# BLINK: A High Throughput Link Layer for Backscatter Communication

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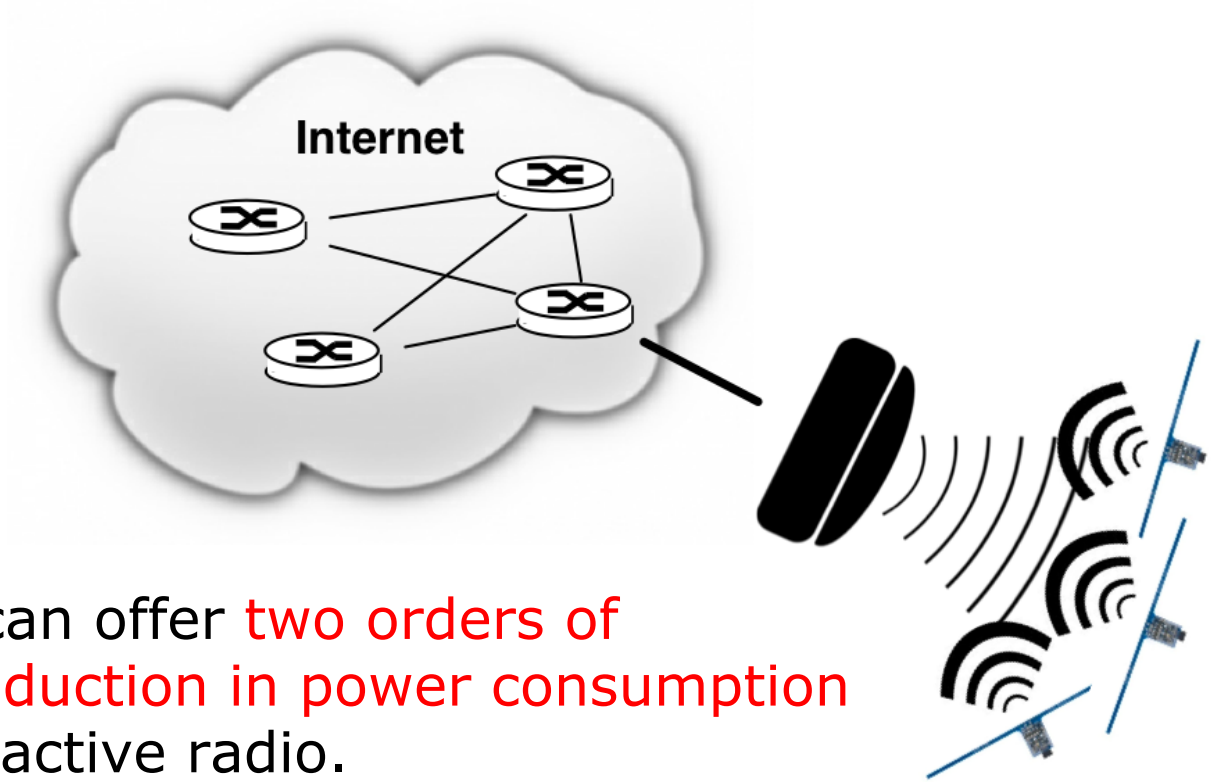
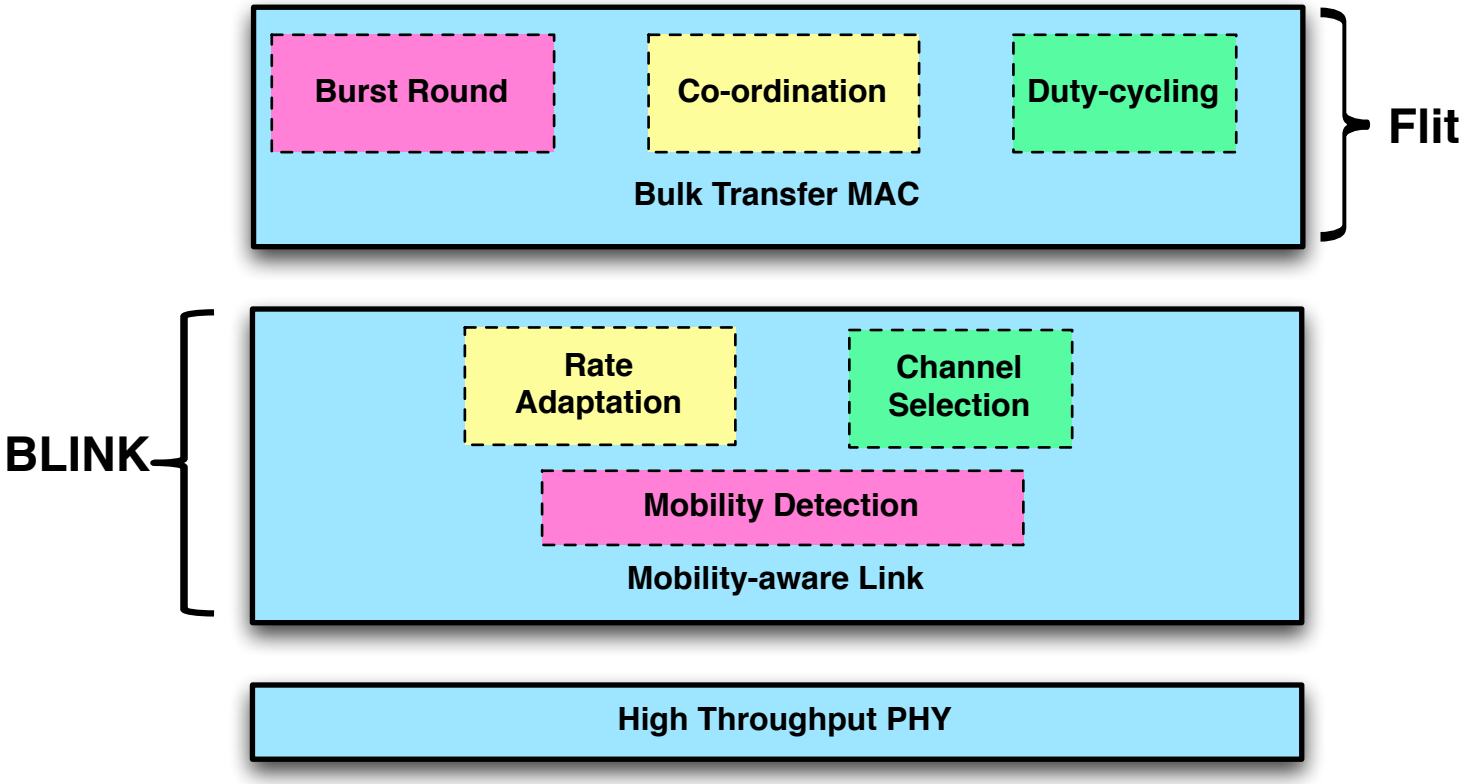
# Why backscatter radio?

*Can backscatter replace active radios as the first wireless hop?*

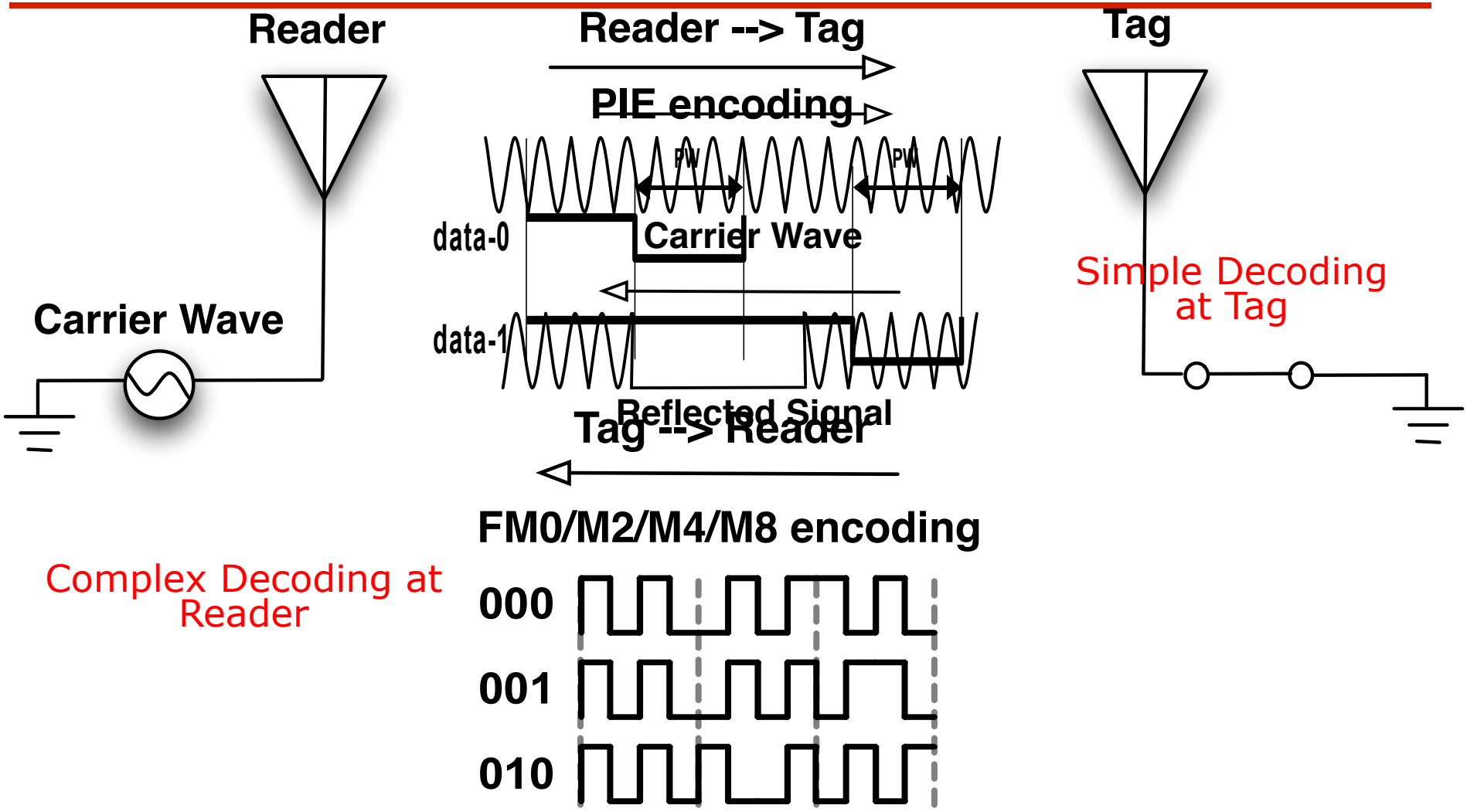



- Backscatter can offer two orders of magnitude reduction in power consumption compared to active radio.

