BLoc: CSI-based Accurate Localization for BLE Tags

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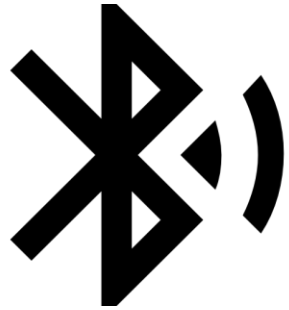
CoNEXT 2018

IoT Vision

Connect everything to the internet and locate them.

BLE



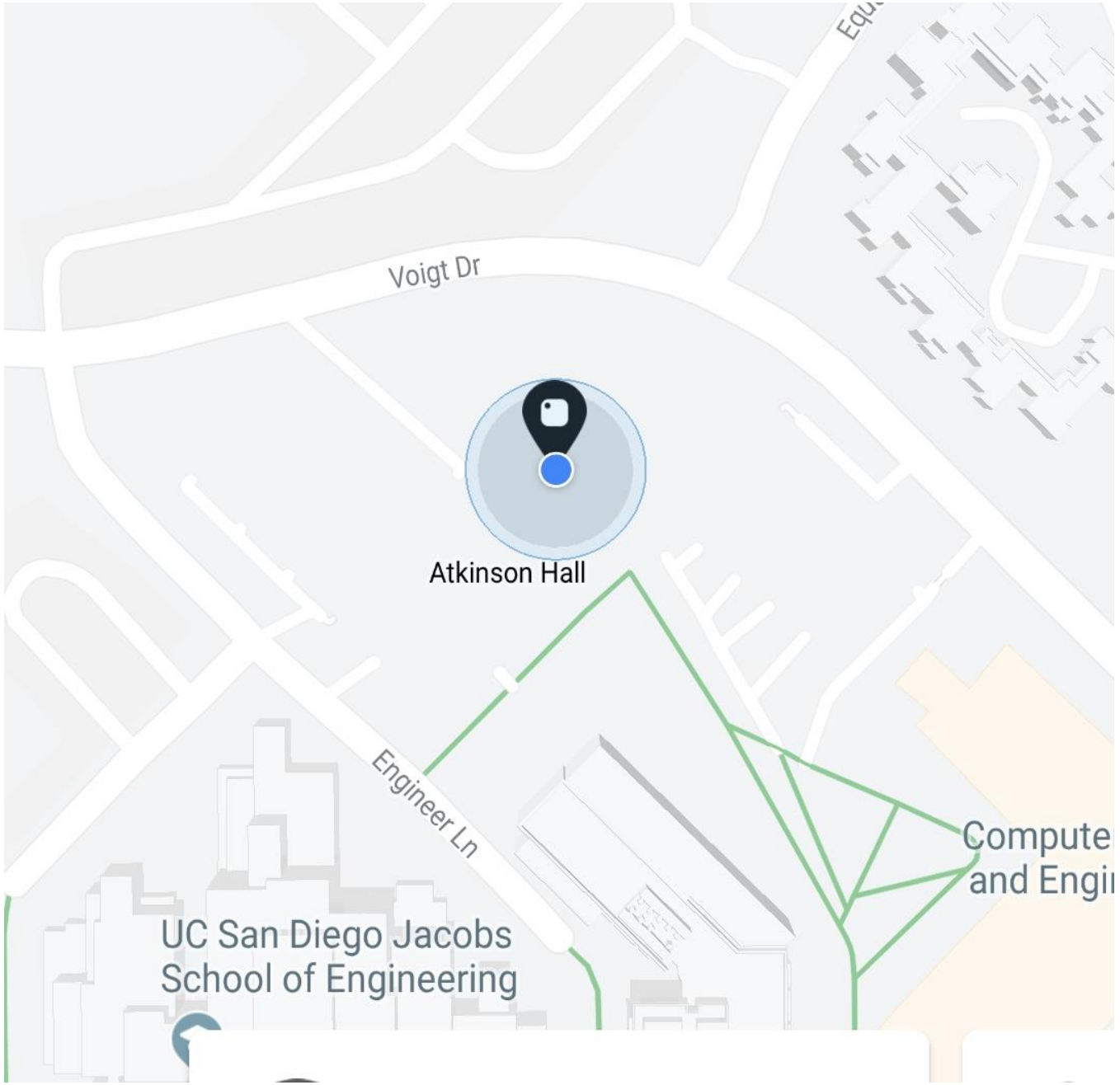
Low Power (10-500mW) : Lifetime of 2yrs

Long Range (5-10m) : Good Enough for Indoor settings

Accessible ($5) : You can buy one online

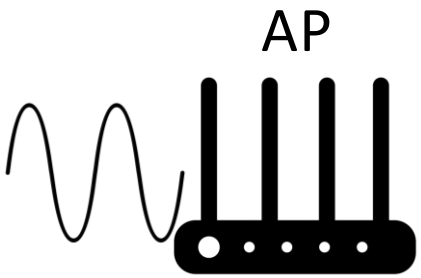
Connects from smartphones, Ipads, laptops

Let’s Locate


Voigt Dr
Atkinson Hall
Engineer Ln
UC San Diego Jacobs
School of Engineering

State of the art in BLE

RSSI based localization



BLE Tag

Wi-Fi achieves sub-meter level accuracies

Chronos[NSDI'16], SpotFi[Mobicom'15], Witrack [NSDI'14],

WiSee[Mobicom'14], ArrayTrack[NSDI'13], . . .

