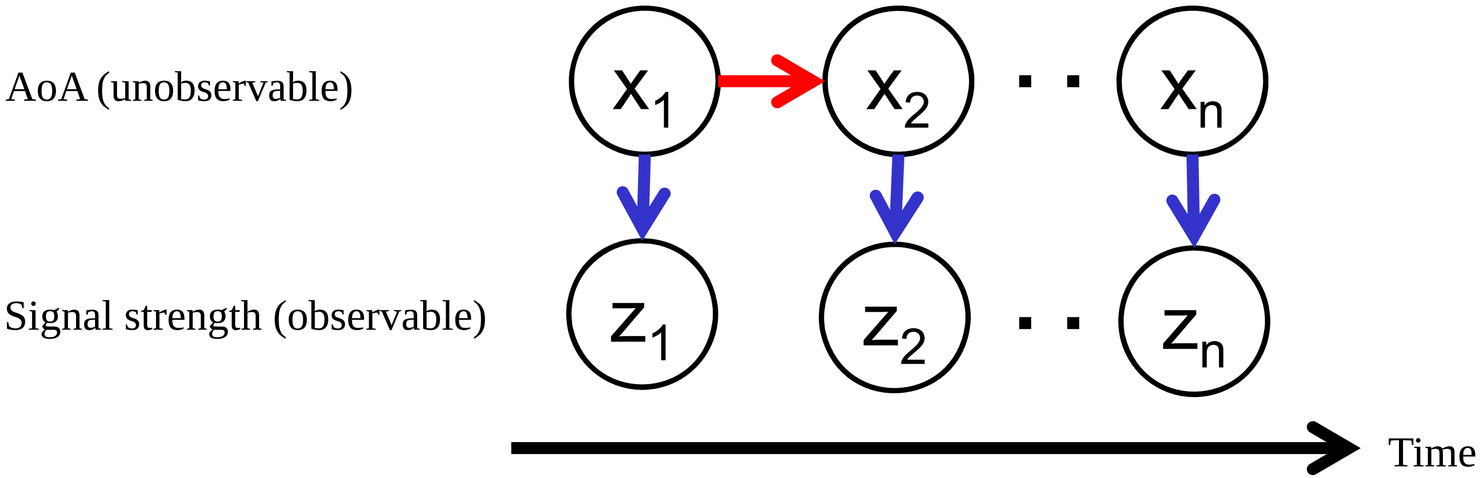
- The discrete state space is therefore 4 dimensional: (p_x,p_y,v_x,v_y).
  - p for position
  - v for velocity

- If the AoA exceeds the plane boundary, a plane switch must take place.

Hidden Markov Model

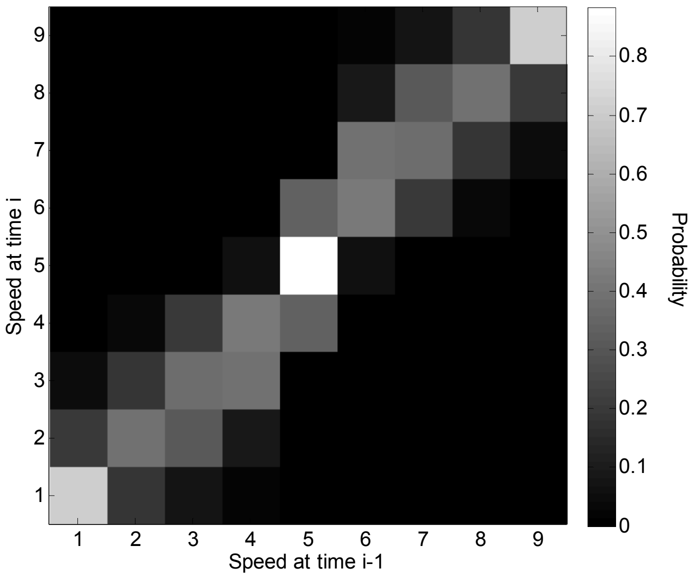
- The Hidden Markov Model is applied to describe the AoA evolvement over time.