# High Throughput Backscatter Stack



# Encoding and Modulation in Backscatter Radio



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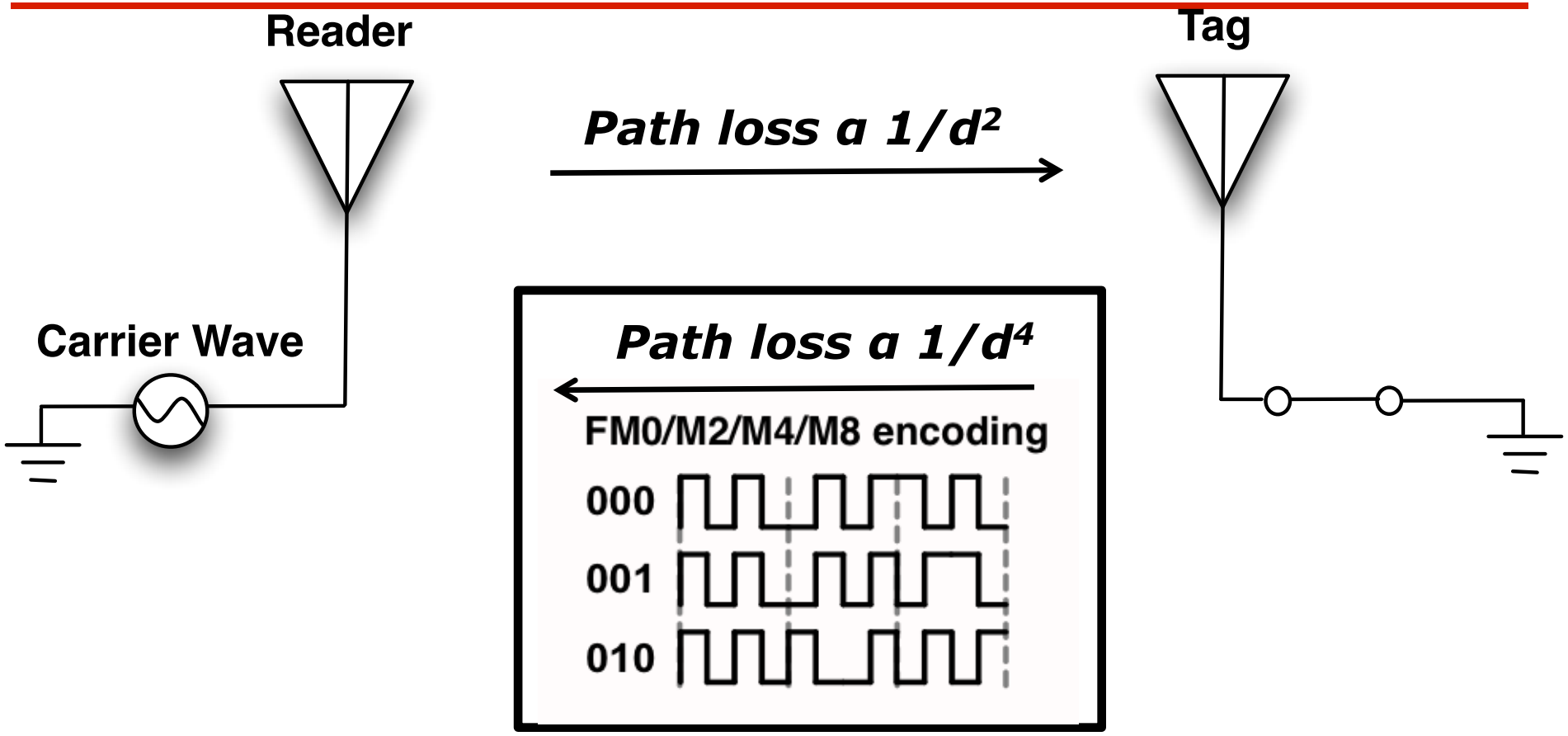
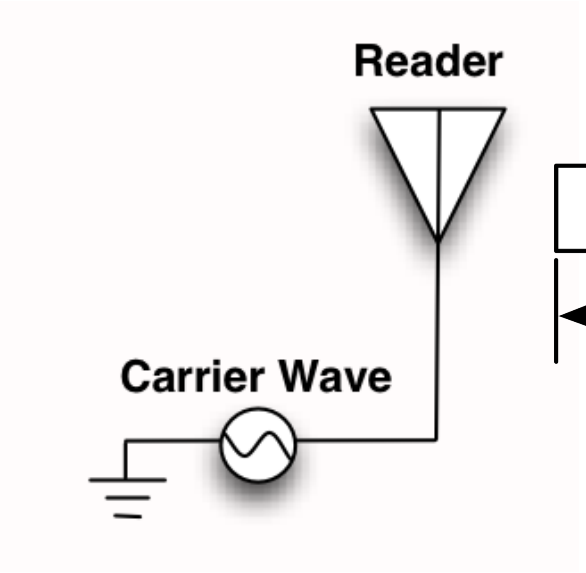
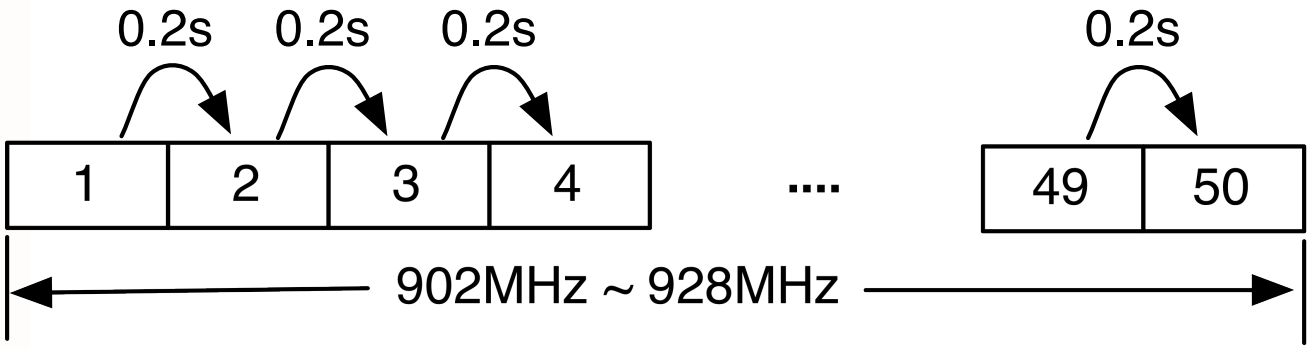



Goal 1: Select optimal bit-rate on tag to reader link

# Channel Hopping in Backscatter Radio




**FCC regulations**: 0.4 channel dwell time within 10s

Goal 2: Design high throughput FCC-compatible channel selection algorithm

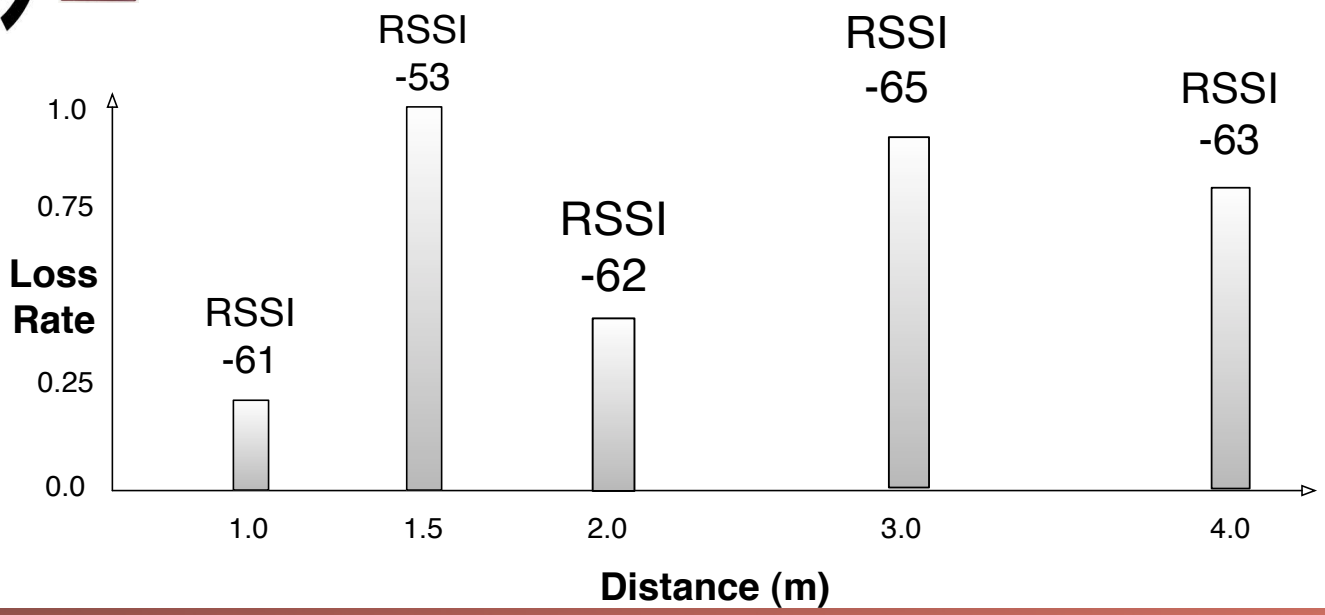
# BLINK Overview

- **Link Metrics**
- Design
- Evaluation
- Conclusion

# Link Metrics in Backscatter Radio

- Commercial reader exposes RSSI and loss rate
  - In active radio, RSSI is correlated with loss rate. Does this hold true for backscatter radios?