HIGH POWER

Using CSI based localization

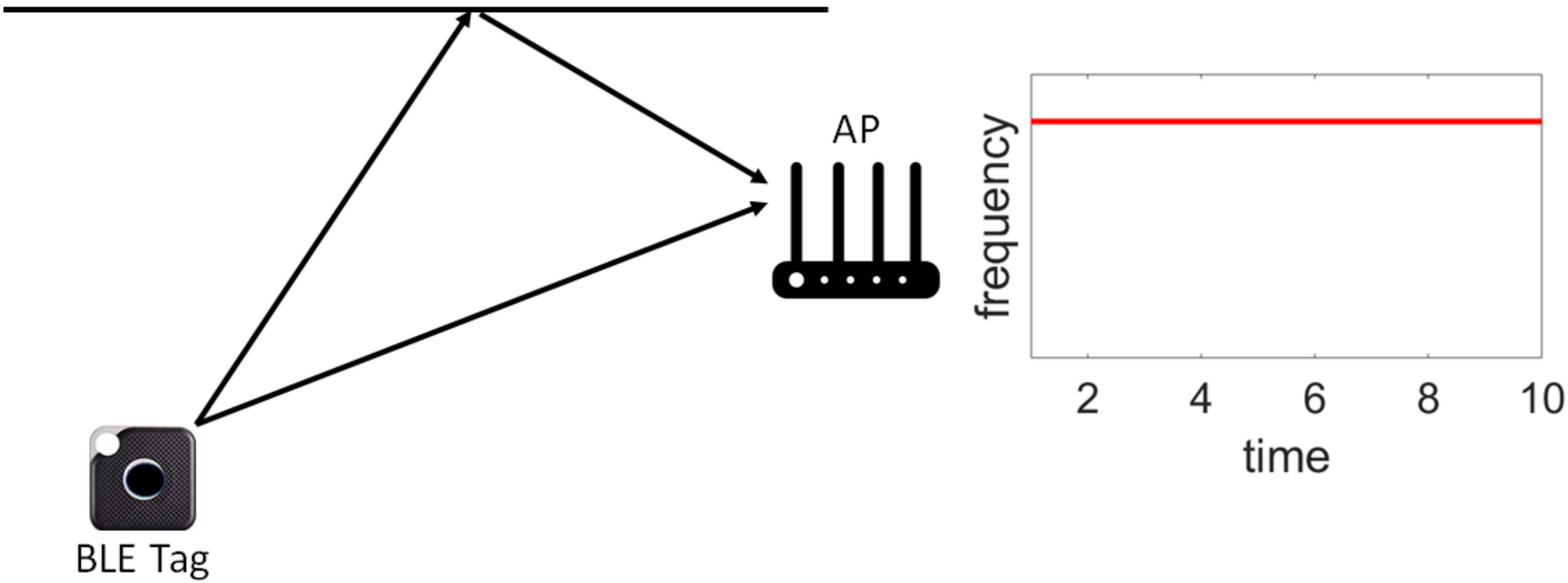
What does it take to bring CSI based localization to BLE tags and achieve sub-m accuracy?

BLoc

BLoc: CSI-based Localization for BLE

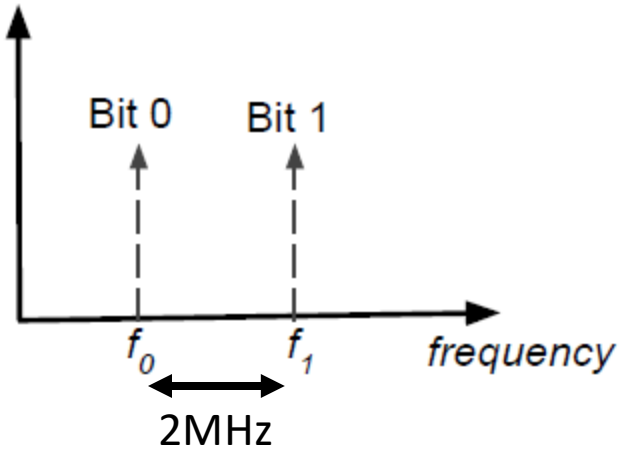
- First CSI based localization system for BLE
- Getting accurate wideband CSI for BLE
- Resolving Multipath
- Achieves sub-meter accuracy in real world deployment

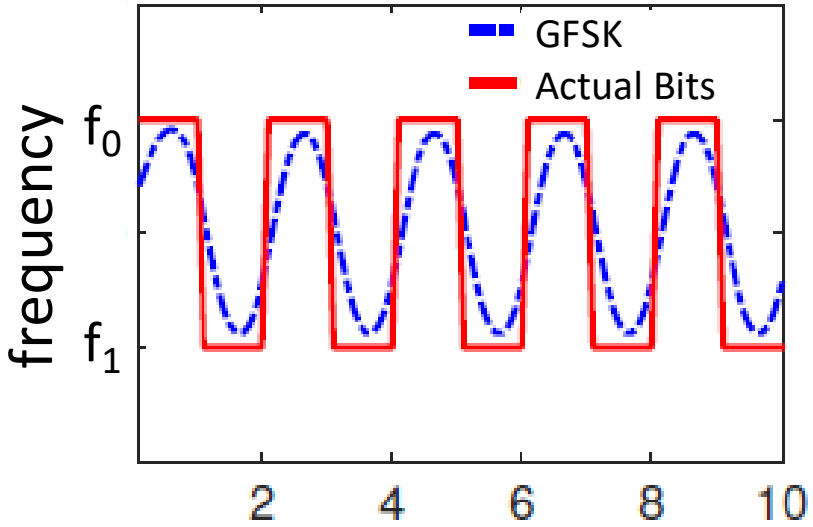
Measuring CSI



How do we get CSI for BLE?

