Data Analytics for Wireless Communication and sensing

Lili Qiu

UT Austin

Use Cases

- Predict wireless performance [INFOCOM’16]
- Network test site selection and diagnosis [ICNP’17]
- Wireless Sensing [MobiCom’19]

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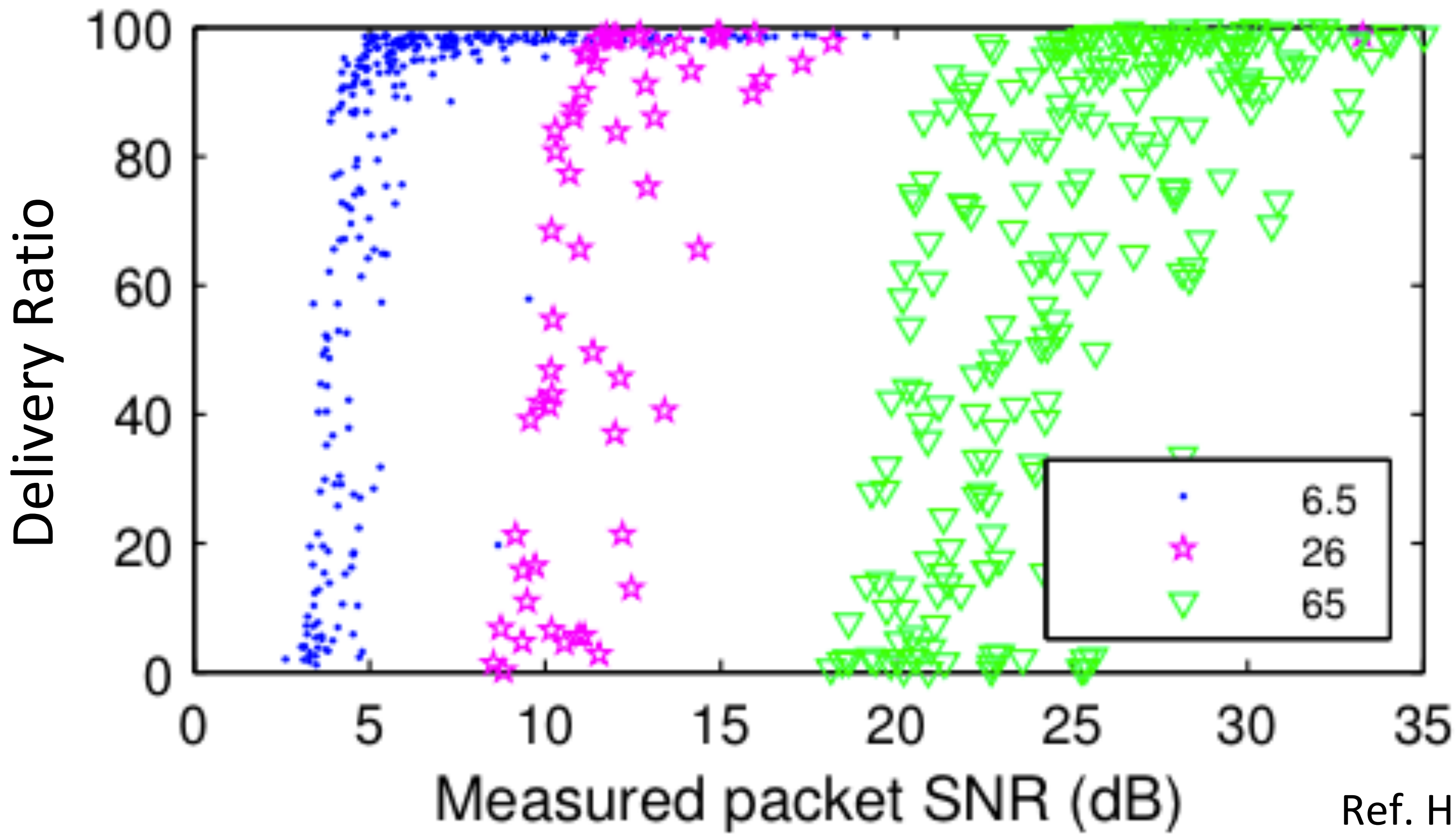
Limitation of Average SNR