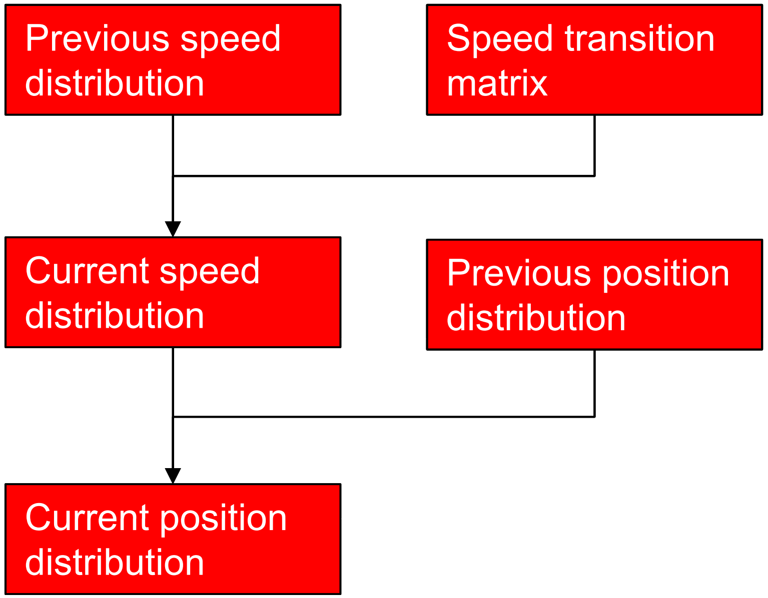
- A-Priori probability: estimate from history
- Emission probability: estimate from observation
- A-Posteriori probability: combination of priori and emission probabilities.



A Priori Probability

- Classification of velocity into 9 levels.
- Characterization of the velocity change with the transition matrix, which should be derived from the field experiments.
- The current position will be calculated according to the previous position estimate and current velocity estimate.



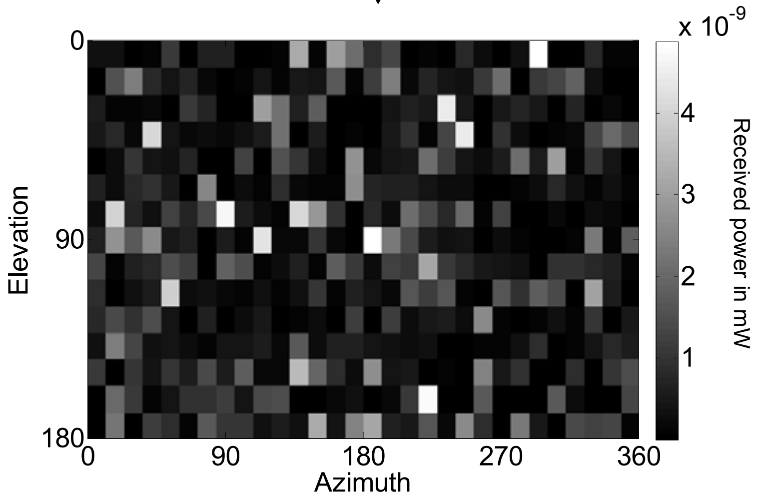


A Posteriori Probability

- The emission probability is calculated according to the noisy scanning result.
- The a posteriori probability is calculated following the Bayesian rule.

Estimate from the measurement

Estimate from the history



Noisy scanning result

$$Pr(x_i|z_1,\ldots,z_i) = \frac{Pr(x_i|z_1,\ldots,z_{i-1})Pr(z_i|x_i)}{Pr(z_i|z_1,\ldots,z_{i-1})}$$

Normalization

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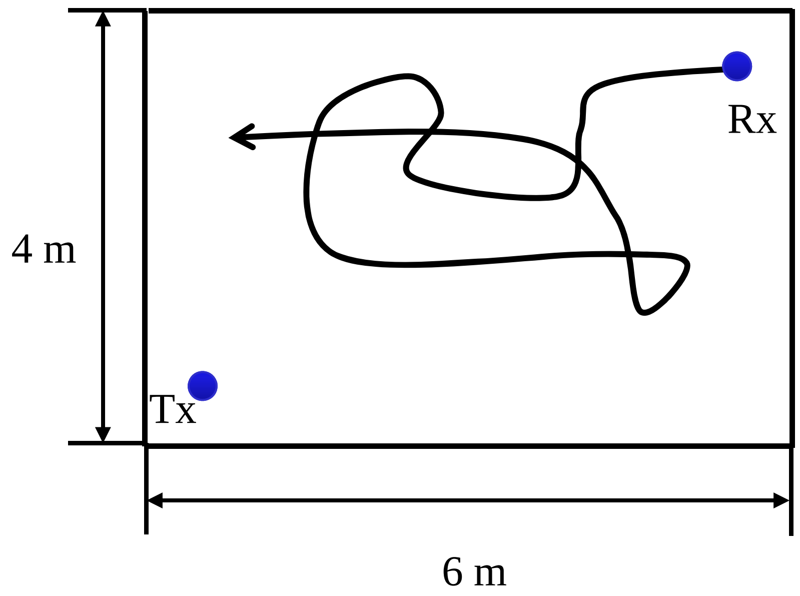
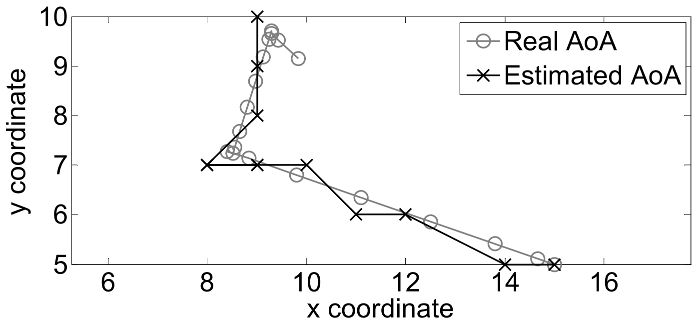
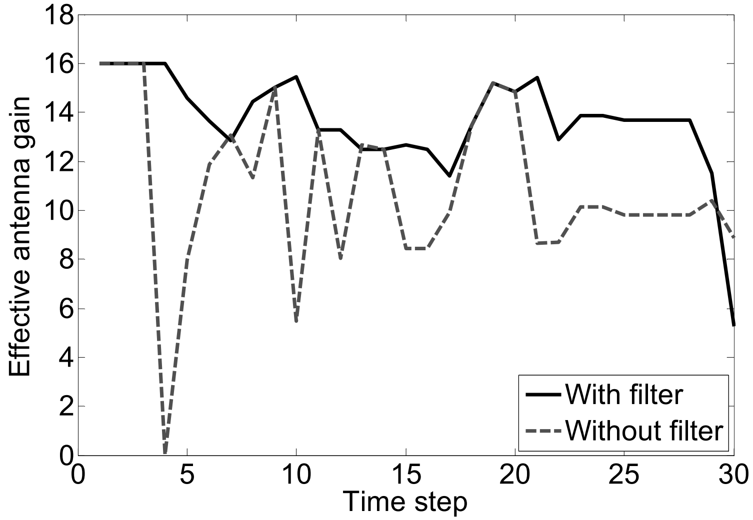
Ray Tracing Simulation