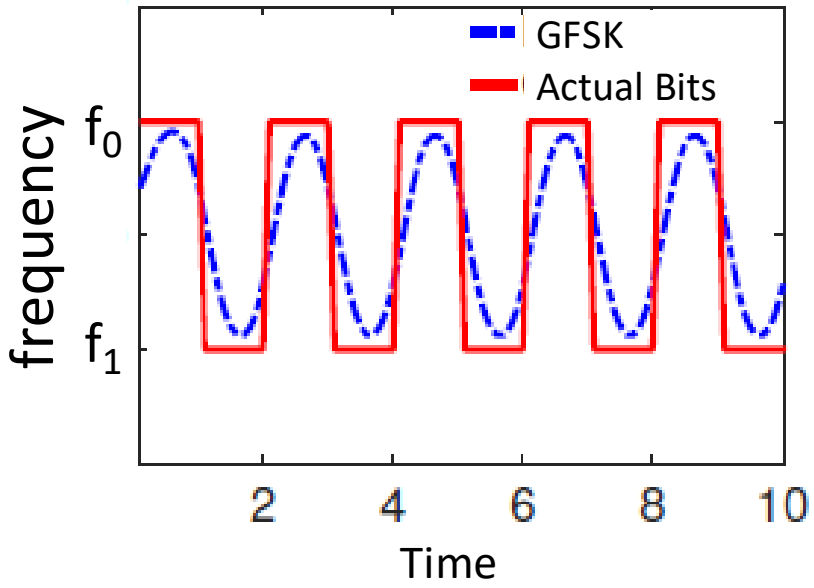
BLE employs GFSK



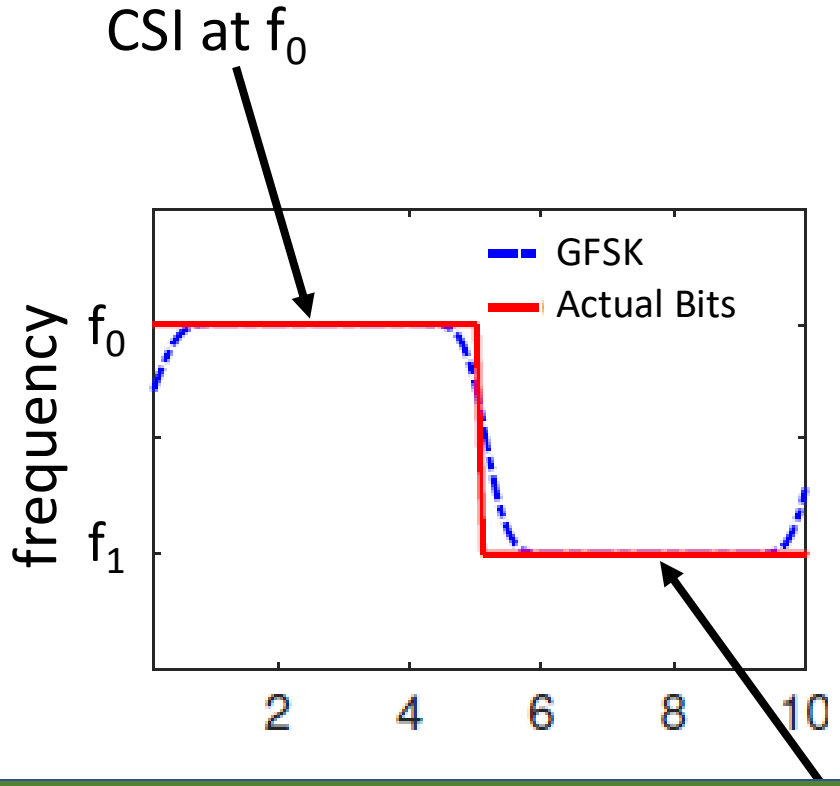


Continuously varying frequency

Transmitting long sequences of 1/0's

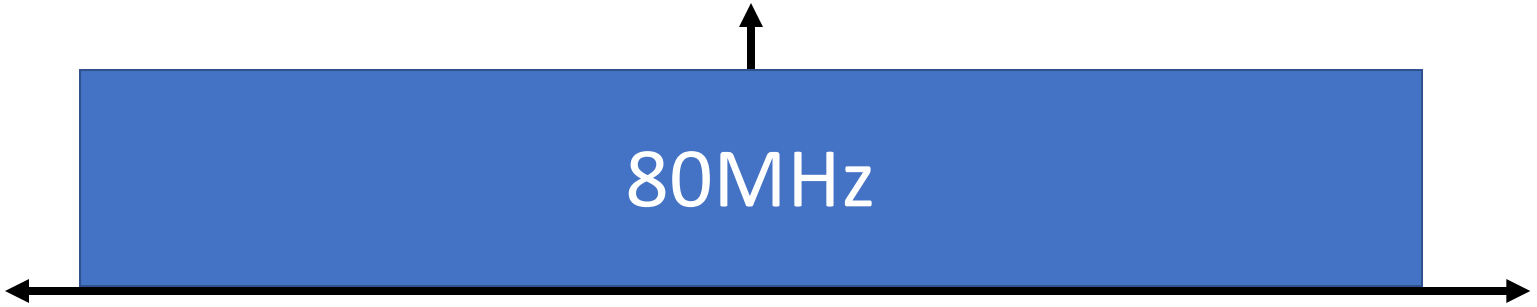


Vs

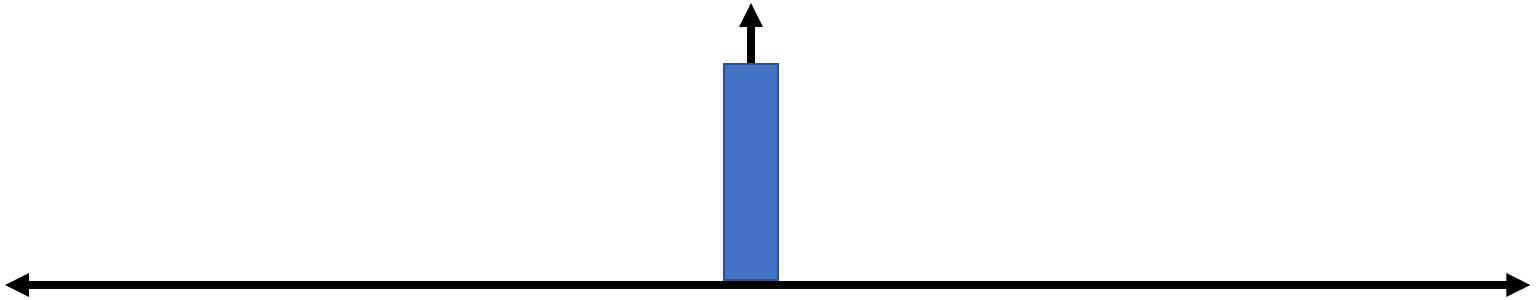


Now we can estimate CSI at f_c subcarrier as *(CSI at f_0+CSI at f_1)/2*

