2nd Buffalo Day *for* 5G and Wireless Internet of Things

LeBeam: Beam Learning in MmWave/THz-band Drone Networks Under In-Flight Mobility Uncertainties

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Motivation and Challenges

- THz-band communication is a key technology to enable ultra-high-data-rate wireless links
- Due to high attenuation in high-frequency band, the range of THz communications is limited (~10m)
- Easily disconnected by beam misalignment of transmit and receive antennas in mobile environments

How to achieve robust mmWave/THz-band communications in mobile environments?

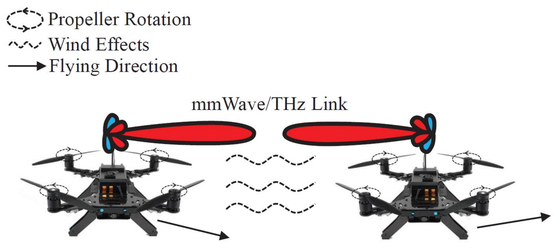


Fig. 1: Drone Communication in mmWave/ THz band

Proposed Solution

- **Goal**: Reduce the outage probability of the mmWave/THz-band wireless links
- We propose an echo state learning-based stochastic beam control scheme called ***LeBeam*** in the presence of multi-scale mobility uncertainties of the flying UAVs

What does *LeBeam* do?

- *LeBeam* dynamically *predicts the best beamwidth* θ based on *statistical information* of the UAV mobility pattern
- **Input:** Mobility information of UAV Tx and UAV Rx
- **Reservoir**: Hidden layer acting as a nonlinear high-dimensional expansion and a memory of the input
- **Output:** Predicted optimal directivity angle θ for UAV Tx

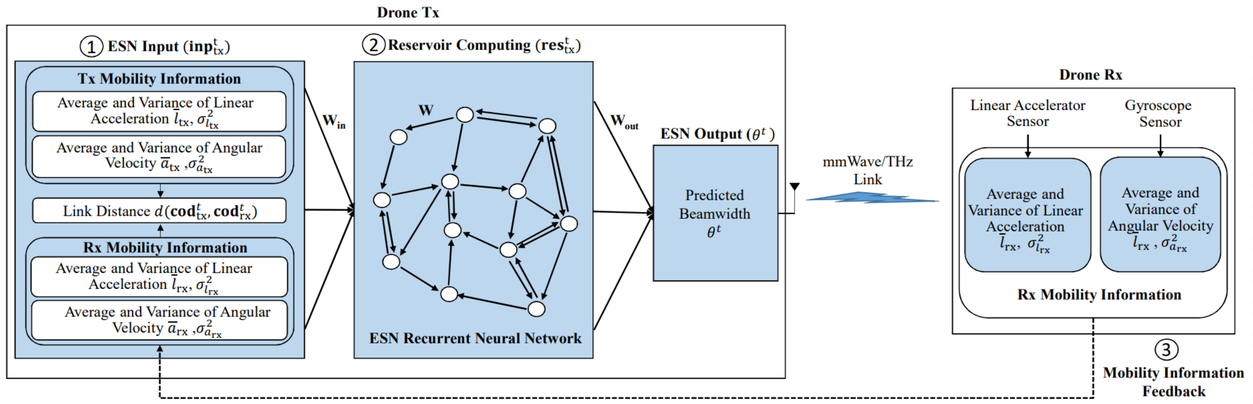


Fig. 2: Diagram of *LeBeam*

How does *LeBeam* predict θ ?

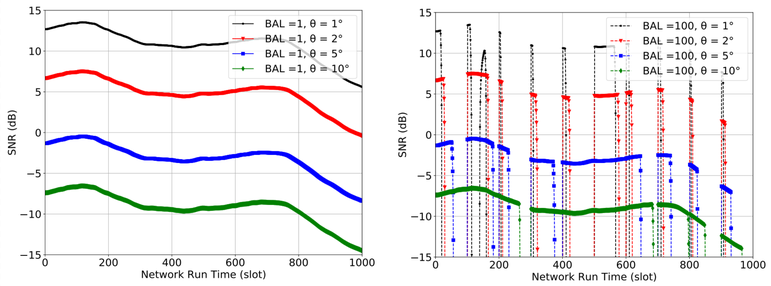
- Approximate the mapping from the input signals to the output signals, by training its input weights $\mathbf{W}_{in}$ and the reservoir weights $\mathbf{W}$

Mobility Measurement

- Three mobility uncertainties - Micro-scale, Small-scale, Large-scale
- Weather Conditions – Windy and Non-windy
- Intel Aero drone along with android smartphone was used to measure the mobility uncertainties

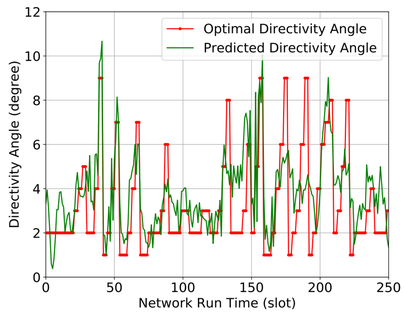
Results

THz Link SNR with different beam alignment latency (BAL)



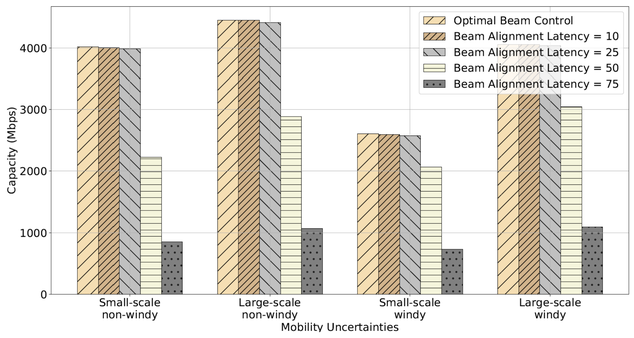
- BAL 1 - Highest SNR (on average 10.85 dB) is achieved with directivity angle of 1°
- BAL 100 - THz-band link is disconnected frequently (probability of 13%-82%) --- because of the misalignment

Prediction accuracy of *LeBeam*



- *LeBeam* is able to predict the optimal directivity angle with very high accuracy.

THz link capacity with different beam alignment latency (BAL)



- Nearly optimal (over 99%) link capacity can be achieved with beam alignment latency of up to 125 ms.
- This verifies the effectiveness of *LeBeam* in improving the robustness of THz-band wireless links in the presence of beam alignment latency

Conclusions

- We proposed a stochastic beam control scheme *LeBeam*, which can predict the optimal beamwidth based on the first- and second-order moments of the drone mobility
- *LeBeam* can achieve nearly optimal link capacity with low and moderate-level beam alignment latency

References

- S. K. Moorthy, Z. Guan, "Beam Learning in MmWave/THz-band Drone Networks Under In-Flight Mobility," IEEE Transactions on Mobile Computing, accepted for publication, Oct. 2020.
- S. K. Moorthy, Z. Guan, "*LeTera*: Stochastic Beam Control Through ESN Learning in Terahertz-Band Wireless UAV Networks," in *Proc. of IEEE INFOCOM Workshop on Wireless Communications and Networking in Extreme Environments (WCNEE)*, Toronto, Canada, July 2020.
- Z. Guan and T. Kulkarni, "On the Effects of Mobility Uncertainties on Wireless Communications Between Flying Drones in the mmWave/THz Bands," in *Proc. of IEEE INFOCOM Workshop on Wireless Communications and Networking in Extreme Environments (WCNEE)*, Paris, France, April 2019.