- Avg. SNR is widely used for delivery ratio estimation

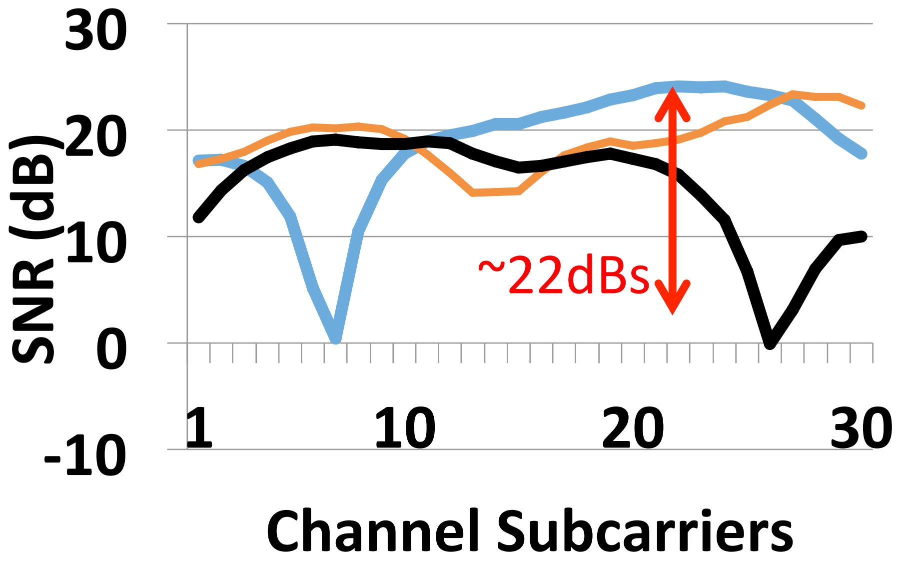


Ref. Halperin10

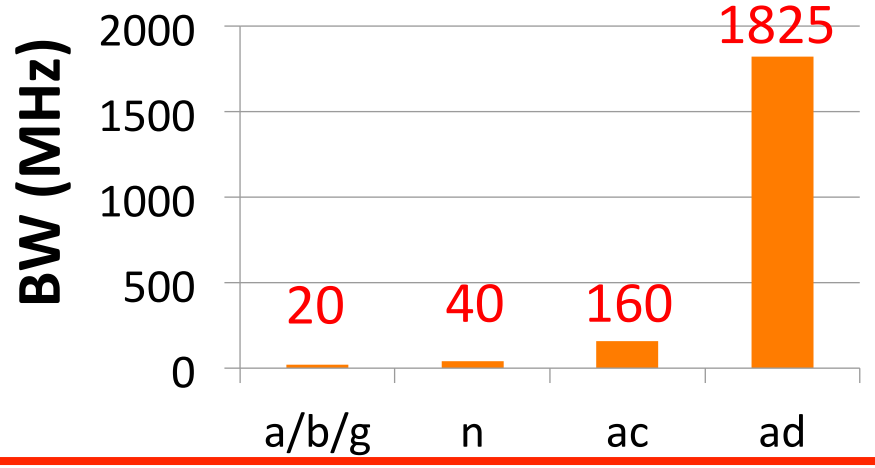
SNR is not a good predictor in Freq. Selective Channels

Frequency Diversity

- Wireless channel are frequency selective



- Bandwidth is increasing with new standards



Due to frequency diversity, average SNR cannot predict wireless performance

Effective SNR

- Effective SNR shows better results than Avg. SNR
- Approach
  1. Map the SNR per subcarrier to BER

$$BER_{eff,k} = \frac{1}{N_{subs}} \sum BER_k(SNR_k)$$

  2. Map $BER_{eff,k}$ back to Effective SNR

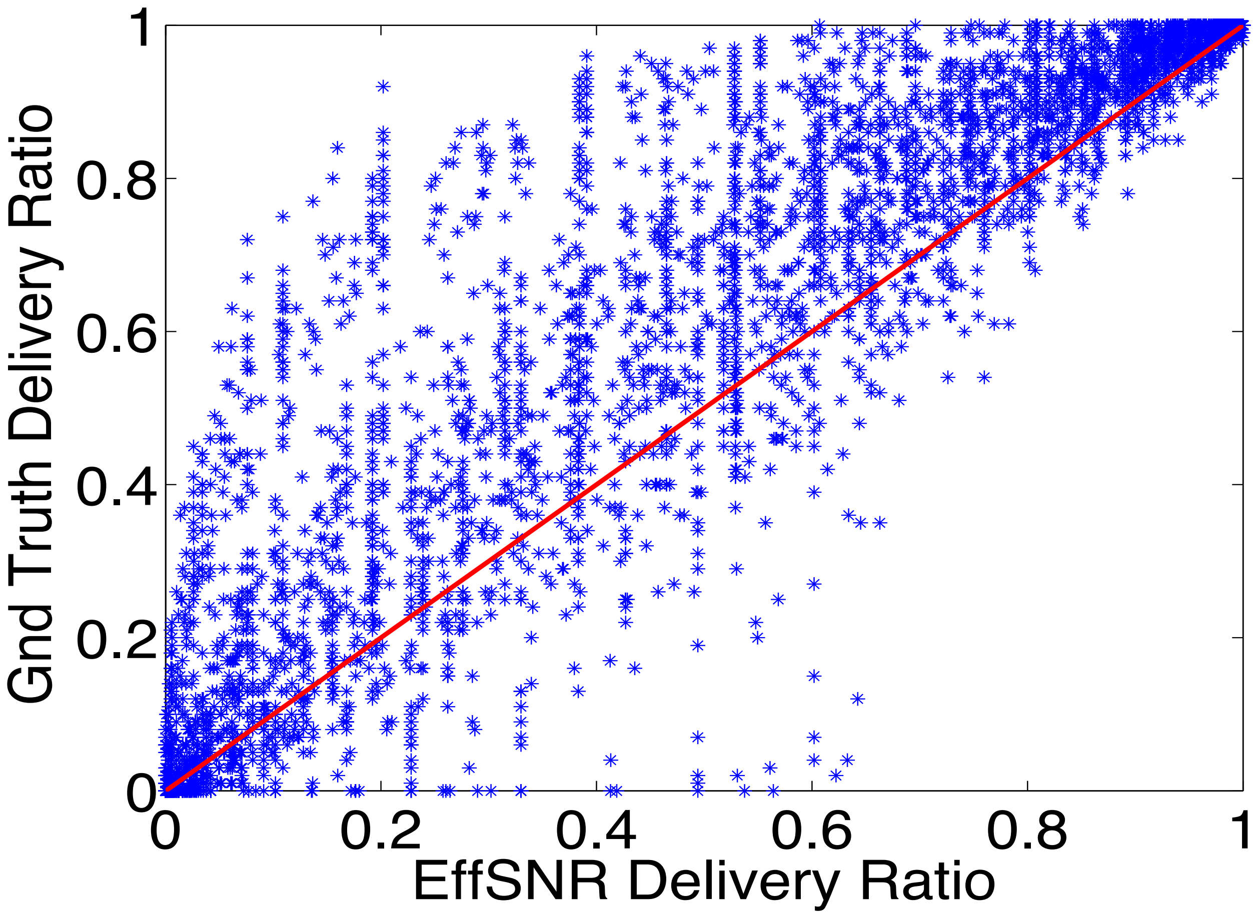
$$\rho_{eff,k} = BER_k^{-1}(BER_{eff,k})$$

  3. Use Effective SNR to select the appropriate rate

How Accurate is Effective SNR?