Bandwidth ∝ Accuracy

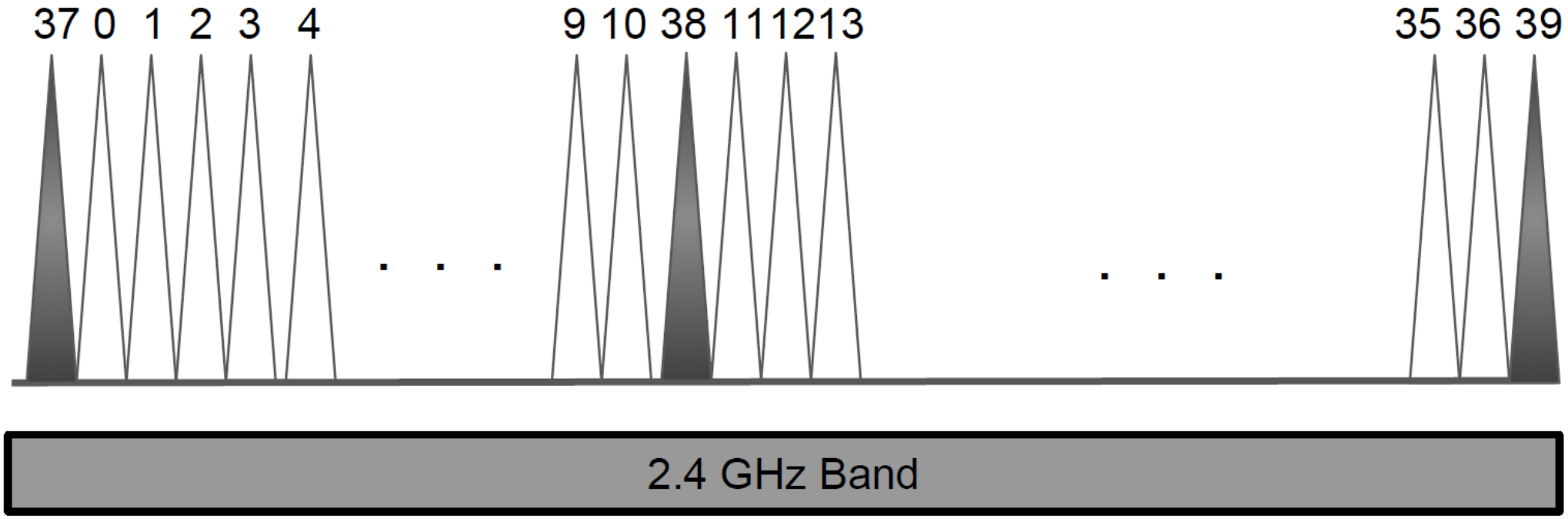


WiFi BW – 20MHz-160MHz



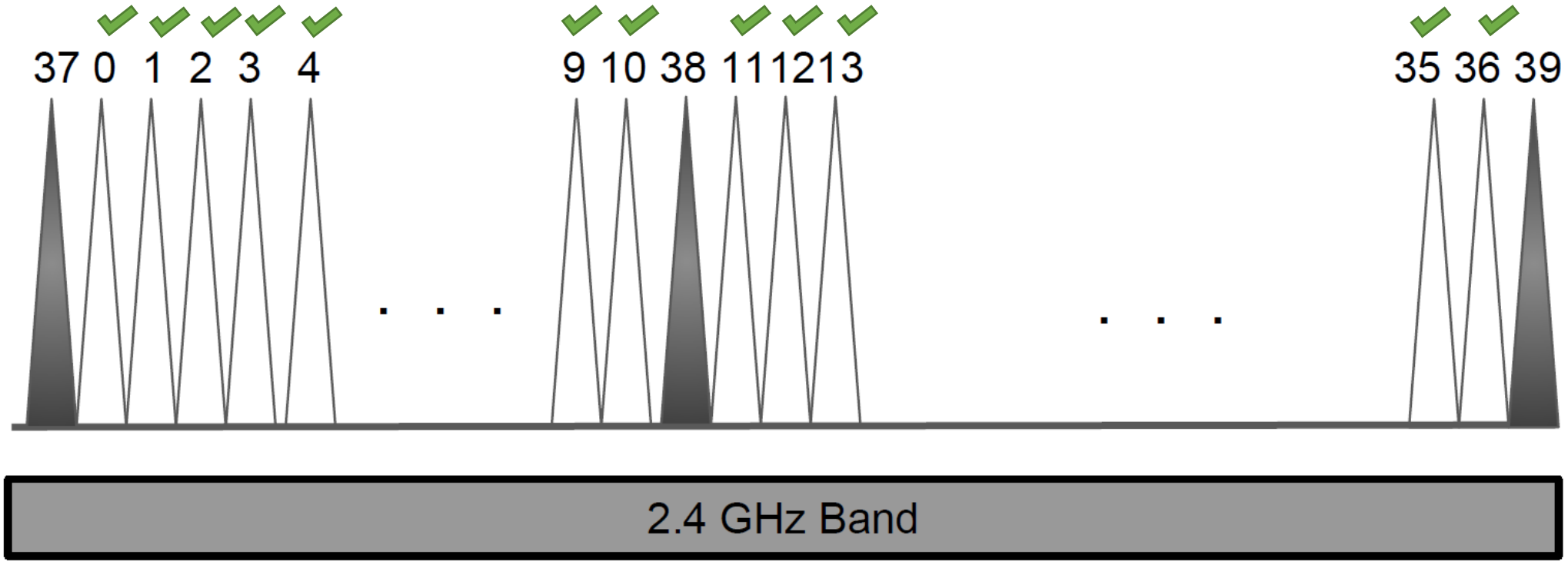
BLE BW – 2MHz

Observation: BLE hops frequency bands



Idea: Stitch information across frequency bands

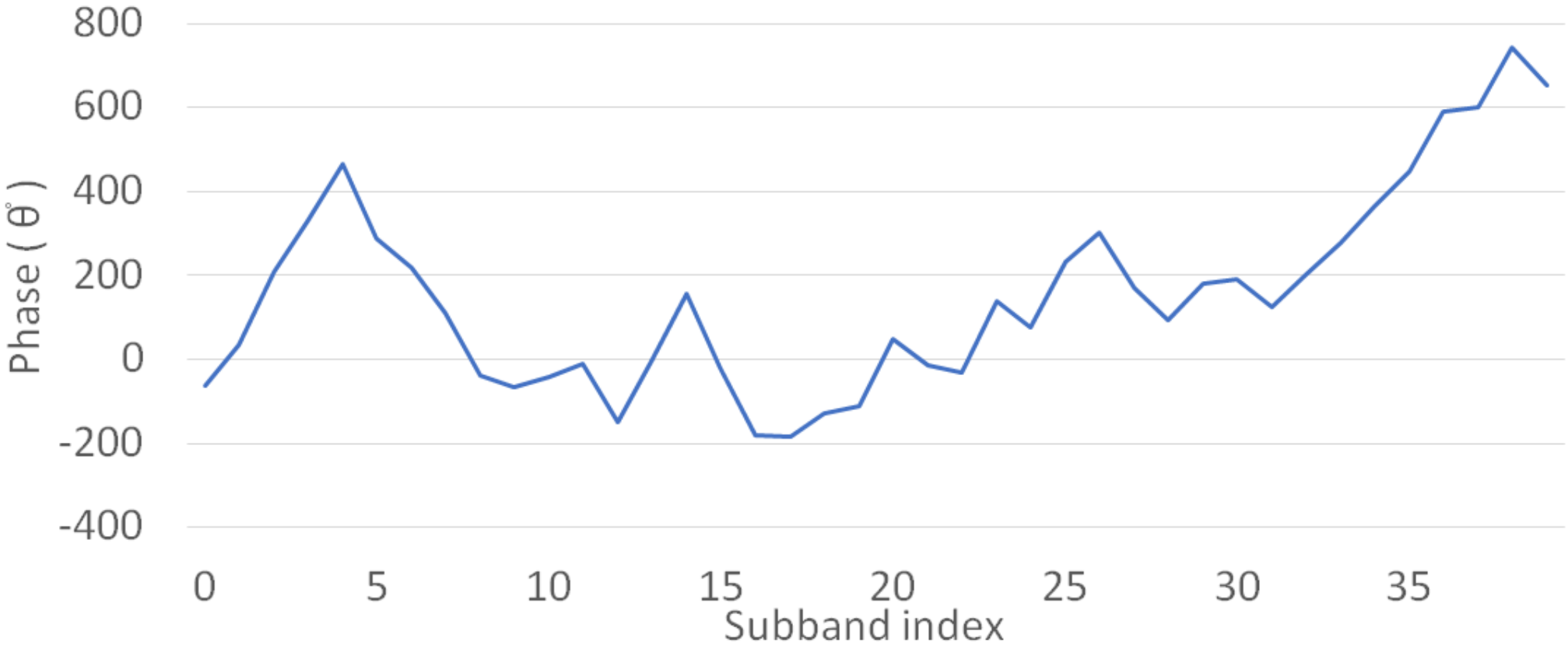
