Towards Efficient Medium Access for Millimeter-wave Networks

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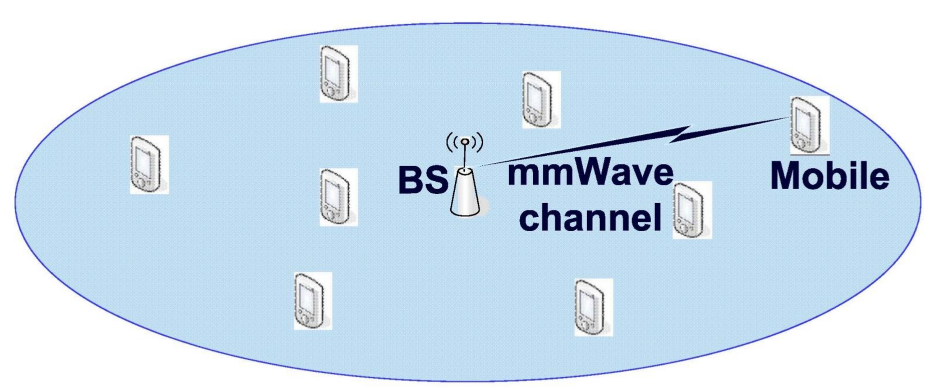
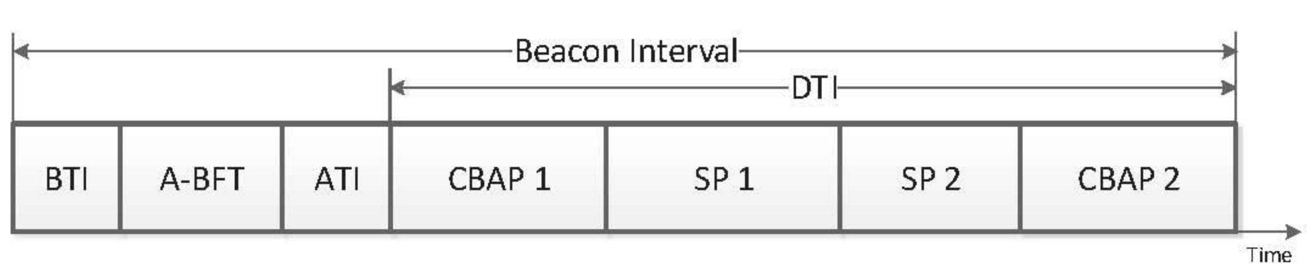
Challenges and Motivation

The need of highly directional communications at mmWave frequencies introduces high overhead for beam training and alignment.

- ❑ Urgent need of efficient beam training & alignment
- ❑ Difficulties in directional medium access control (MAC).
- ❑ Necessity to concurrently schedule radio resources for beam training and data transmission.





(DTI), Service period (SP), Contention-based access period (CBAP). IEEE 802.11ad Beacon Interval: (BI): Beacon transmission interval (BTI), Association beamforming training (A-BFT), Announcement transmission interval (ATI), Data transmission interval