- Expt: Measure RSSI/loss-rate for single tag over distance



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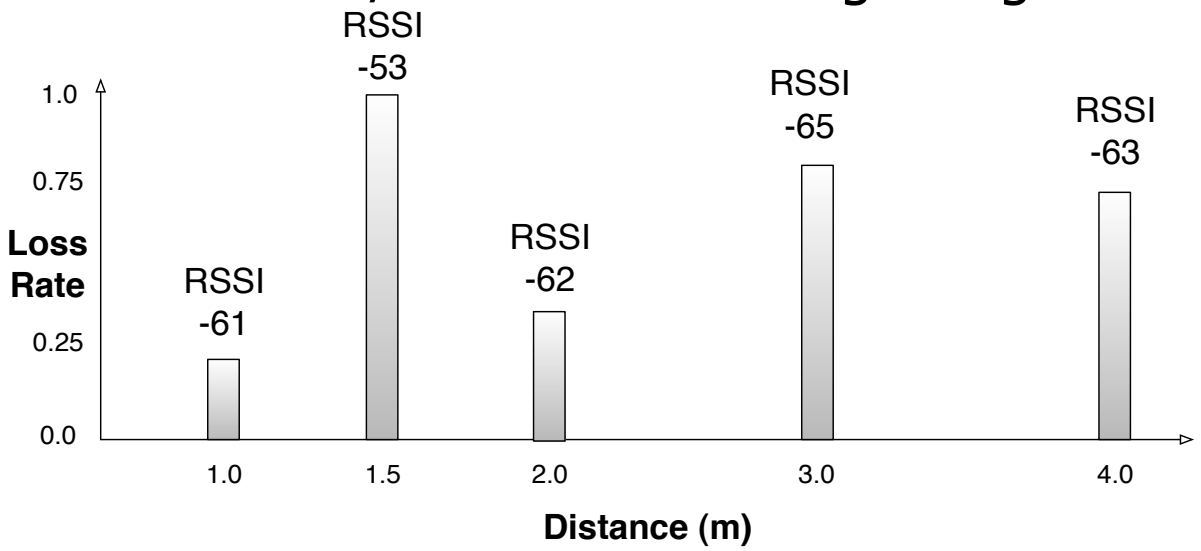
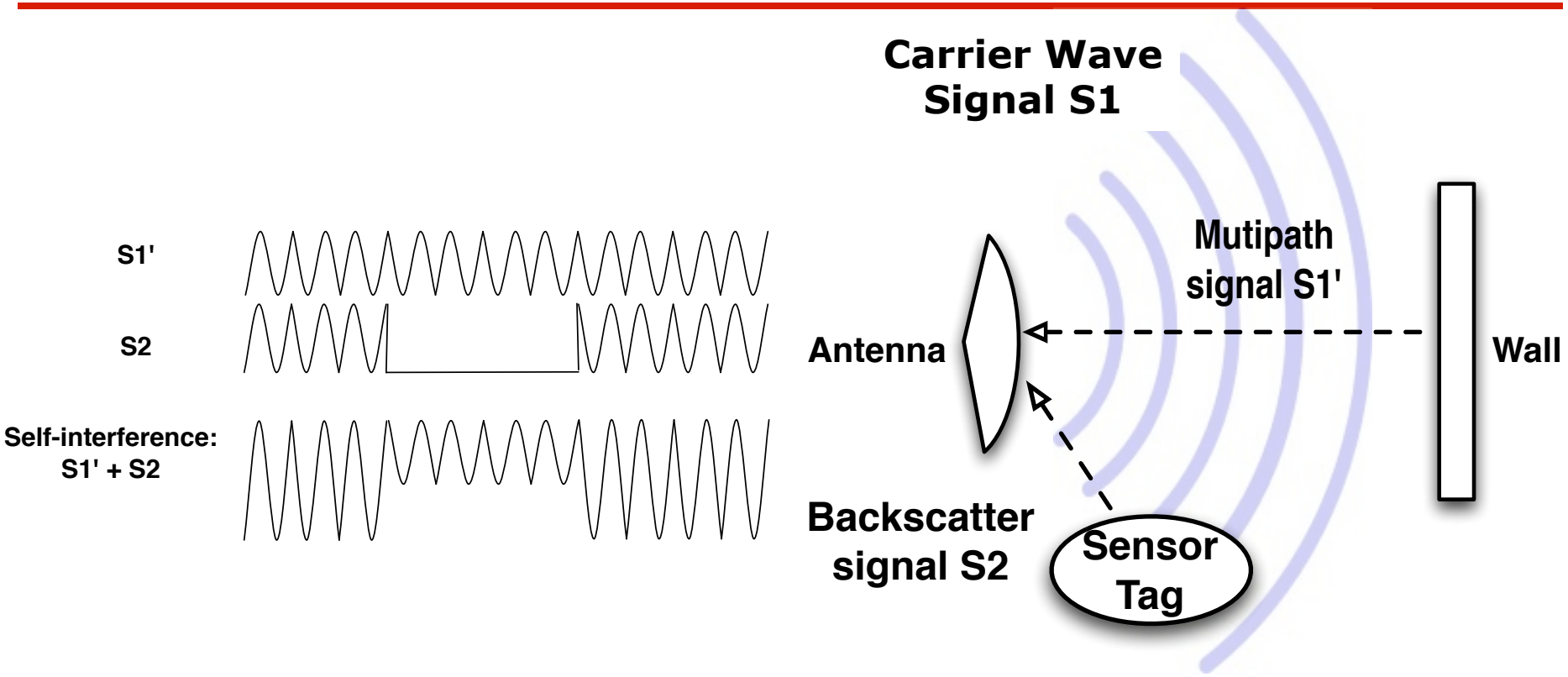


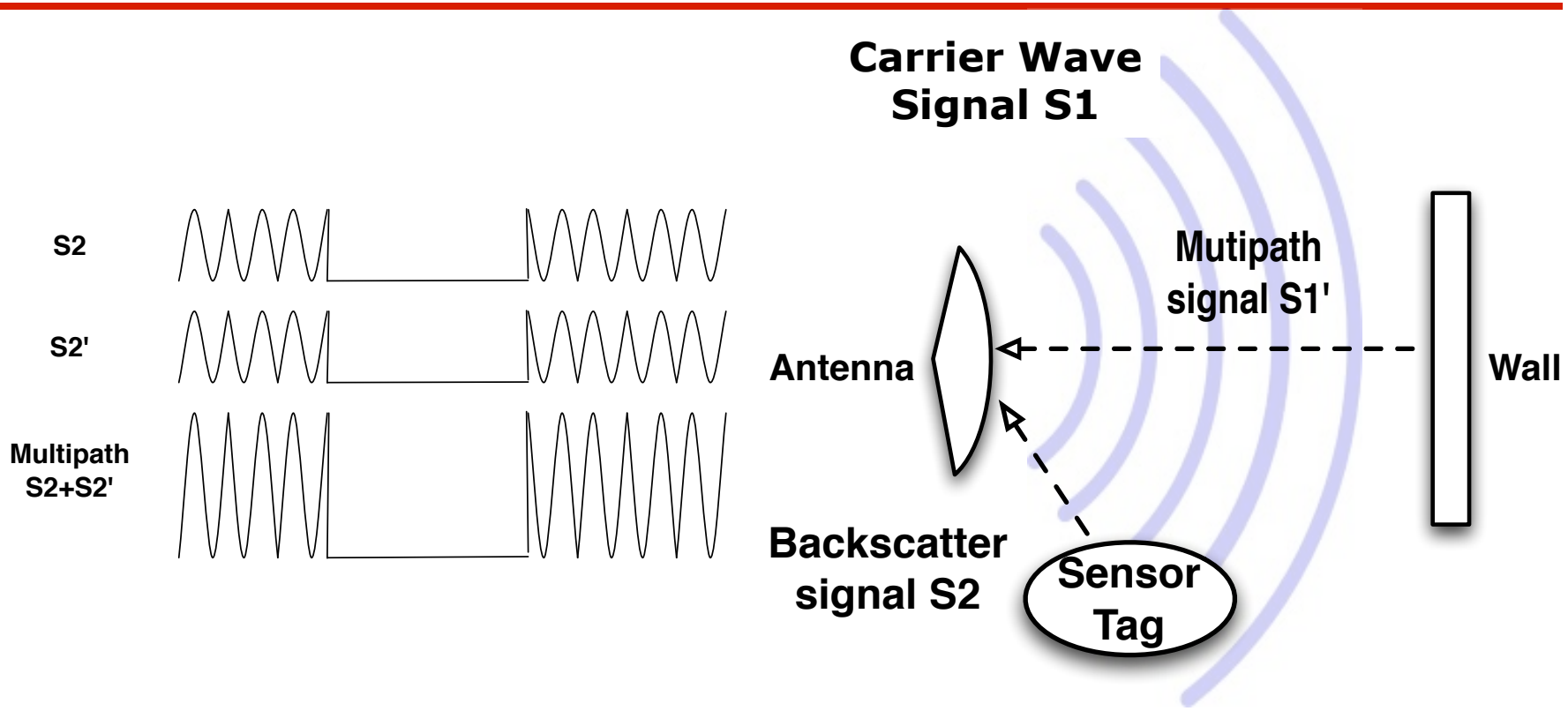

*Why is there low correlation between RSSI and loss rate?*

# Reason: Multipath Self-interference




- Key insight: self-interference causes high losses even if signals interfere constructively i.e. RSSI is high!