Band Stitching



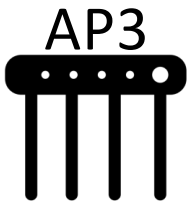
Now we have an effective Bandwidth of 80MHz

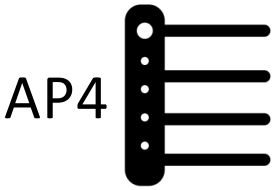
Problem: Phase is not consistent across frequency hops

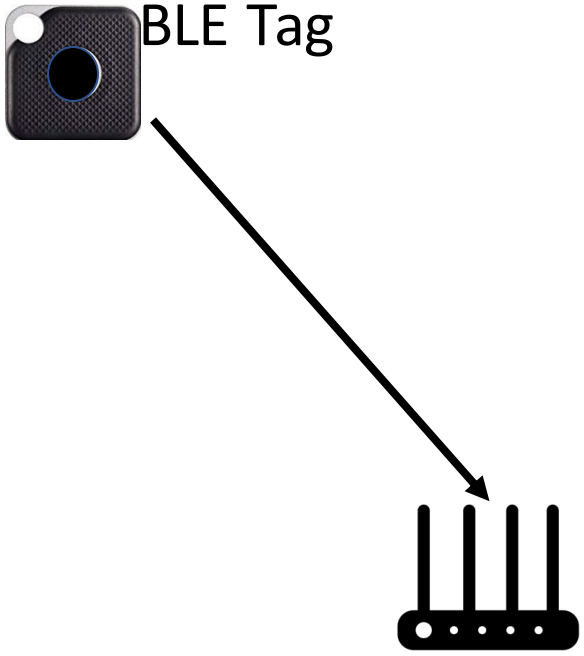
Each Frequency hop has a different initial phase