Effective SNR Accuracy

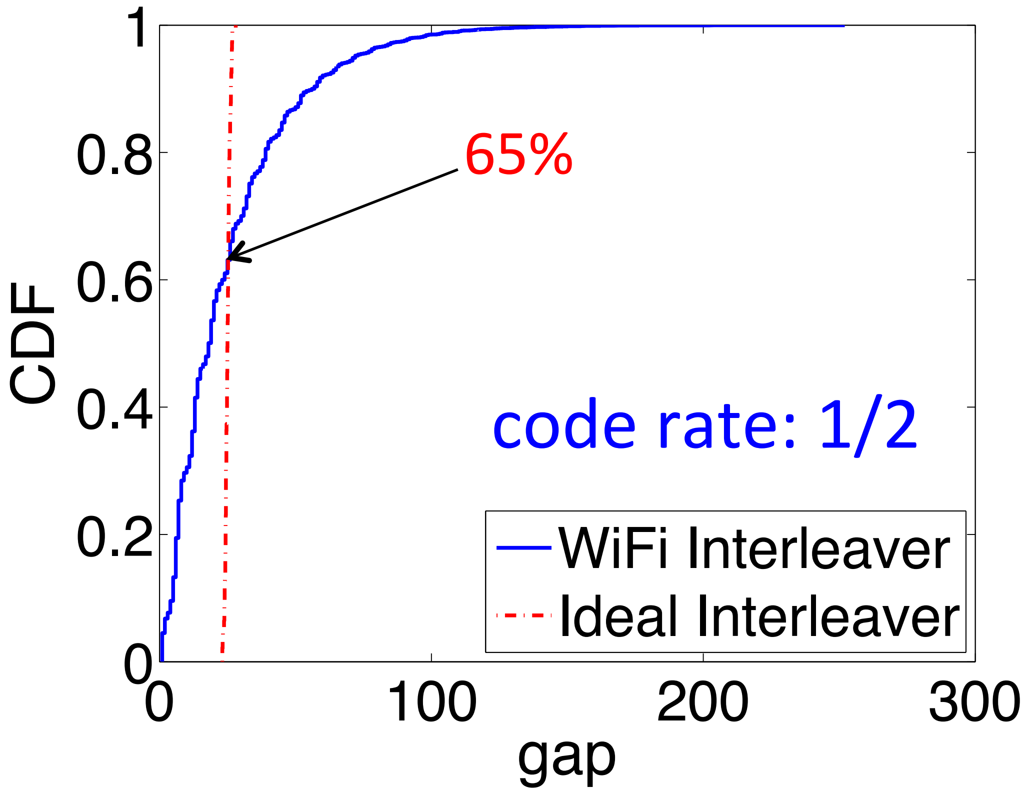
- Scatter plot of Estimated delivery ratio vs. gnd. truth



Effective SNR is also not very accurate

Error Burstiness across Frame

- Assumes that interleaver uniformly distributes bit errors



- WiFi interleaver has a skewed distribution
- Error still bursty in WiFi interleaver

Delivery rate estimation must incorporate error burstiness

Problem Formulation

- Goal
  - To accurately predict delivery ratio using CSI information
- Options
  1. Analytical modeling
     - Hard for freq. selective channels.
  2. Simulate online
     - Prohibitively expensive
  3. Lookup table based approach
     - Pre compute delivery rate for error patterns
     - Error pattern capture the burstiness patterns
  4. Machine learning based approach
     - Use supervised learning to estimate delivery rate

Option 4. Machine Learning Approach

- Propose a machine learning based solution
- Motivation
  - Avoids the time and space complexity of lookup tables
  - Machine learning can provide faster online solution
- Machine learning algorithm
  - We chose Neural Networks
- Reason
  - Supports non-linear continuous functions
  - Appropriate for delivery ratio

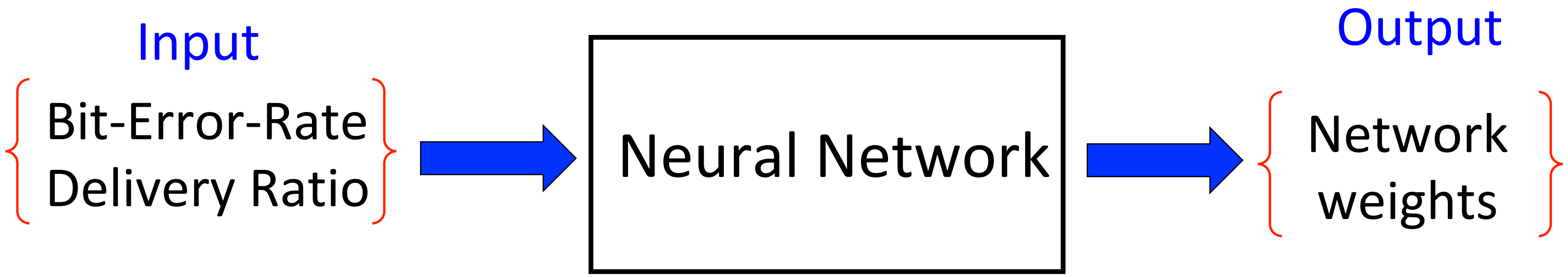
Feature Set

- Feature Set
  - Use BER per subcarrier

- Advantage
  - Easy to obtain from CSI information
  - Allows de-coupling from the interleaver and modulation scheme
  - Feature size is limited by number of bits in OFDM symbol