# Reason: Multipath Self-interference




- Key insight: self-interference causes high losses even if signals interfere constructively i.e. RSSI is high!
- Implication: Use both RSSI (range effects) and lossrate (self-interference effects).

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- Link Metrics
- **Design**
  - Mobility Detection
  - Rate Adaptation
  - Channel Switching
- Evaluation
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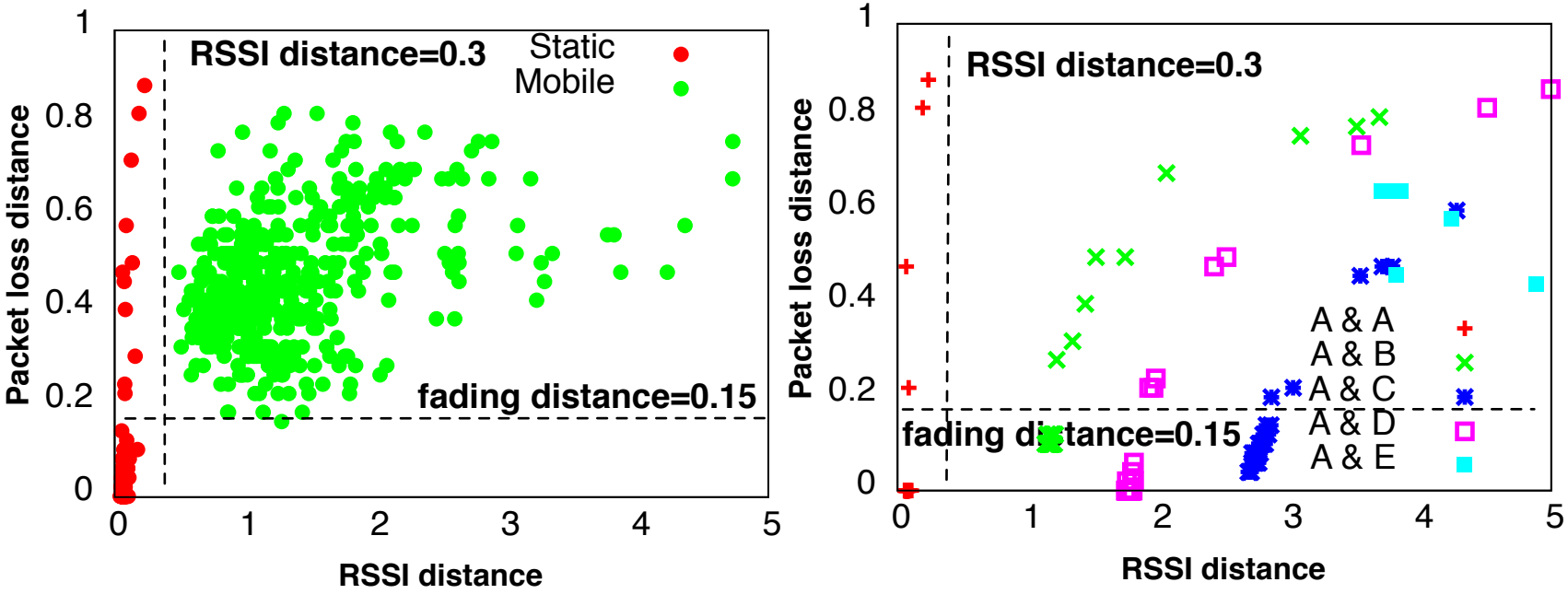
# Mobility Detection

- **Link Signature**: Euclidean distance between successive RSSI/Lossrate scans of 50 channels




- Result: Can reliably detect change of tag position and movement pattern with over 90% accuracy.

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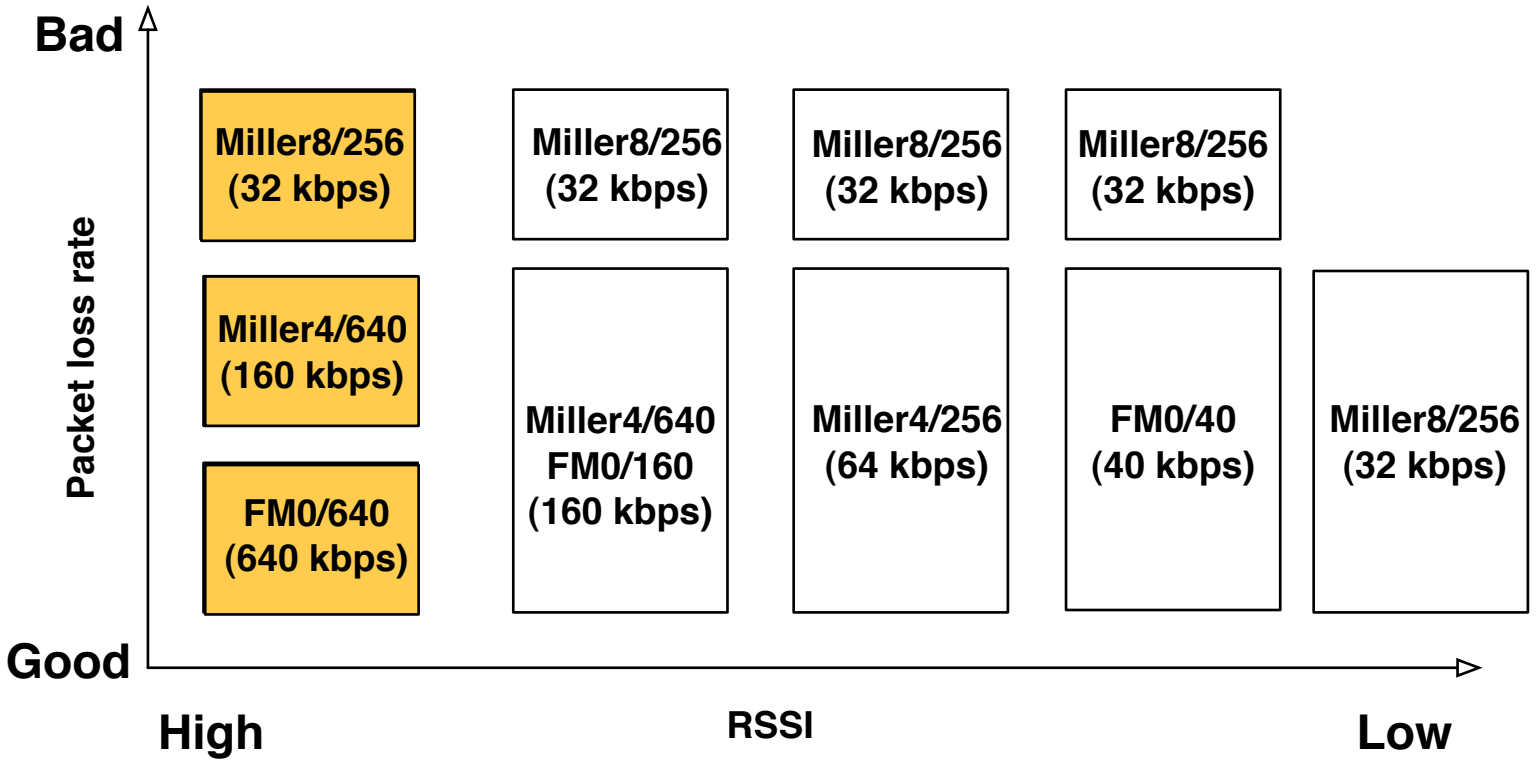
# Rate Adaptation

- Goal: choose among six encoding/baudrate combinations based on observed RSSI/loss rate

| Bitrate (symbol/s) | Throughput (kbps) |
|---|---|
| FM0/640 | 640 |
| FM0/160 | 160 |
| Miller4/640 | 160 |
| Miller4/256 | 64 |
| FM0/40 | 40 |
| Miller8/256 | 32 |