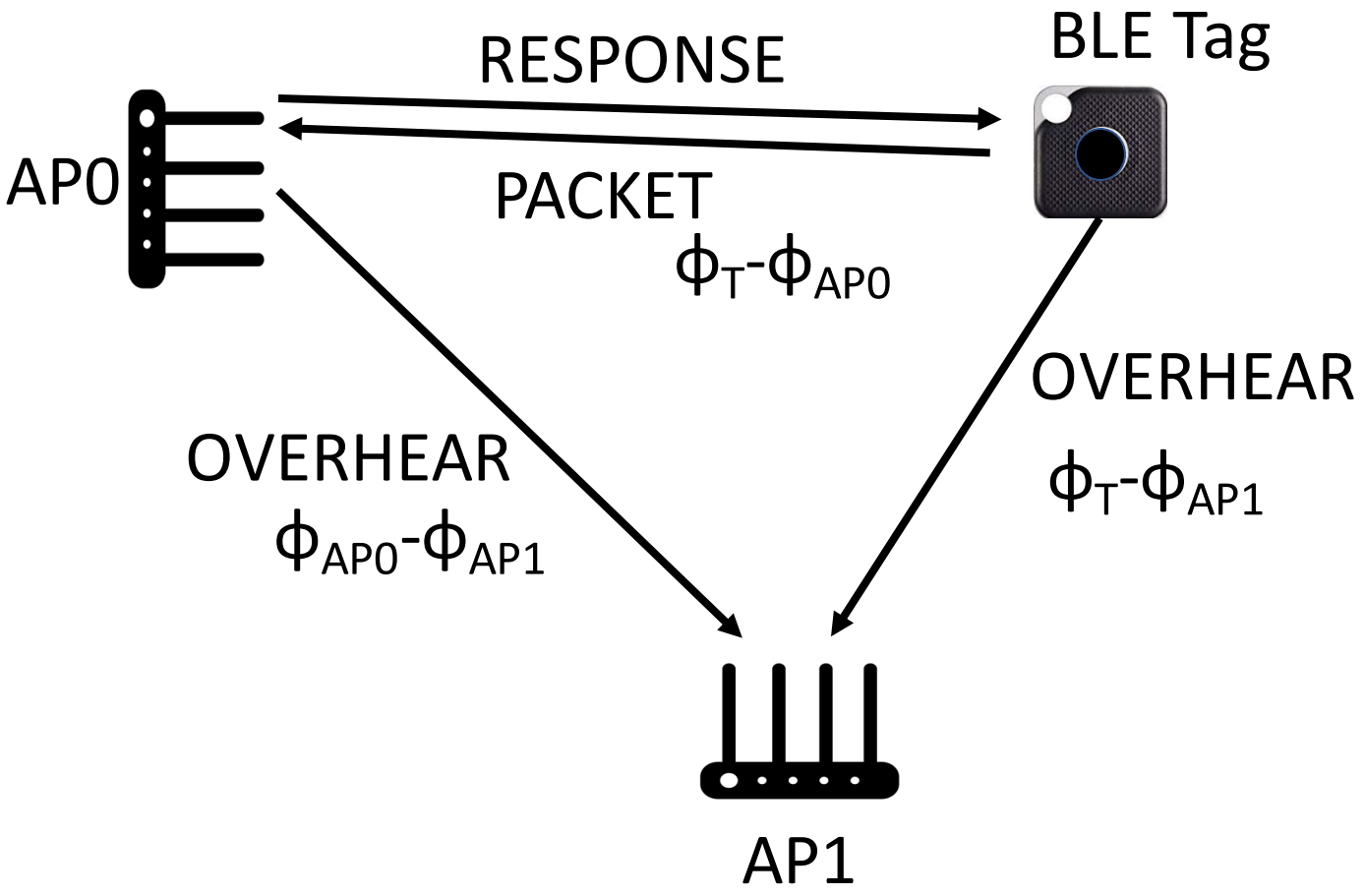


Consider





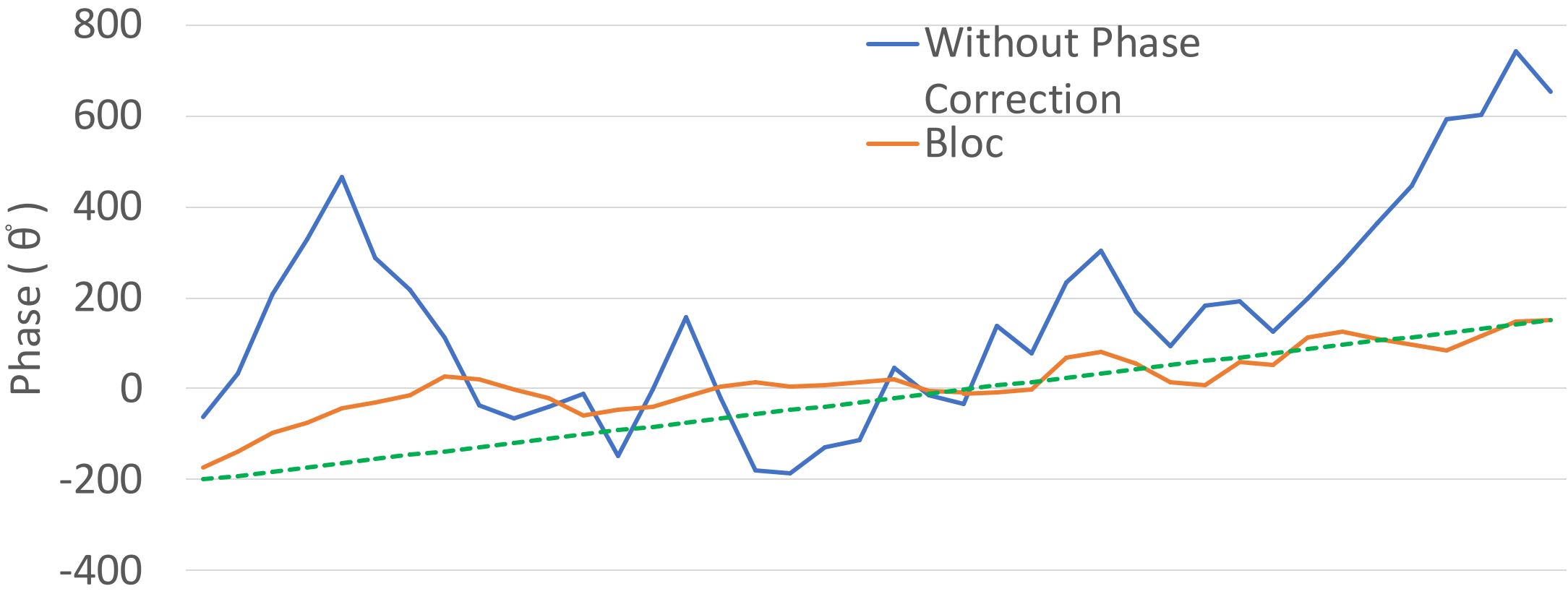




Let's combine these Phase offsets as following:

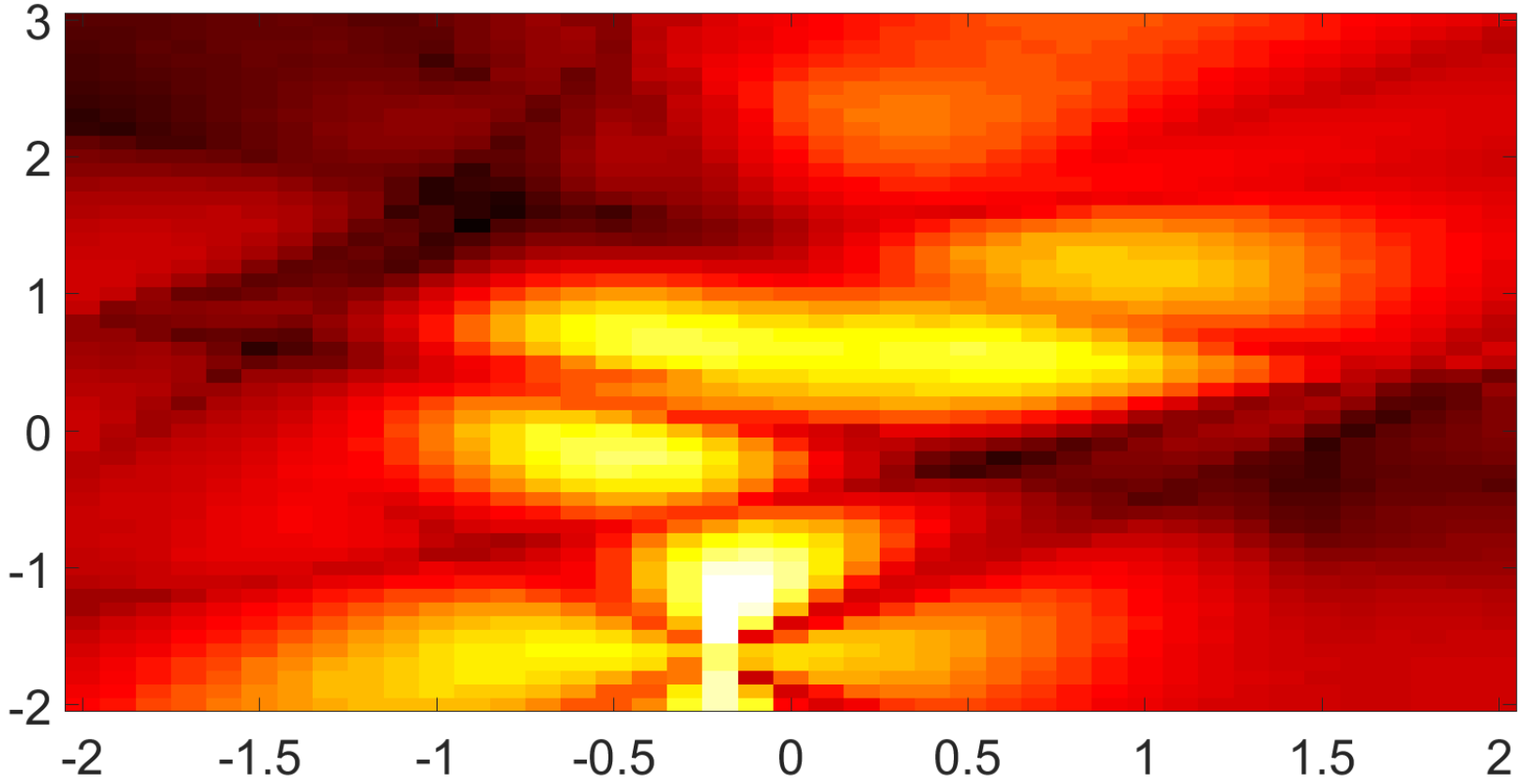
$(\phi_T-\phi_{AP1}) - (\phi_{AP0}-\phi_{AP1}) - (\phi_T-\phi_{AP0}) = 0$