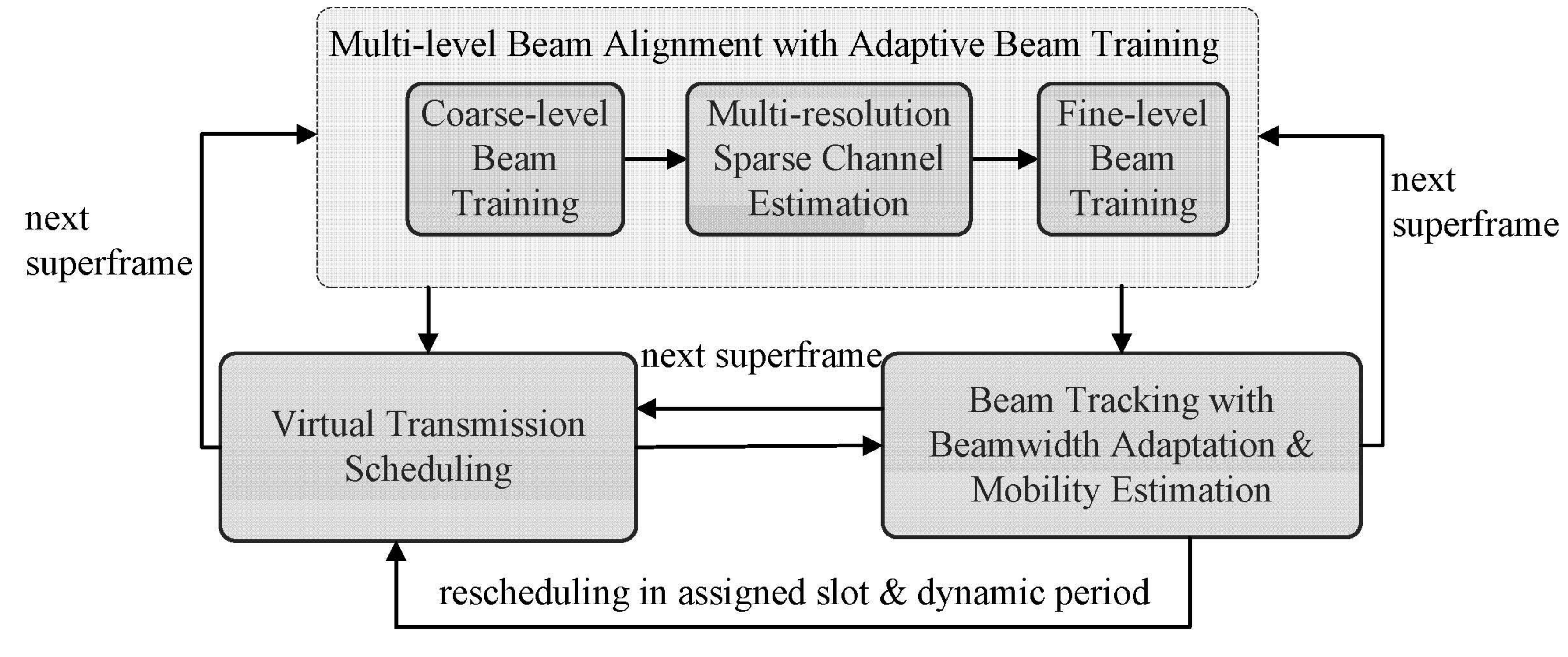
Objectives

Achieve high performance mmWave transmissions

- ❑ Efficient beam training and alignment with lower training overhead and higher beam gain
- ❑ Joint beam training and transmission scheduling to efficiently allocate resources among users while coping with environment dynamics

---channel condition, user population, location, traffic

Proposed Design

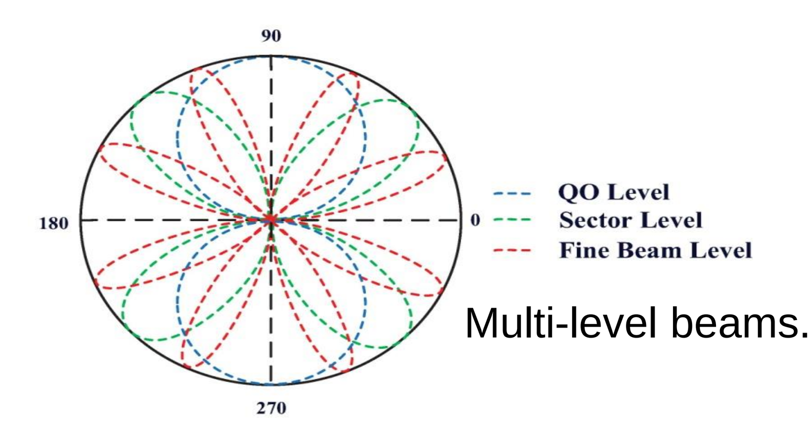


Joint Beam Training and Transmission Scheduling

Integrated MAC design for high performance mmWave network transmissions with 3 closely interactive components:

❑Accurate & light-weight beam training

- multi-user, multi-level. bi-directional coarse training



- block-sparse channel modeling

$$\mathbf{a} = [\underbrace{a_{11}, a_{12}, \ldots, a_{1L}}_{\text{cluster 1}}, \underbrace{a_{21}, a_{22}, \ldots, a_{2L}}_{\text{cluster 2}}, \ldots, \underbrace{a_{K1}, a_{K2}, \ldots, a_{KL}}_{\text{cluster } K}]^T,$$

- fine beam adaptive training with multi-resolution channel estimation

$$dim(\mathrm{H}_{QOL}) < dim(\mathrm{H}_{SBS}) < dim(\mathrm{H}_{FBS})$$

❑Joint beam training and data transmission scheduling

- self-adaptive virtual resource scheduling

$$x = \arg\max_{x} a(x)W(x)r(x)/\overline{R}(x),$$

a: priority parameter, W: queuing delay, r: transmission rate, R: average rate obtained

- Trade off among beam training, data transmission and beam tracking for an overall high network performance

$$T_{sf} = T_{BT} + T_{DTI} \qquad T_{DTI} = T_{ran} + T_{sp} + T_{dp}$$

❑Effective beam tracking for more stable beam alignment

- beam-width adaptation
- mobility estimation

$$\theta_{dev} = T_{lat} \sum_{i=1}^{N_p} |\theta_{dev}^i| / \sum_{i=1}^{N_p} T_{lat}^i$$