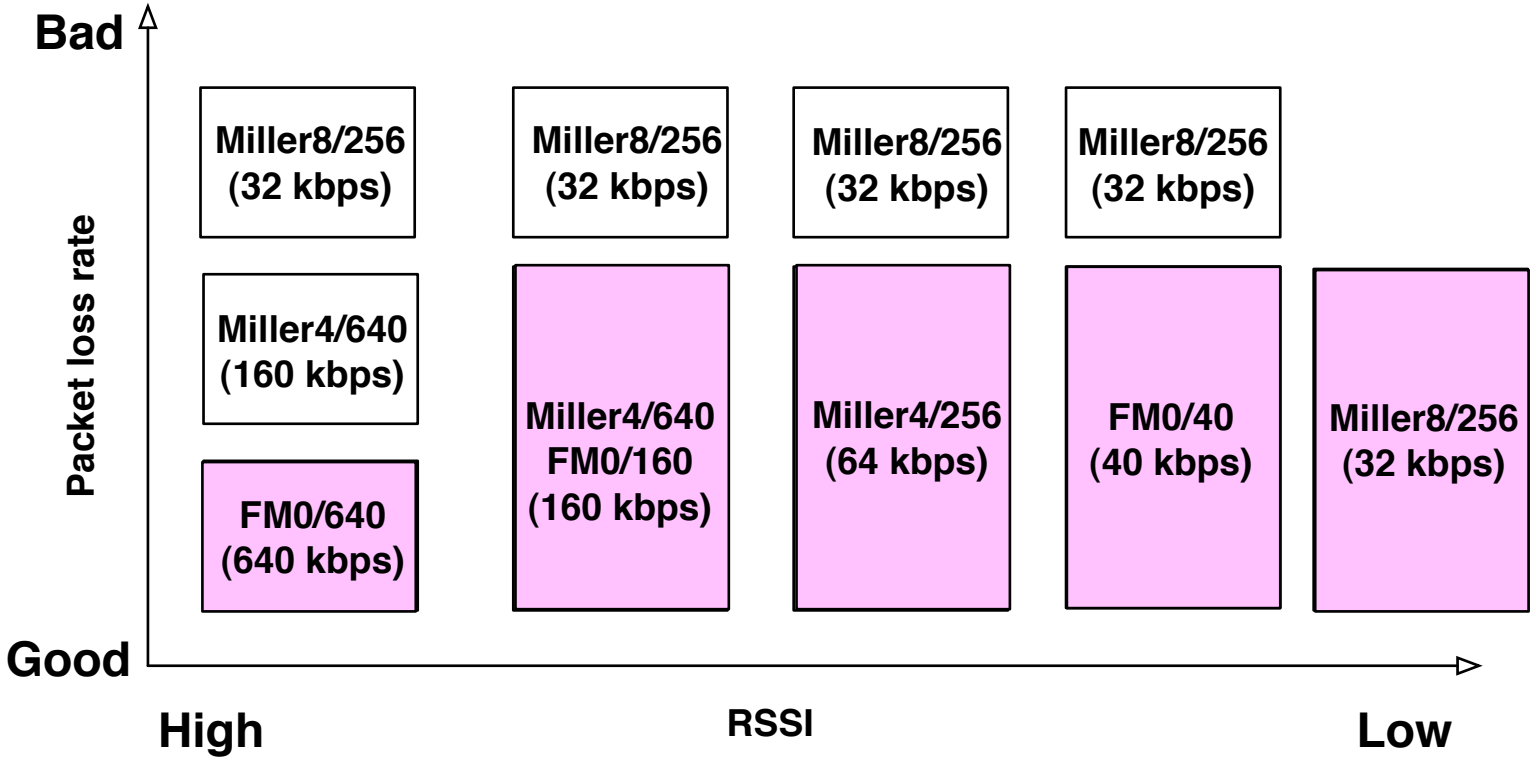
# Rate Adaptation

- Intuition: Loss rate increase caused primarily by self-interference, hence choose stronger encoding.



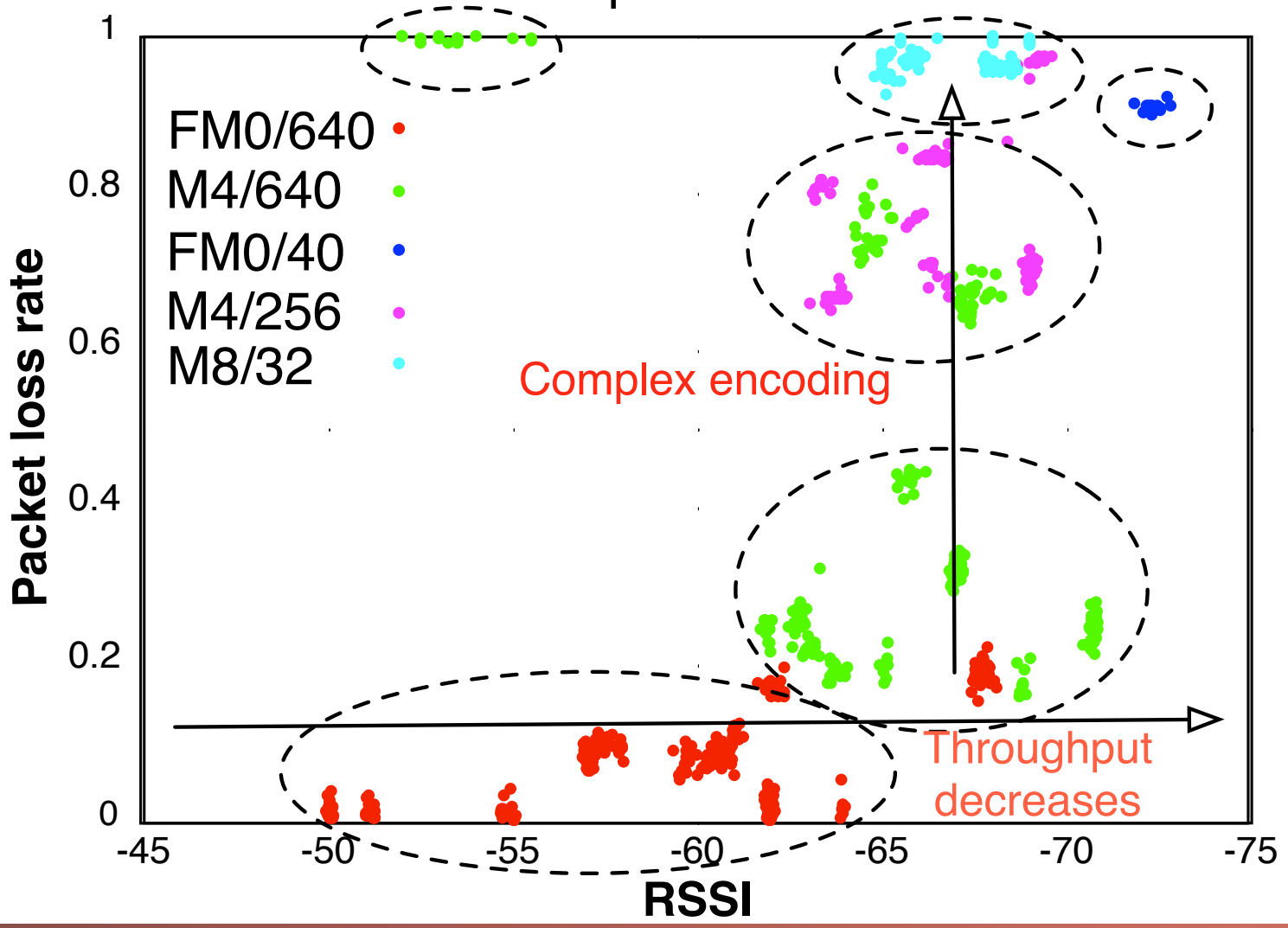
# Rate Adaptation

- Intuition: RSSI reduction caused primarily by range effects, hence choose the next lower bitrate.



# Rate Adaptation

- Does our intuition hold in practice?



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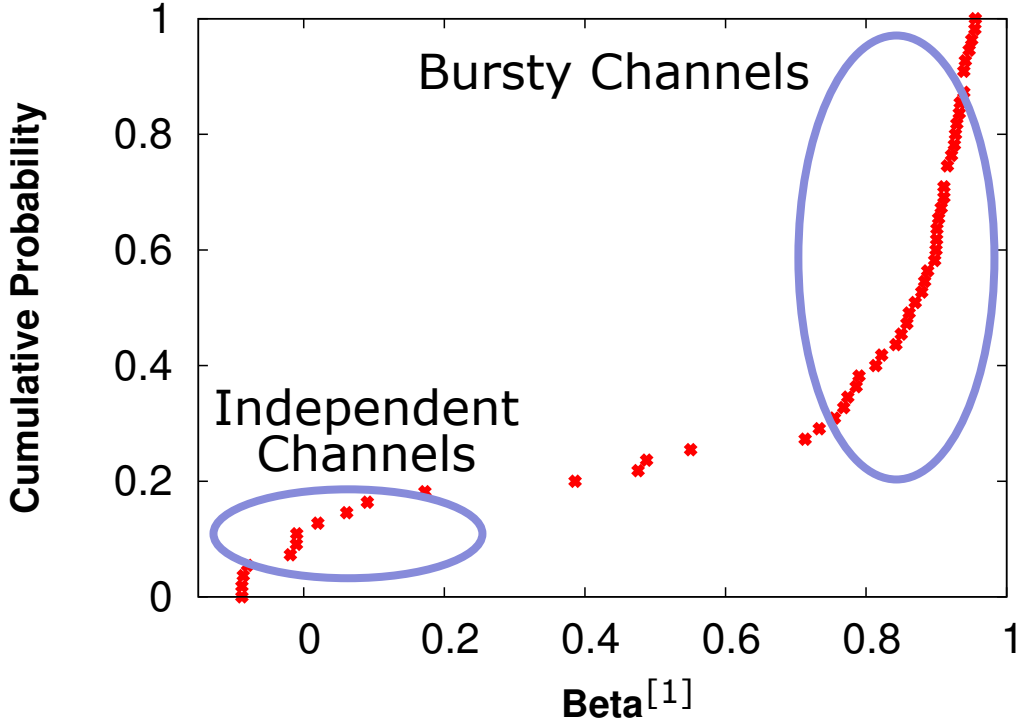
- Recall: Dwell time of 0.2s - 0.4s per channel. How can we exploit the flexibility?