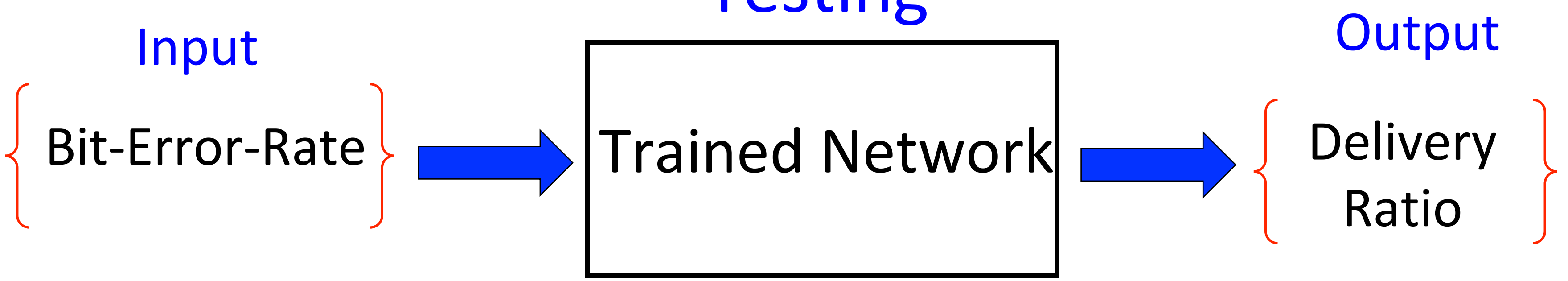
Neural Network Operation

Training

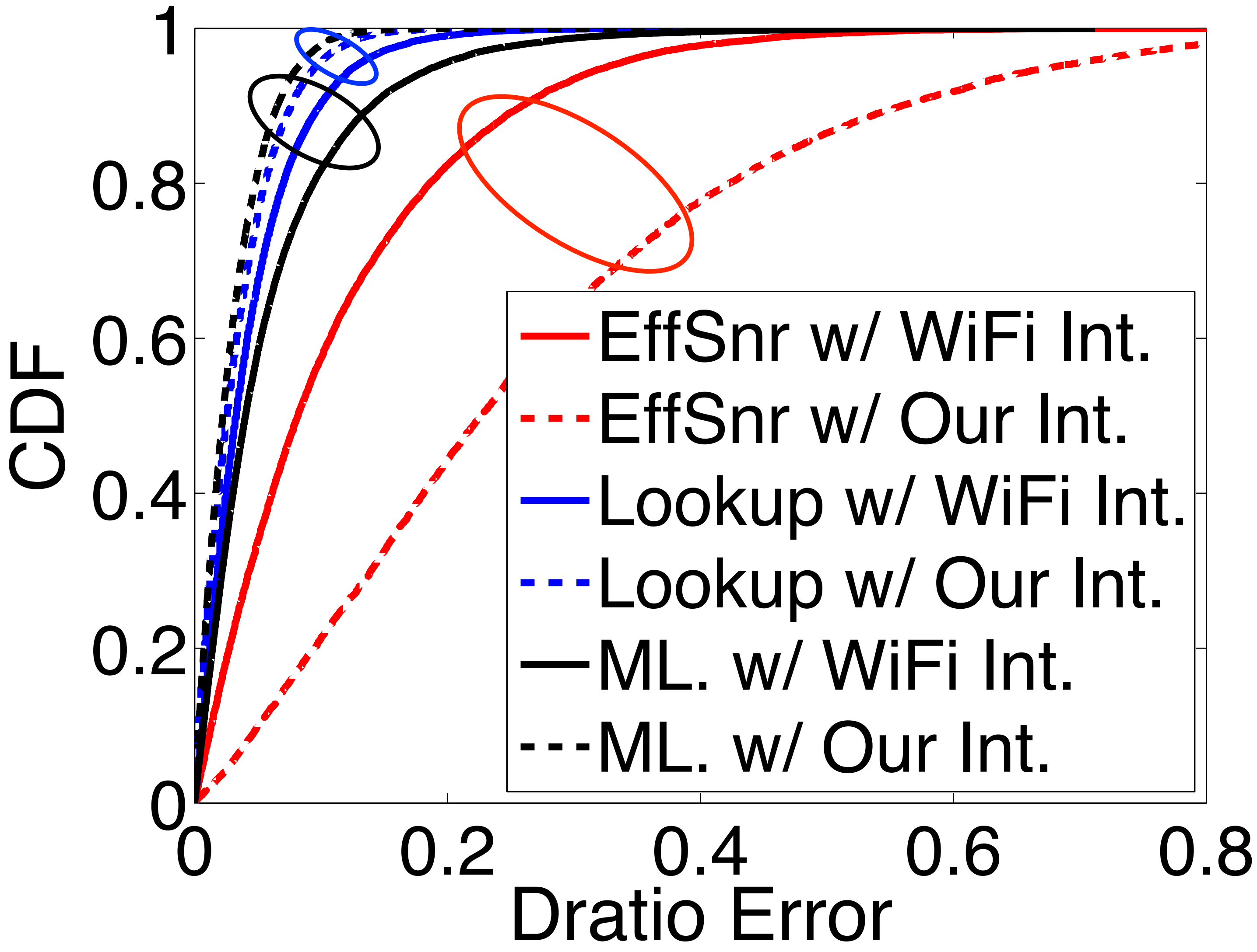


Intel Channel Traces
TGn Channel models

Testing



Delivery Ratio Accuracy (40MHz)