Simulation Results

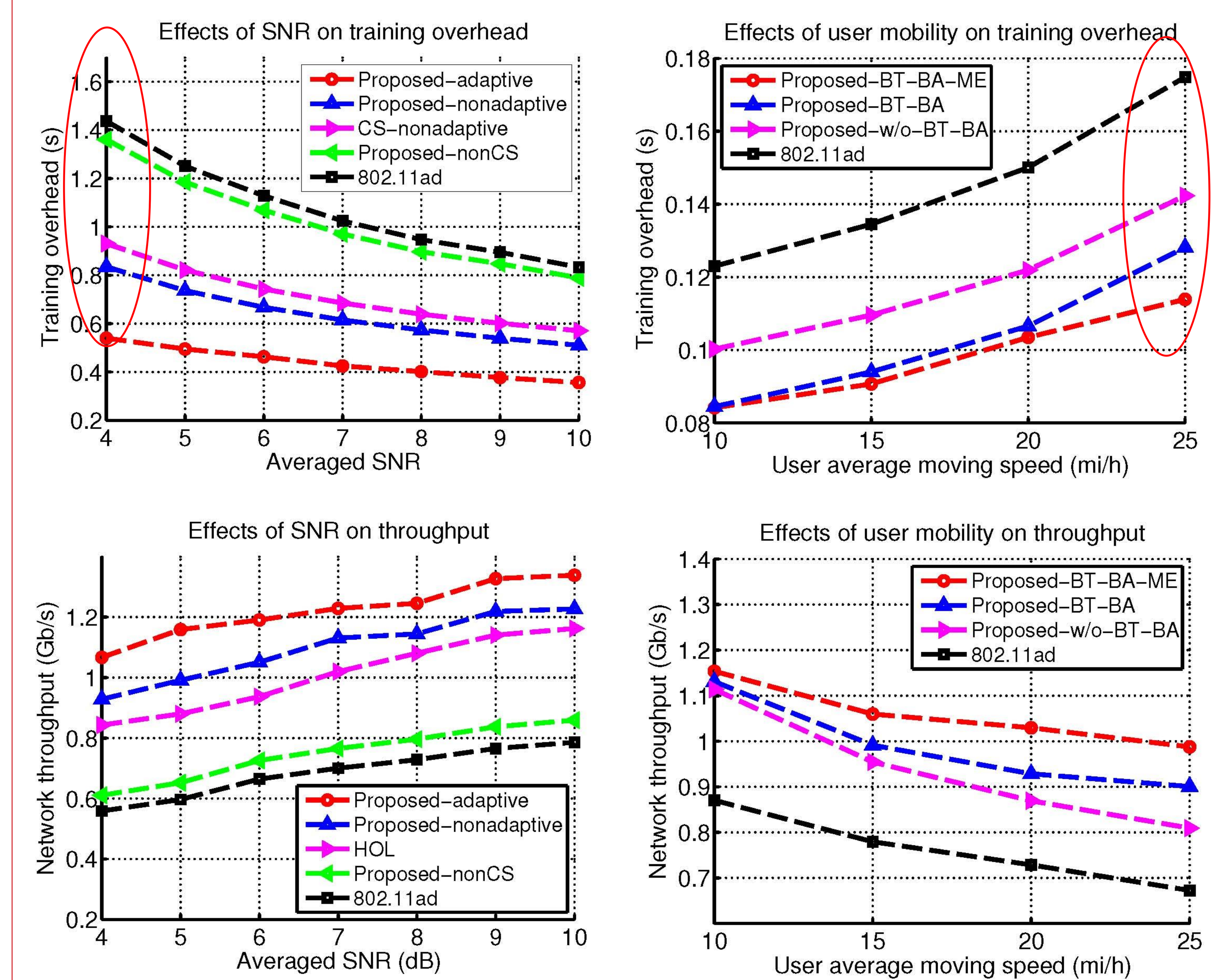
Bandwidth: 1GHz

Carrier Frequiemcy: 60GHz

#QO level: 4

#sector per QO level: 4

#fine beams per sector AP/DEV: 8/4



Conclusion

The proposed schemes significantly reduce training overhead and improve throughput with the interaction of:

- ❑ a low-cost multi-user beam training scheme
  - -multi-level coarse training
  - -multi-resolution adaptive sparse channel estimation for fine beam alignment
- ❑ concurrent allocation of radio resources for beam training and data transmission
  - -virtual scheduling based on user application types and demands
- ❑ flexible beam tracking scheme
  - -beamwidth adaptation
  - -mobility estimation