# Channel Switching

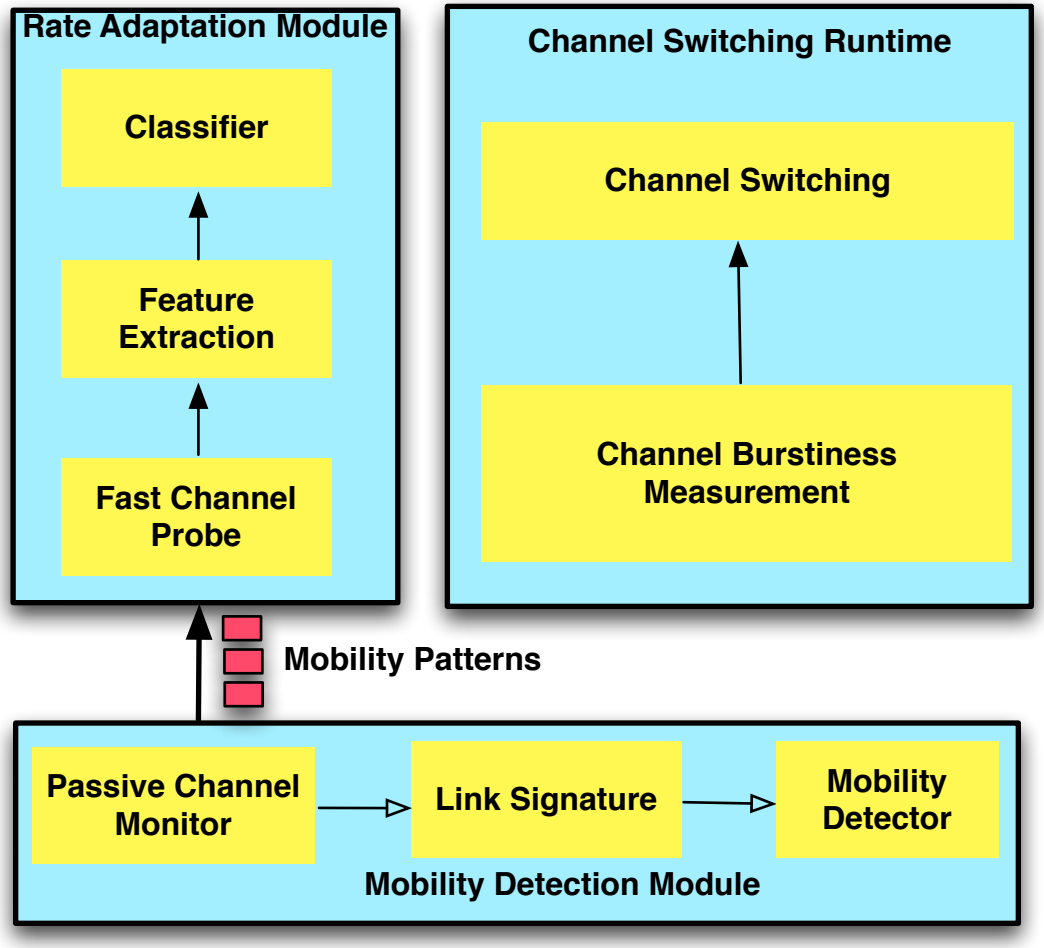
- Recall: Dwell time of 0.2s - 0.4s per channel. How can we exploit the flexibility?
- Observation: Channel is bursty i.e. we observe a string of successful packet transmission or losses




*Algorithm: switch channels upon single loss*

[1] Srinivasan, K. and et al "The beta-factor: Improving bimodal wireless networks" in SenSys 2007

# Putting it together



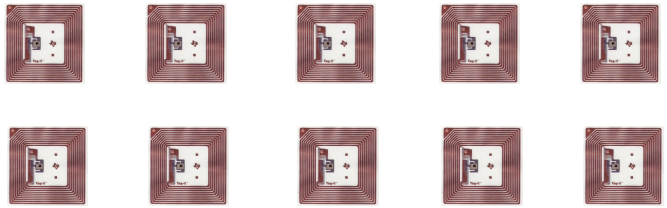
# BLINK Overview

- Link Metrics
- Design
- **Evaluation**
  - Experiment Setup
  - Rate Adaptation
  - Channel Switching
  - Overall System Performance
- Conclusion