Phase Offset corrected

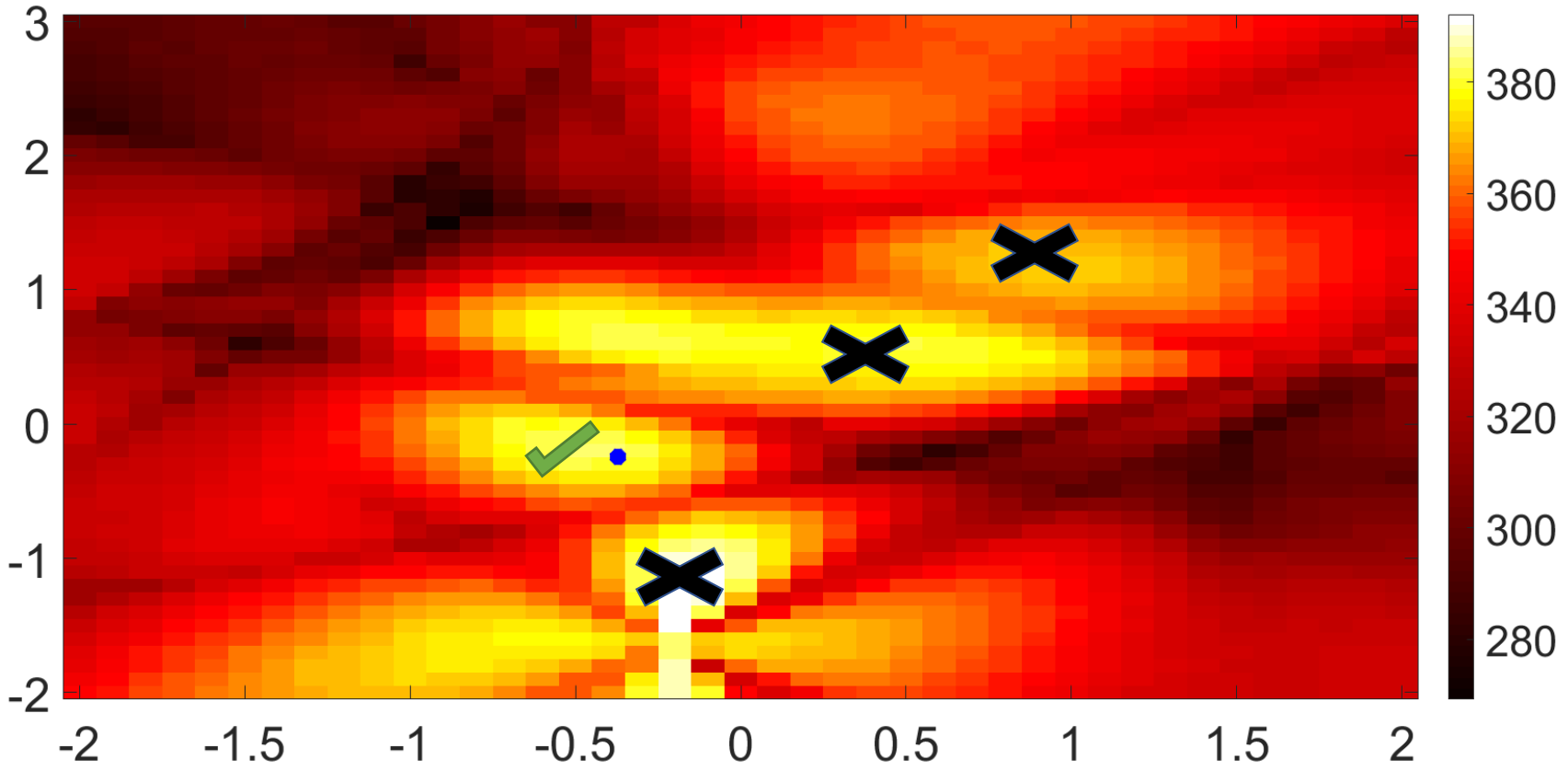


Accurate wideband CSI calculated for BLE

CSI to Location



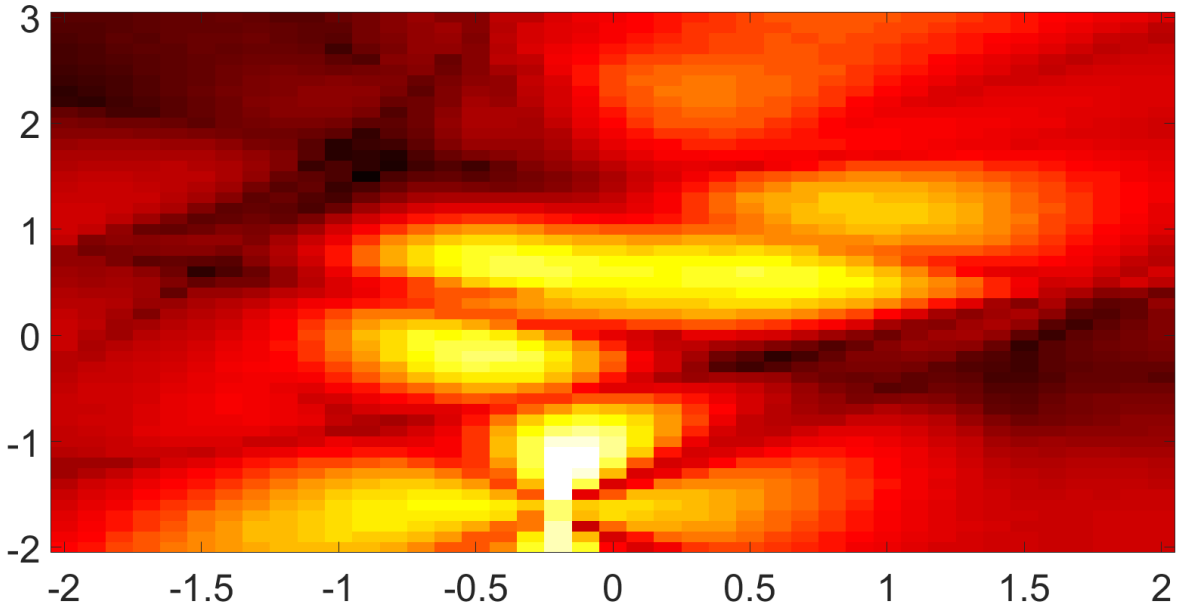
Multipath



Observations

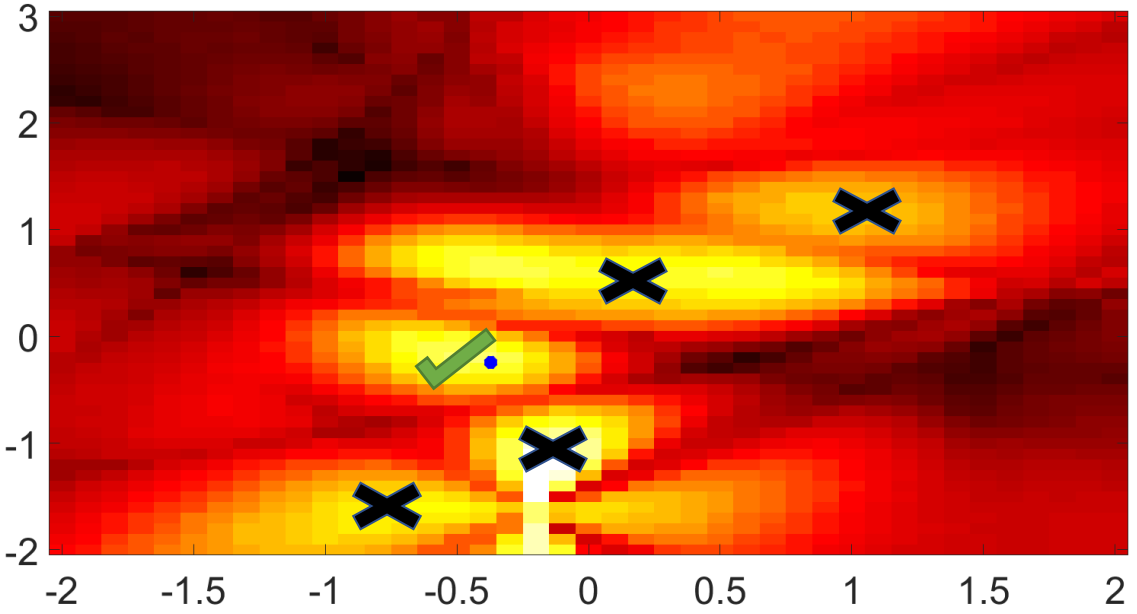
1. Shortest distance path is the direct path