EffSNR
Wifi: 11%
Our: 27%

Lookup
Wifi: 4.5%
Our: 3%

ML
Wifi: 6%
Our: 3%

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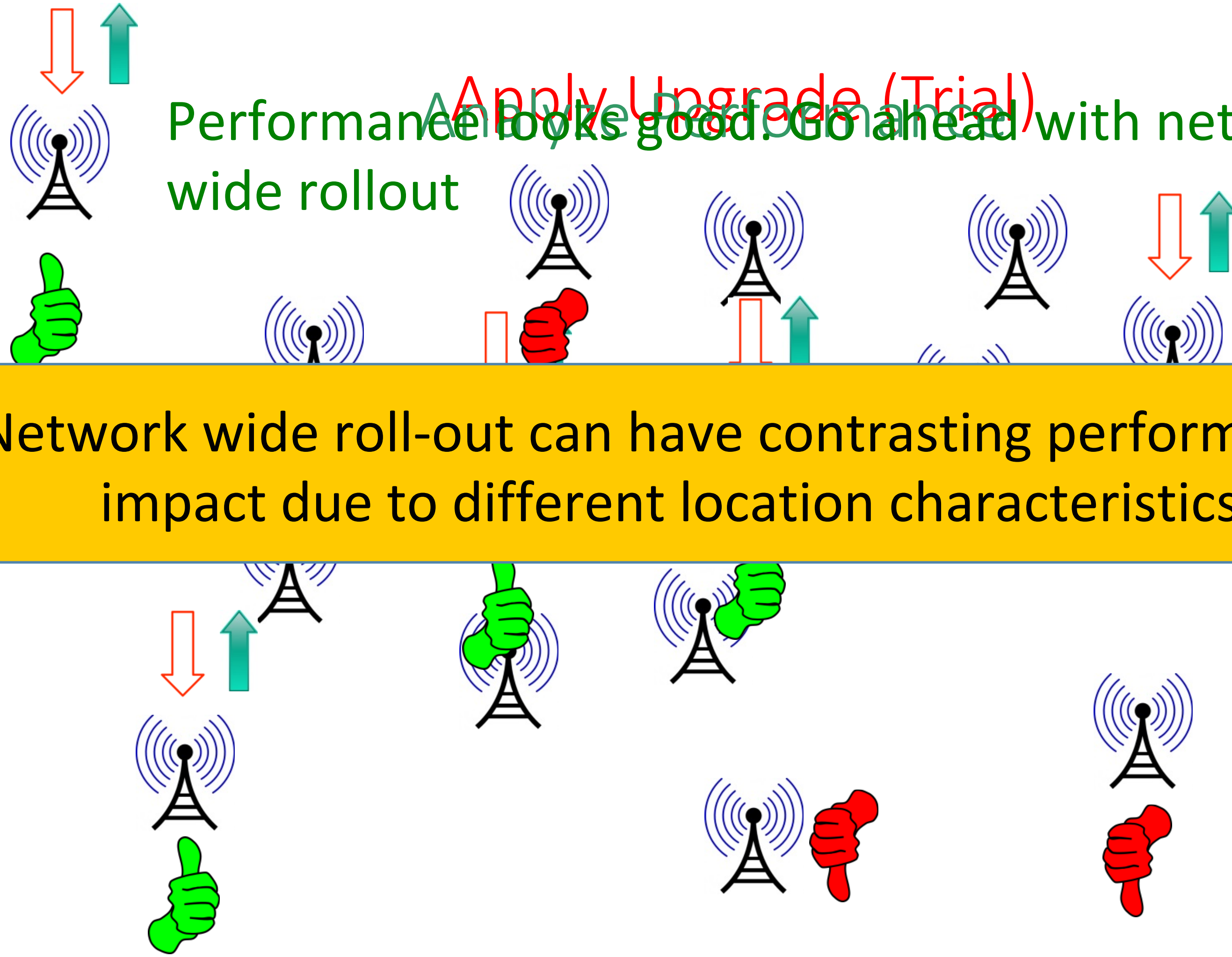
Field Testing Process

Apply Upgrade (Trial)

Analyze Performance

Performance looks good. Go ahead with network-wide rollout



Network wide roll-out can have contrasting performance impact due to different location characteristics

Test Site Selection

- Problem: How to select test sites to maximize early problem detection?
  - Low sampling rate
  - Other contexts: car crash test, medicine design