# Experimental Setup

Impinj Reader

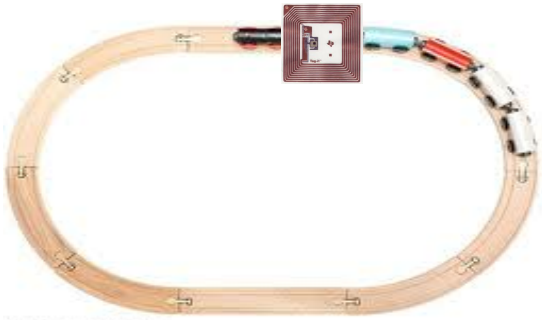
Static tags



Mobile tags

Pedestrian

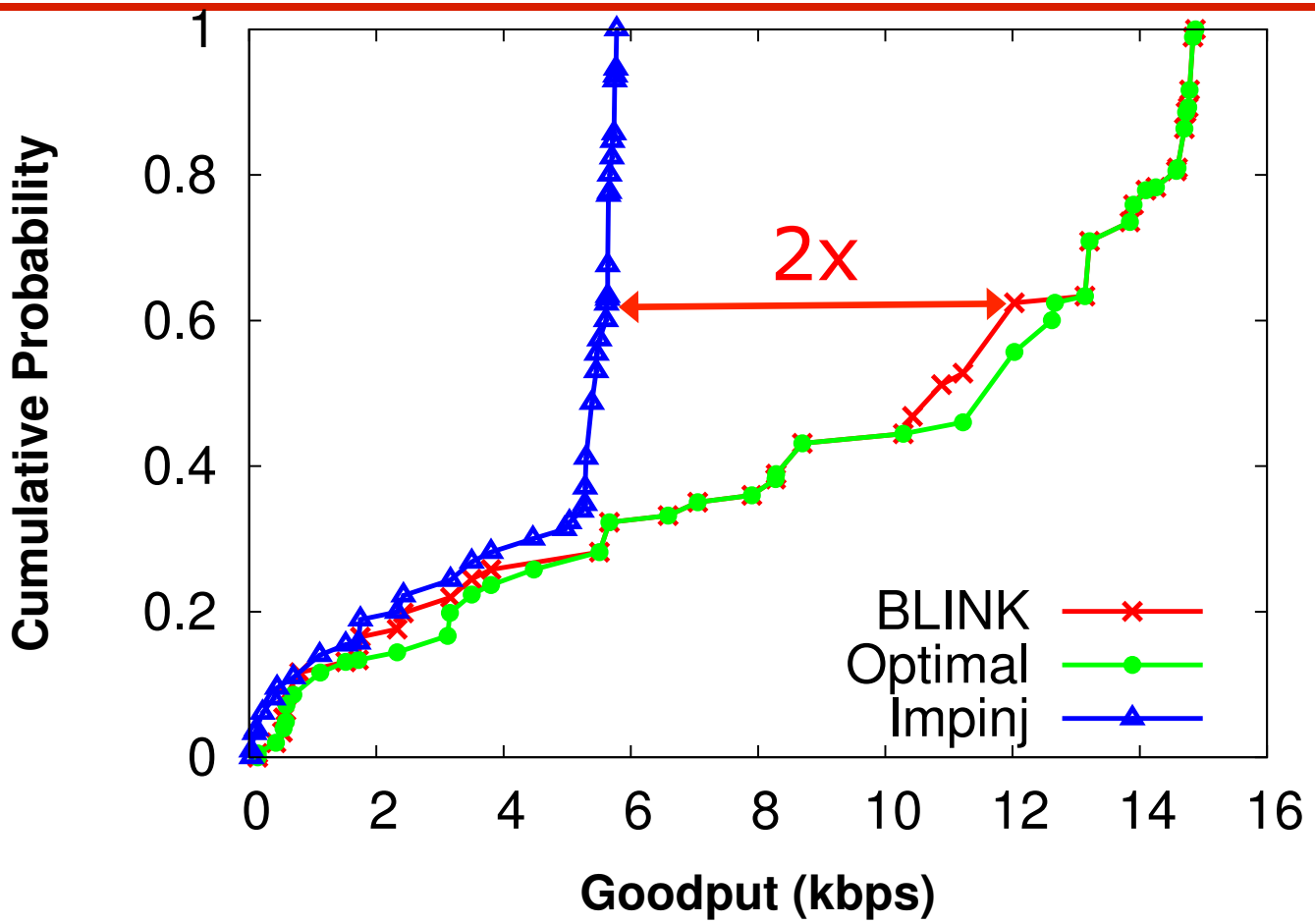
Toy train



Collected data set

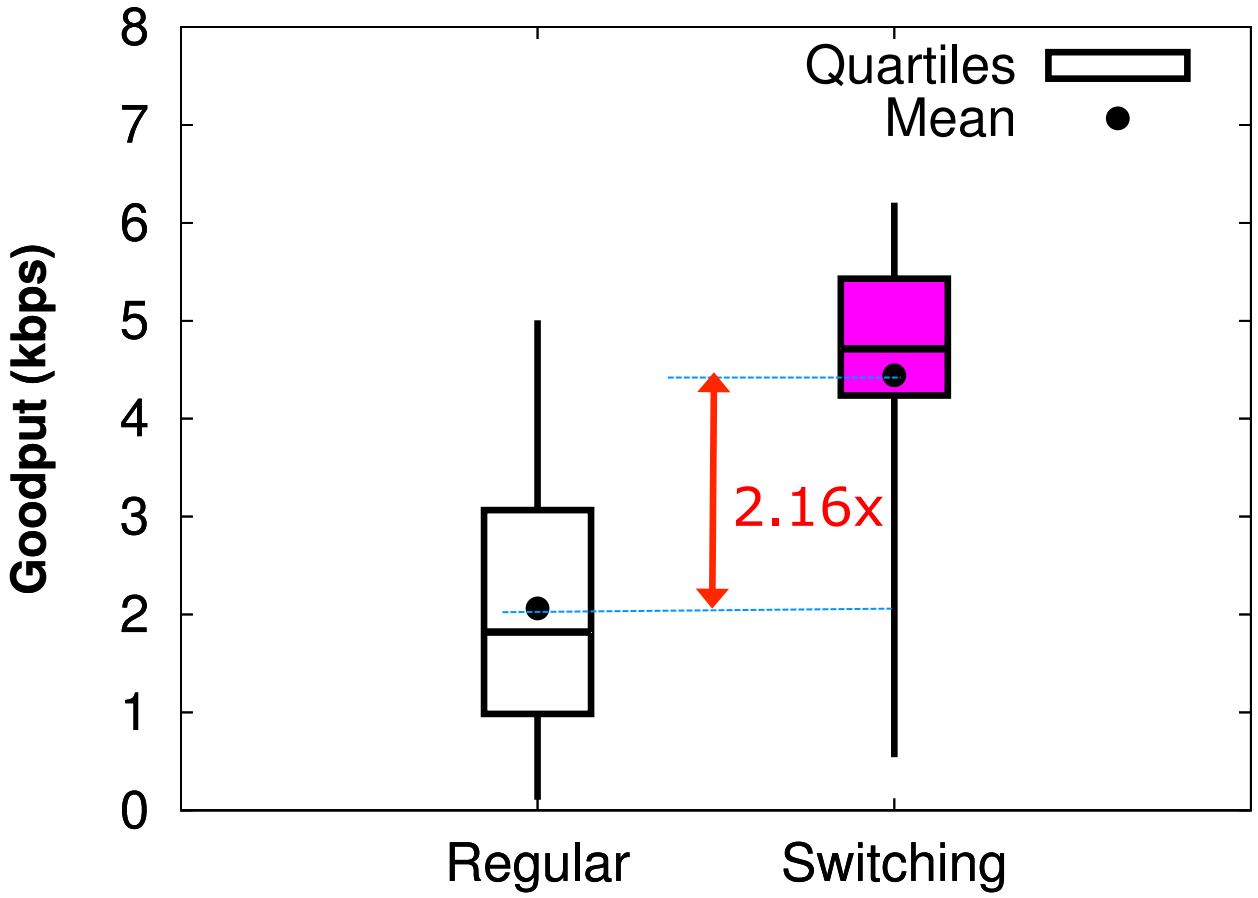
| | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Training data | room/day 1 | room/day 1 | room/day 1 |
| Testing data | room/day 2 | corridor1/day 3 | corridor2/day 4 |
| Training size | 158 | 158 | 158 |
| Test size | 347 | 161 | 162 |