- The ray tracing simualtion is used to evaluate the method
- We choose a simple empty room for the simulation scenario to demonstrate our concept.
- The Tx is stationary while the Rx is moving around randomly.



Simulation Results (1/2)

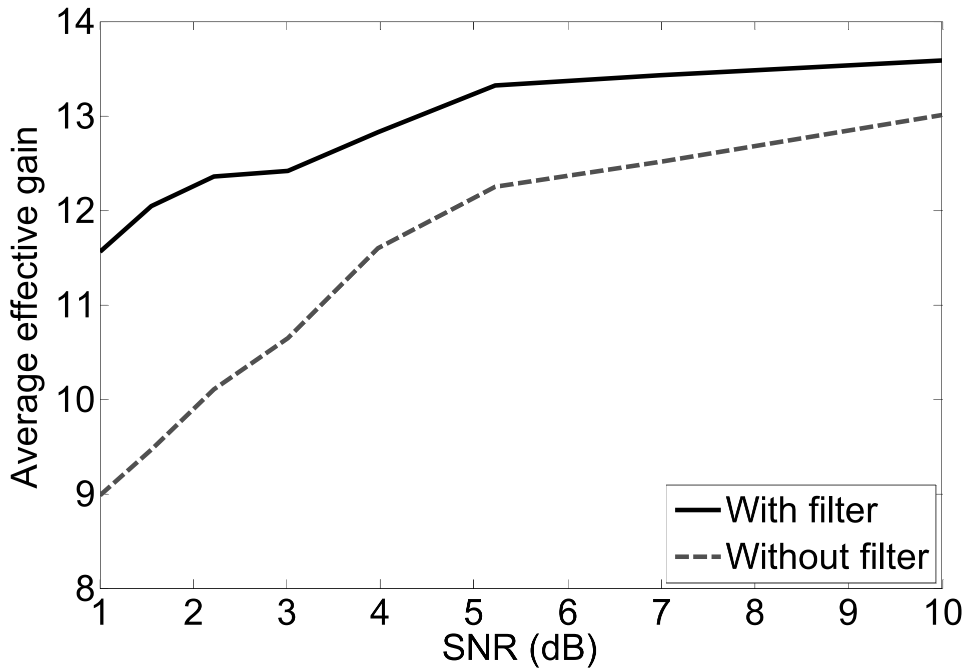




Real and estimated AoA

Effective antenna gain

Simulation Results (2/2)



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Conclusion

- The grid based Bayesian filter utilizes the temporaral continuity of the propagation channel and outperforms the traditional AoA estimation scanning with a considerable advantage.
- The estimate with the Bayesian filter outperforms the estimate without Bayesian filter considerably.
- Future works
  - Experiment verification
  - Refine the a Priori Probability
  - Improve the algorithm efficiency
  - Further data fusion

References

[1] B. Peng, S. Priebe, T. Kürner, Fast Beam Searching Concept for Indoor Terahertz Communications, accepted for publication in Proc. The 9th European Conference on Antennas and Propagation (EUCAP), Lisbon, April 12-17 April, 2015