- Bayesian experiment design

- Greedy heuristic: Incrementally choose locations that diversify feature values

$$\forall j, Max(min_i(Hamming([n_i], n_j)))$$

- Testing 1% nodes can identify major features that affect upgrade performance

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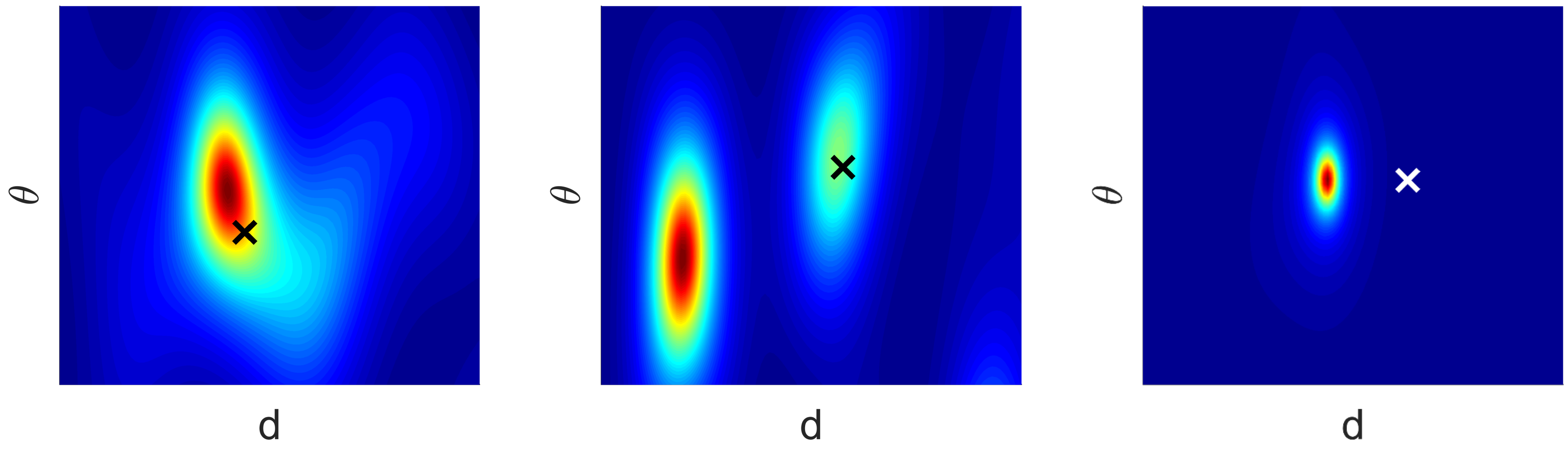
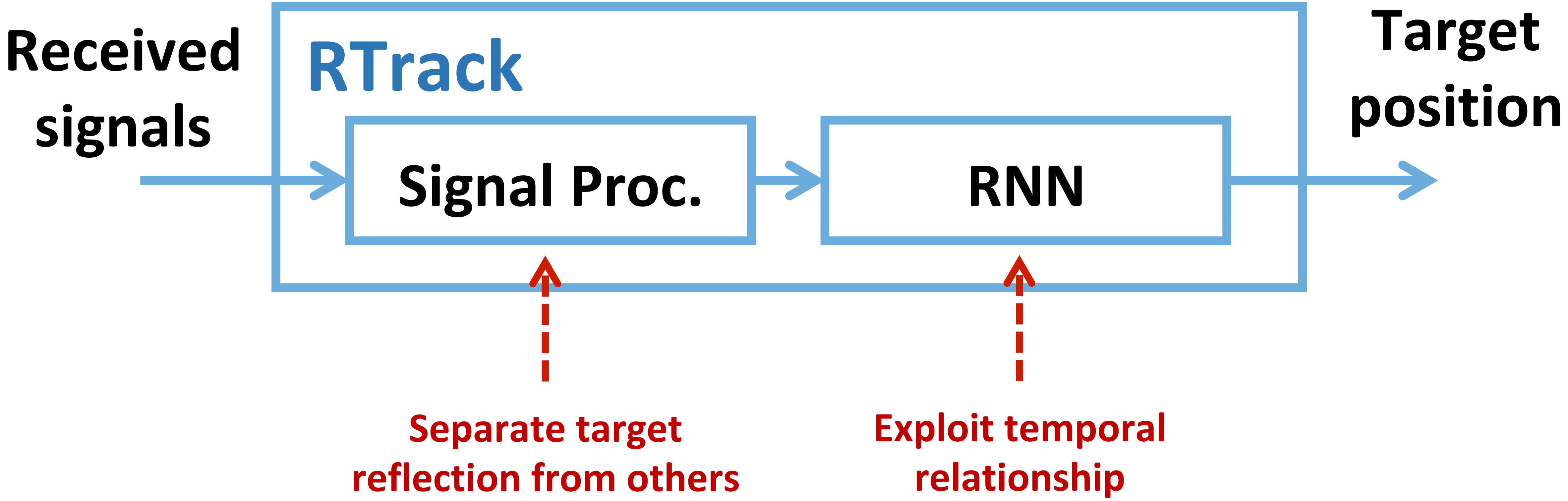
- Wireless motion sensing [MobiCom’19]