# Benefits of Rate Adaptation



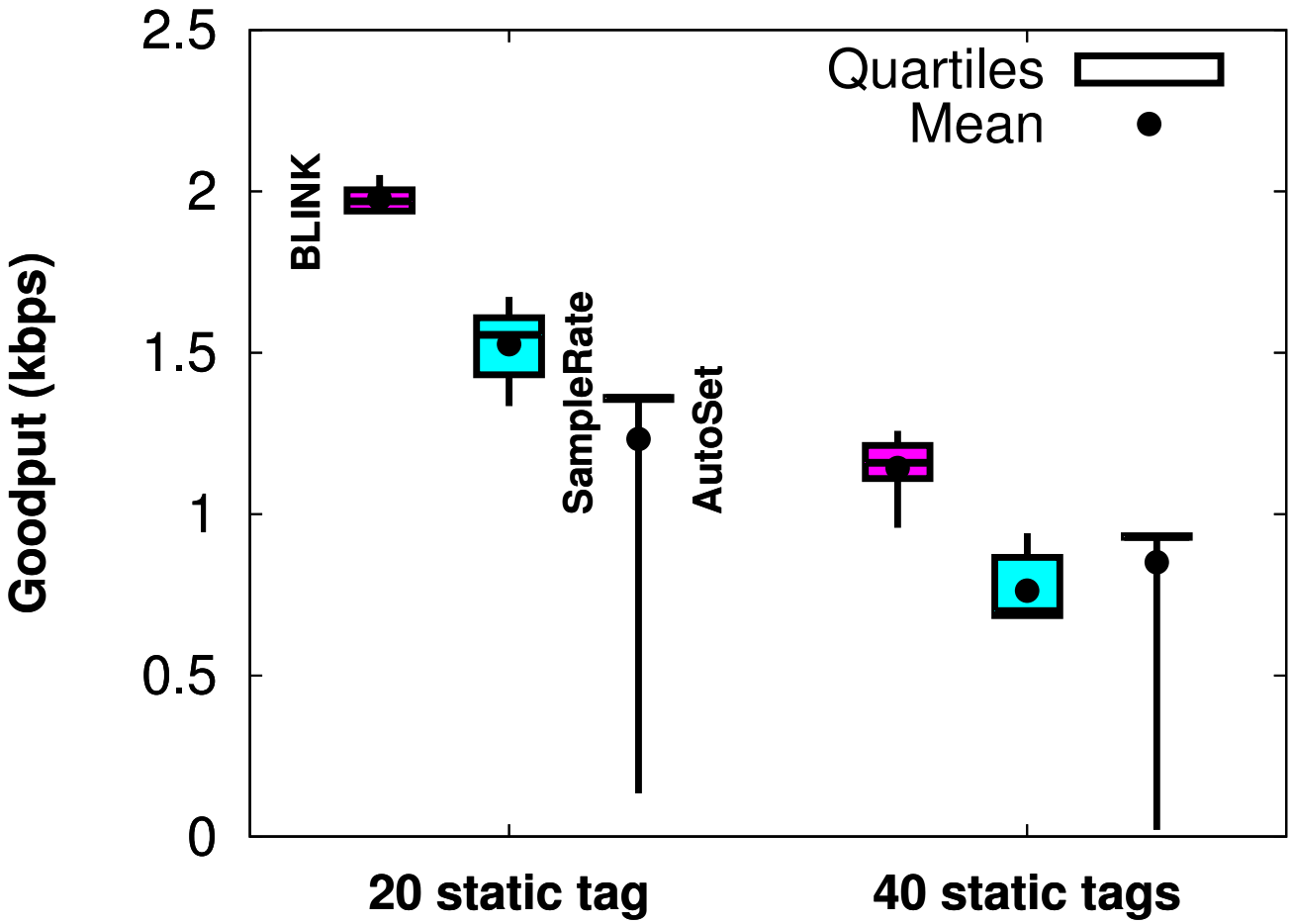

*Blink Rate adaptation is close to optimal bitrate*

# Benefits of Channel Switching



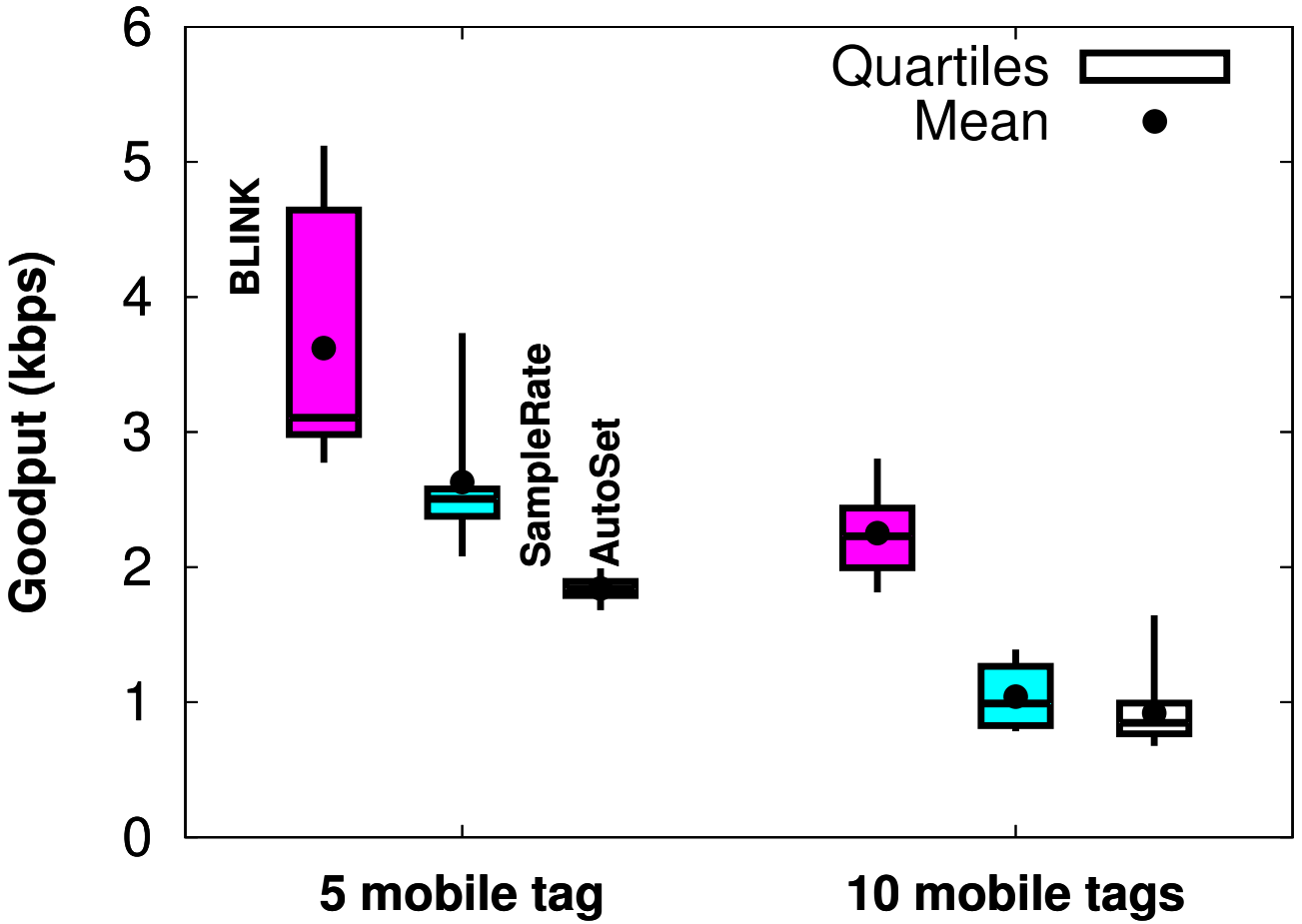

*BLINK improves throughput by 2x through burstiness-aware channel switching.*

# Impact of Scale: Static Tags




*BLINK is 1.3x-1.5x better than SampleRate and 1.4x-1.6x better than AutoSet.*

# Impact of Scale: Mobile Tags




*BLINK is 1.4x-2x better than SampleRate and 2x-2.5x better than AutoSet*

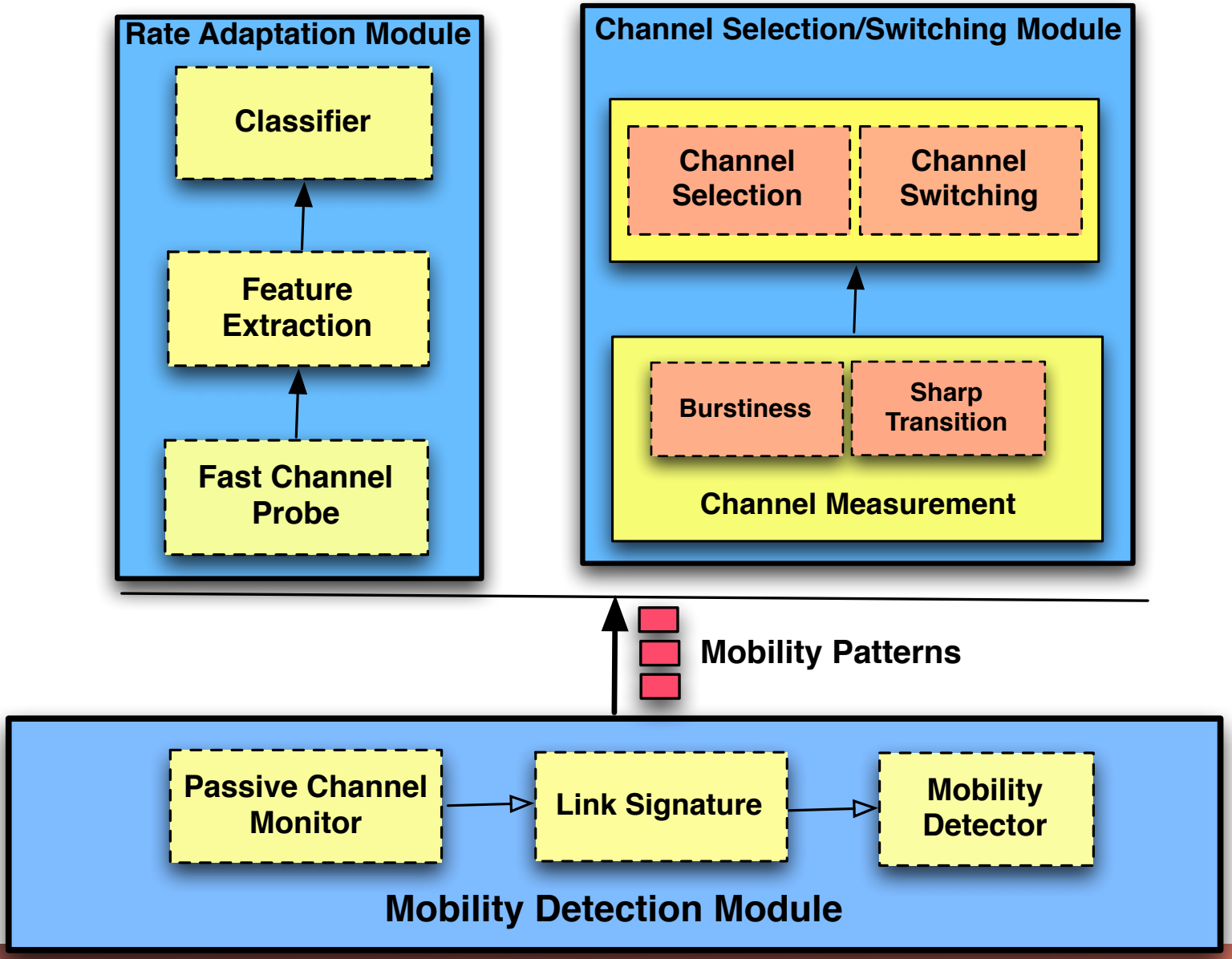
# Conclusion

- Understand role of multipath self-interference on link metrics for backscatter links.
- Clustering-based rate adaptation and burstiness-aware channel switching.
- Up to ***3x*** improvement in throughput over a range of scales, channel conditions and mobility scenarios.

***Thank you!***

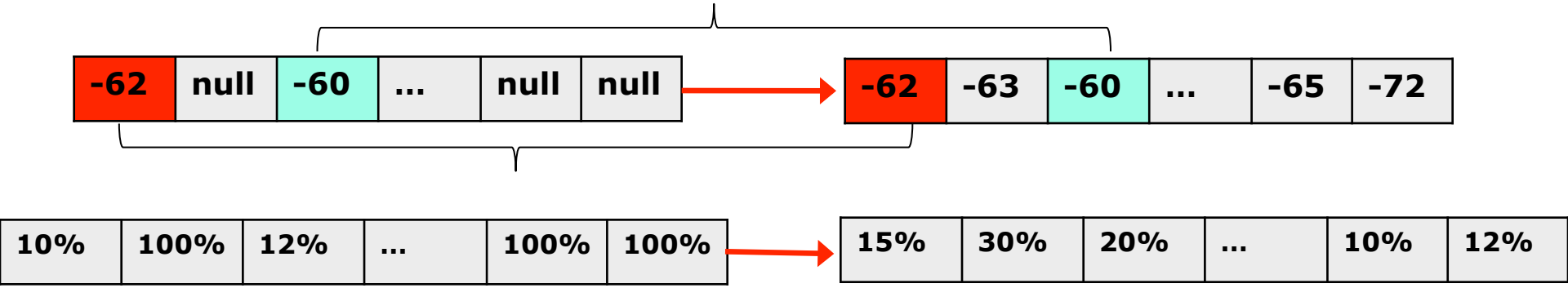
# Backup Slides

# BLINK Overview

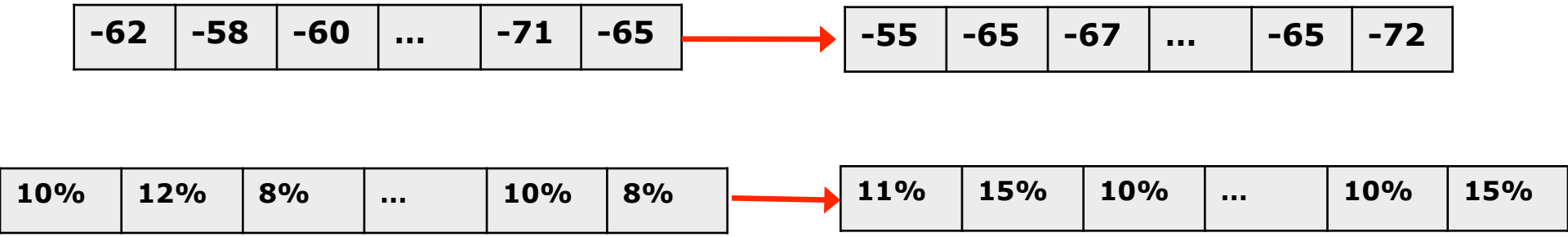


# Euclidean distance between RSSI and loss rate vector

- **Euclidean distance between link signatures**
  - Need to compare both RSSI vector and loss rate vector
  - Exploit only RSSI vector?




  - Exploit only loss rate vector?



# Channel Probe

- **Rate adaptation waits for link metrics to be obtained before selecting best bitrate. How long does this take?**
  - 7 queries per channel → 5s probe
- **Can we reduce channel Probe time?**
  - Observation: Sharp transition

  Between good and bad channels
  - Implication: One packet per channel to probe
  - Result: 5s → 0.7s