Modeling and Combating Blockage in Millimeter Wave Systems

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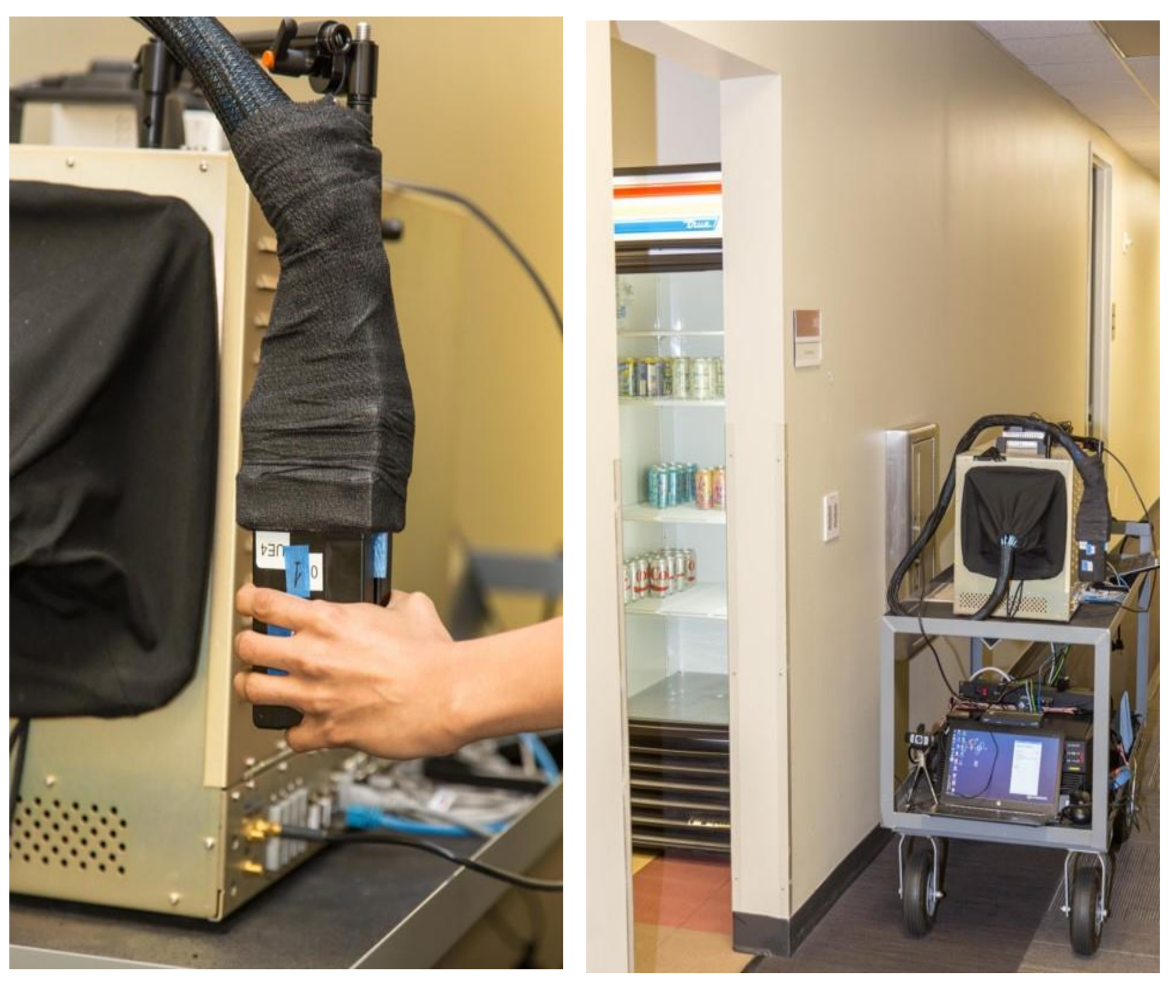
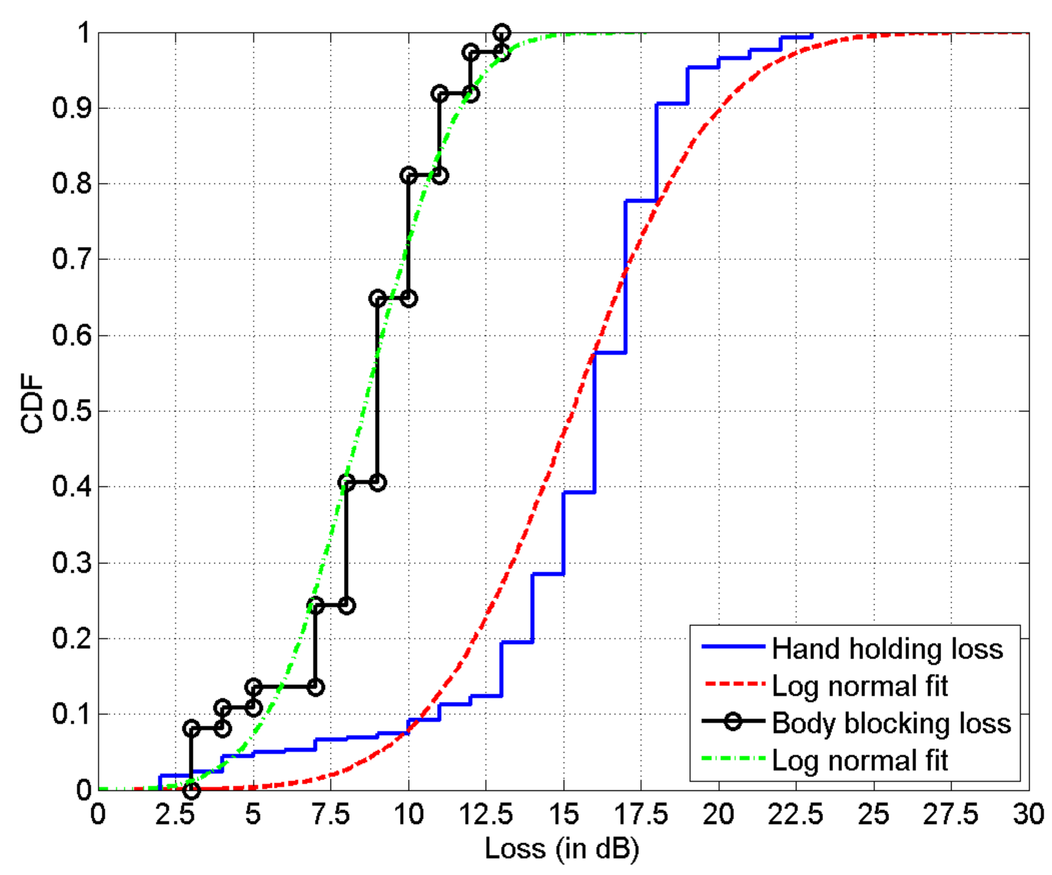
Broad Objectives