Signal Processing is Not Enough

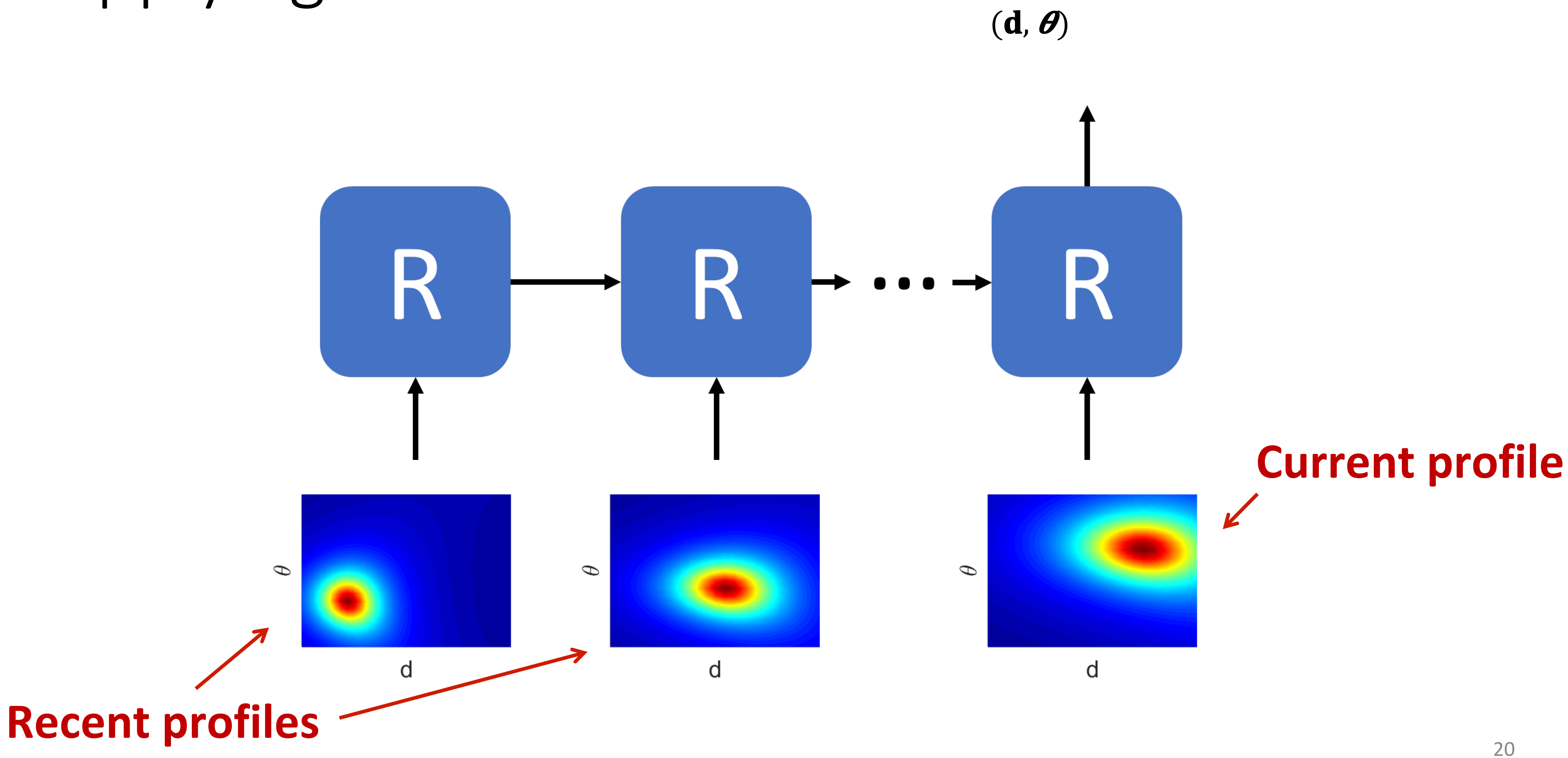


X *is the ground truth position*

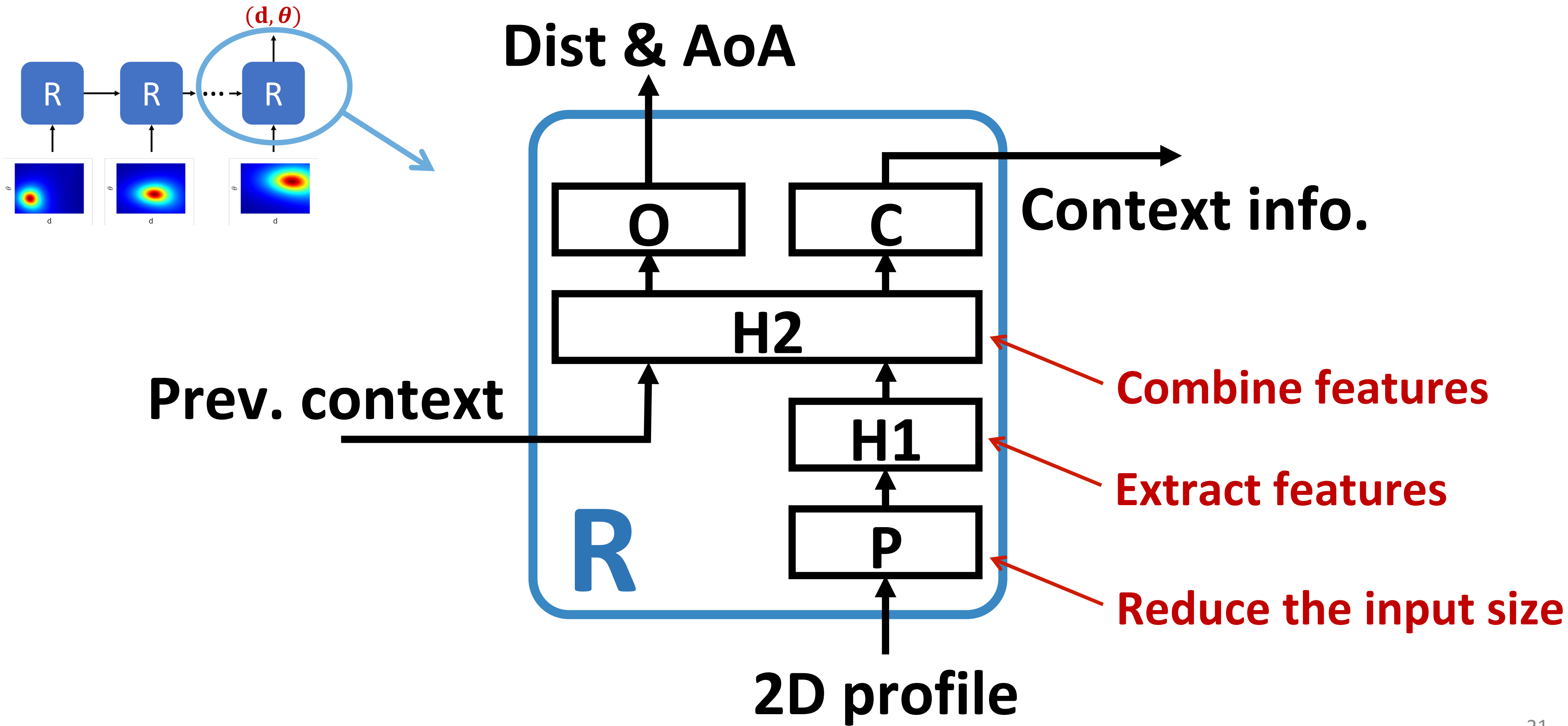
Our Approach



Applying RNN



Network Architecture



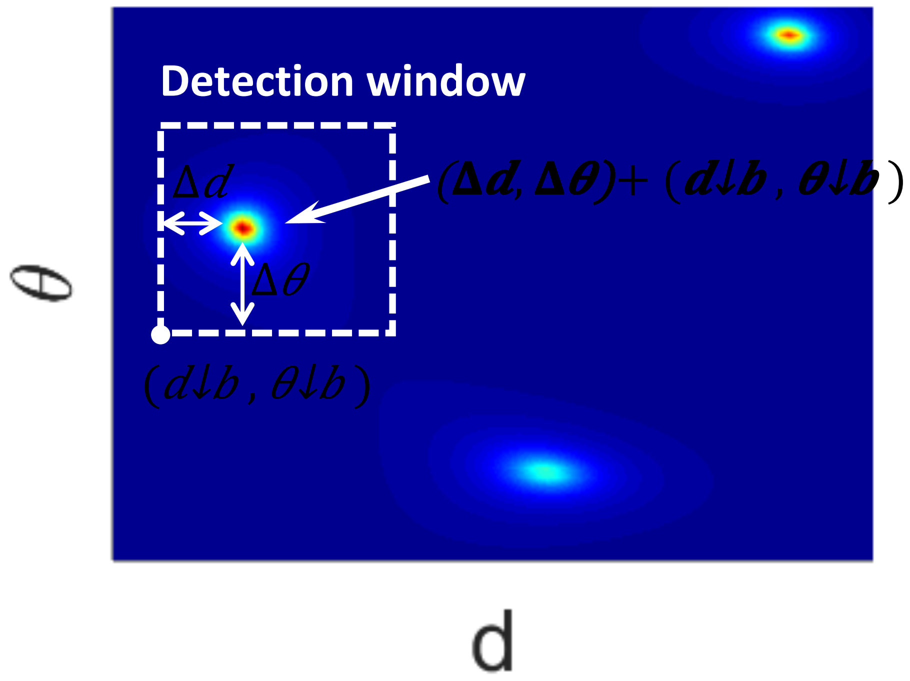
Context Layer

- Consist of 5 neurons

	d	θ	v_r	v_t	a_r	a_t
1	**0.94**	0.04	0.06	0.00	0.34	0.09
2	0.20	**0.76**	0.14	0.06	0.08	0.30
3	0.03	0.24	**0.79**	0.13	0.28	0.10
