Beam Tracking for Mobile Millimeter Wave Communication Systems

Vutha Va, Haris Vikalo, and Robert W. Heath, Jr.

Wireless Networking and Communications Group, The University of Texas at Austin
Email: vutha.va@utexas.edu, hvikalo@ece.utexas.edu, rheath@utexas.edu

I. Introduction

Millimeter wave (mmWave) has many applications

- 5G cellular [2]
- Vehicular comm. [3]

MmWave beam alignment is expensive

- Sector level search
- Beam level search

IEEE 802.11ad beam training can take up to ~50 ms for beamwidth of 10° [4]

Our contributions:
- Proposed a low overhead beam tracking method
- Investigate impacts of SINR and array size on tracking

II. System model

Channel model:
- Number of paths $N_p$
- Complex channel gain $G[k]$
- Angle of arrival $\theta_a[k]$
- Angle of departure $\theta_d[k]$
- Rate of change of AoA $\dot{\theta}_a[k]$
- Rate of change of AoD $\dot{\theta}_d[k]$

MmWave beam alignment is expensive

Too small arrays are not sensitive enough

Estimation sparsity, focusing on only one path

Path can disappear, e.g., due to blockage

Switch beam when the error exceeds the threshold

A natural choice for the threshold is 1/2 beamwidth

Extended Kalman filter (EKF) is applied on the state-space model

No

Tracking is reliable? Path still exists?

Yes

No

III. Proposed beam tracking

AoA/AoD Estimation

Set beam direction $\beta$

Beam tracking $\phi$

Tracking is reliable? Path still exists?

No

$|\phi - \phi_t| > \phi_t$

Yes

$|\phi - \phi_t| < \phi_t$

IV. Numerical results

Effect of SINR

16-element uniform linear array (ULA-16)

Effect of array size

ULA-16 is best

Comparison with prior work [5]

Lower rate of change because low overhead allows transient pruning

Optimal array size depends on the rate of change of AoA/AoD

The low measurement overhead makes our method better for fast changing environments

Effect of array size

ULA-16 is best

Large jump between 10 and 20 dB

Excessive SINR does not help much

Enough SINR is needed for good tracking performance

V. Conclusions

- Proposed a beam tracking method with low overhead
- Tracking performance improvement saturates at high SINR
- Appropriate choice of array size needed for good tracking
  - Too small arrays are not sensitive enough
  - Too large arrays cannot keep up with changes in AoA/AoD
- Future work
  - Introduce more structure in evolution model to differentiate angle change due to linear displacement and rotation
  - Propose solutions for all the gray blocks in Section III

Future work

- Proposed a beam tracking method with low overhead
- Tracking performance improvement saturates at high SINR
- Appropriate choice of array size needed for good tracking
  - Too small arrays are not sensitive enough
  - Too large arrays cannot keep up with changes in AoA/AoD

Acknowledgement

This research is supported in part by the U.S. Department of Transportation through the Data-Supported Transportation Operations and Planning (D-STOP) Tier I University Transportation Center and by a gift from TOYOTA InfoTechnology Center, U.S.A., Inc.

References