- **Millimeter wave (mmW) systems are a key component of 5G-NR**
  - ➢ Hundreds of works have appeared on channel modeling, system design, network level impact, etc.
  - ➢ Key practical viability issues still need to be addressed as we approach commercial deployments
    - ▪ Penetration of mmW signals through common materials in residential and urban deployments
    - ▪ Blockage of mmW signals through the hand, with the human body, etc.
- **Prior work on blockage modeling**
  - ➢ 802.11ad proposes a ray tracing-based blockage model for the probability of cluster blockage and distribution of power attenuation
  - ➢ METIS proposes a human blockage model based on DKED framework
  - ➢ 5GCM proposes models using measurements at ~73 GHz
    - ▪ 30-40 dB loss is suggested, but these are based on horn antenna measurements
    - ▪ They correspond to short distances between the human and the horn
  - ➢ 3GPP has a blockage model in two options (stochastic and map-based variants)
    - ▪ Angular blockage due to impact of hand on a form-factor UE design
    - ▪ Flat 30 dB loss for the hand over the blocked region
    - ▪ DKED model for blockage due to other objects
  - ➢ Some recent works from the mmMAGIC project, but similar in flavor
- **Fundamental contributions**
  - ➢ **Conclusion 1:** Considerably more optimistic blockage estimates than 3GPP blockage model or prior work
    - ▪ Median of hand blockage loss is ~15 dB
    - ▪ Median of body blockage loss is ~8.5 dB
  - ➢ Key differences stem from wider beamwidths of phased arrays that allow more signal capture and lesser losses
  - ➢ **Conclusion 2:** Time-scales at which signal degradation happens is on the order of a few 100 ms (or more)
    - ▪ These time-scales correspond to *physical* movements of blocker(s) and/or transmitter/receiver
    - ▪ Given the effective sub- or a few ms latencies in 5G-NR, alternate viable links can be made before the existing link breaks