4	0.10	0.31	0.31	0.22	0.03	0.07
5	0.01	0.10	0.04	0.06	0.06	0.07

Detection Window

- Use a local profile near the target



☺ **Isolate environment impacts**

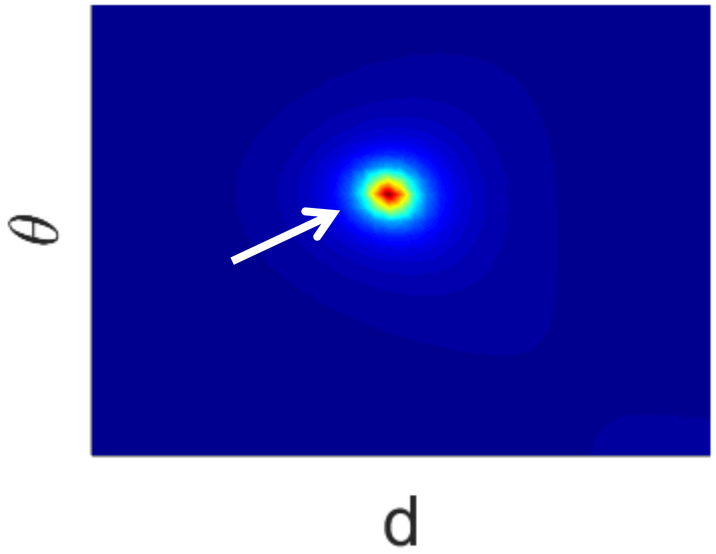
☺ **Save training efforts**

☺ **Support multiple users**

☺ **Reduce computation cost**

Data Augmentation

- Generate more training data with existing data
- Our framework is easy to augment data



Thank you!

lili@cs.utexas.edu