Hand and Body Blockage

- **Proposed methodology**
  - ➢ Use of mmW measurements from a 28 GHz experimental prototype with a 5G base-station (16 x 8 antenna array) and a form-factor UE (4 x 1 patch and dipole subarrays across multiple antenna modules) to study blockage
  - ➢ Prototype uses a proprietary transmission structure (125 us subframe) that allows directional beamforming at both ends
    - ▪ 16 beams at gNB side
    - ▪ 5 beams x 4 subarrays = 20 beams at UE side
    - ▪ One full beam scan = 40 ms
  - ➢ Blockage loss estimated as RSSI differential between two controlled studies (without and with hand/body)
- **Example illustration**

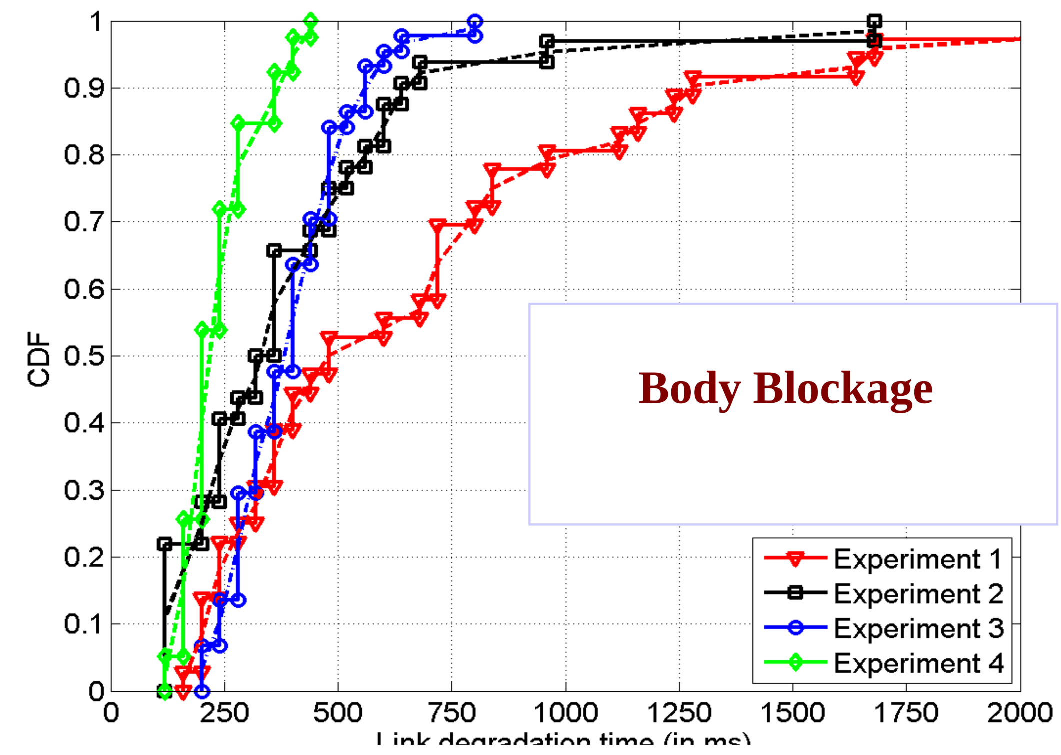


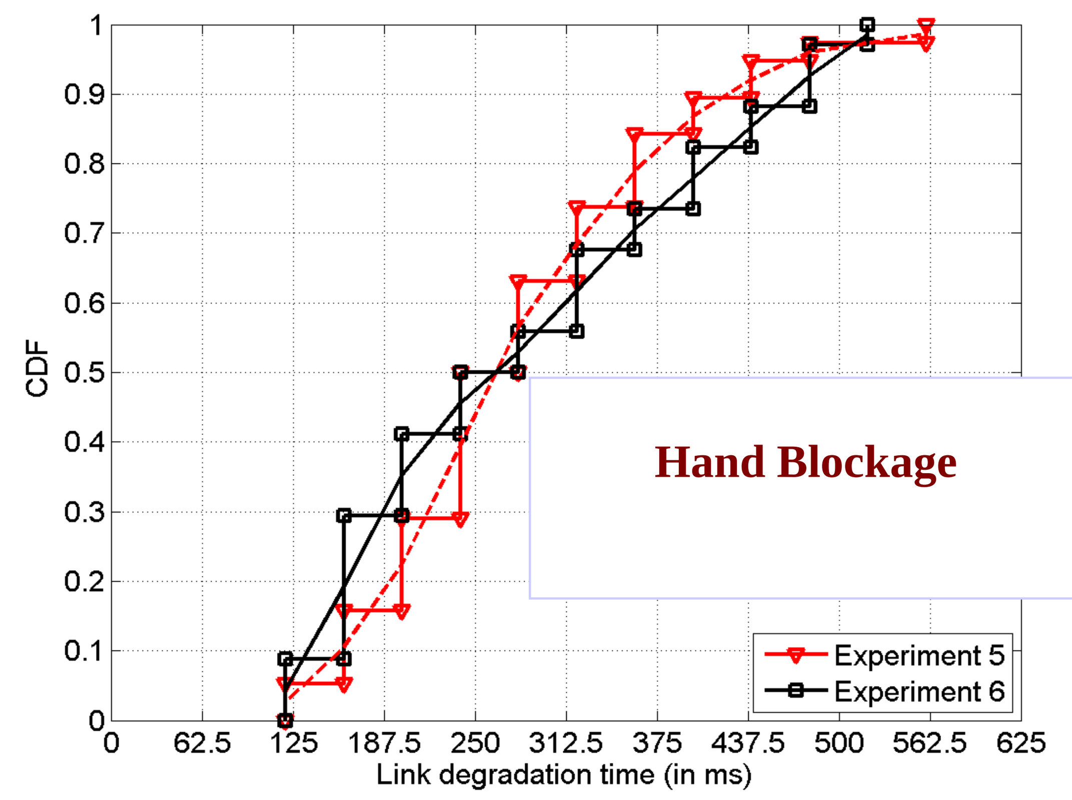


- **Key lessons learned**
  - ➢ Phased arrays allow more signal capture with unblocked/partially blocked antennas
  - ➢ Simple log-normal fits are sufficient to understand system level impact
  - ➢ A more accurate (but complicated) model is a Gauss-Weibull mixture
  - ➢ A 15 dB loss is still significant and substantial ← → Essentially a link loss

Time-Scales of Blockage

- **Link degradation time**
  - ➢ Good channel condition: Time taken for the RSSI to drop from its steady-state value to its minima
  - ➢ Poor channel condition: Time taken for the link to be completely lost
  - ➢ Worst-case link degradation time >120 ms even for the poorest channel condition





Mitigation Strategies

- **Step 1: Densify the network**
  - ➢ Channel becomes more richer as ISD decreases
  - ➢ Also, a number of gNBs to switch to
- **Step 2: More antenna modules/subarrays at UE side**
  - ➢ Trades off cost, power, real-estate and/or complexity
- **Step 3: Learn the clusters in the channel**
  - ➢ More modules/subarrays = Higher beam management overhead/cost
- **Solutions**
  - ➢ SA deployments
    - ▪ Perform handover, or perform a gNB beam switching
    - ▪ Perform UE side subarray/beam switching
    - ▪ Or, stuck with current cluster → Perform a proprietary beam refinement for perhaps a few dB improvement
  - ➢ NSA deployments → In addition to the above, fall back to sub-6 NR, LTE or DC