2. Multipath reflections are more spread out while direct path is more peaky



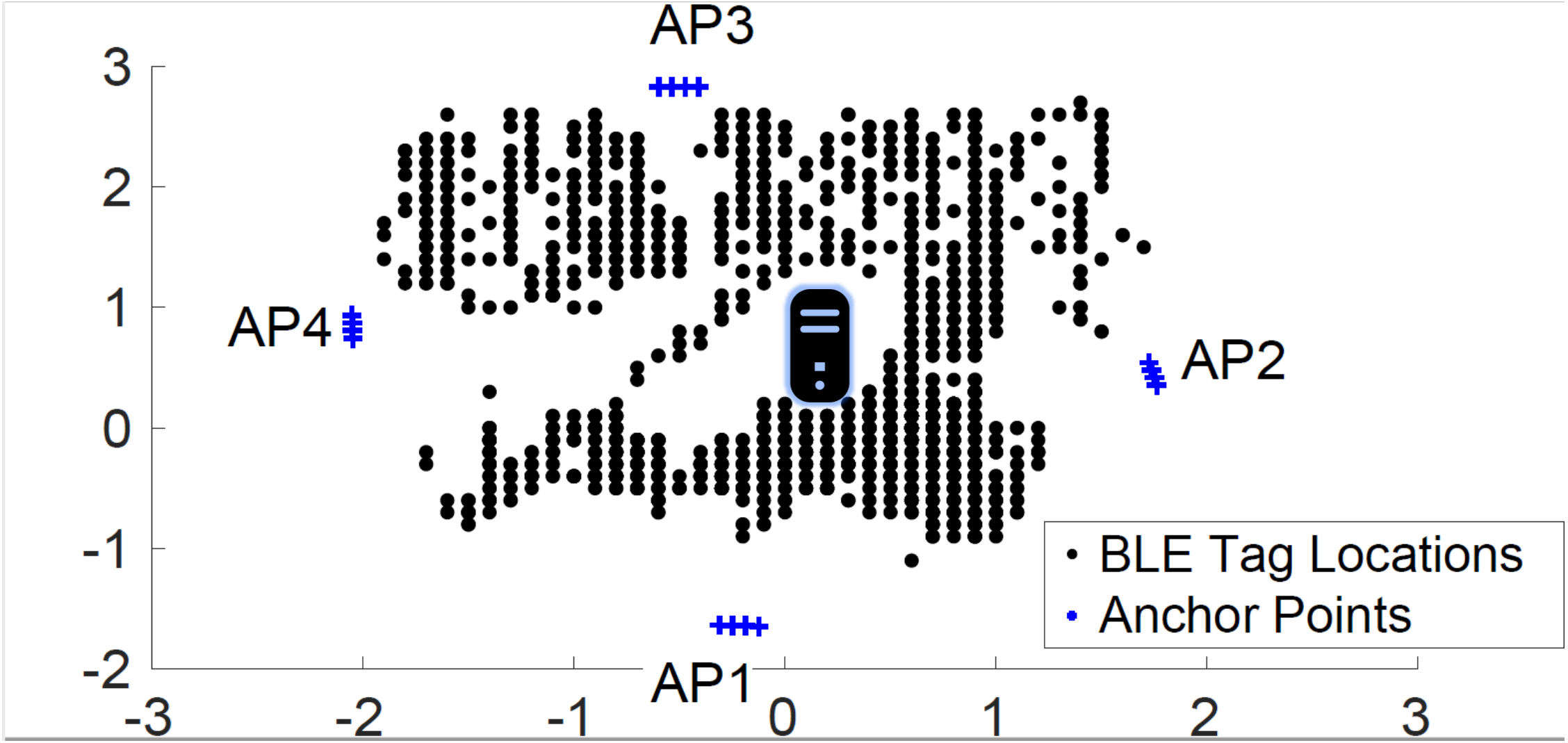
Algorithm

- Identify all the local maxima
- For each of these spots I calculate entropy (*H*) and the summed up path distance from each Anchor
- Use this information to weigh each peaks probability and pick the global maxima

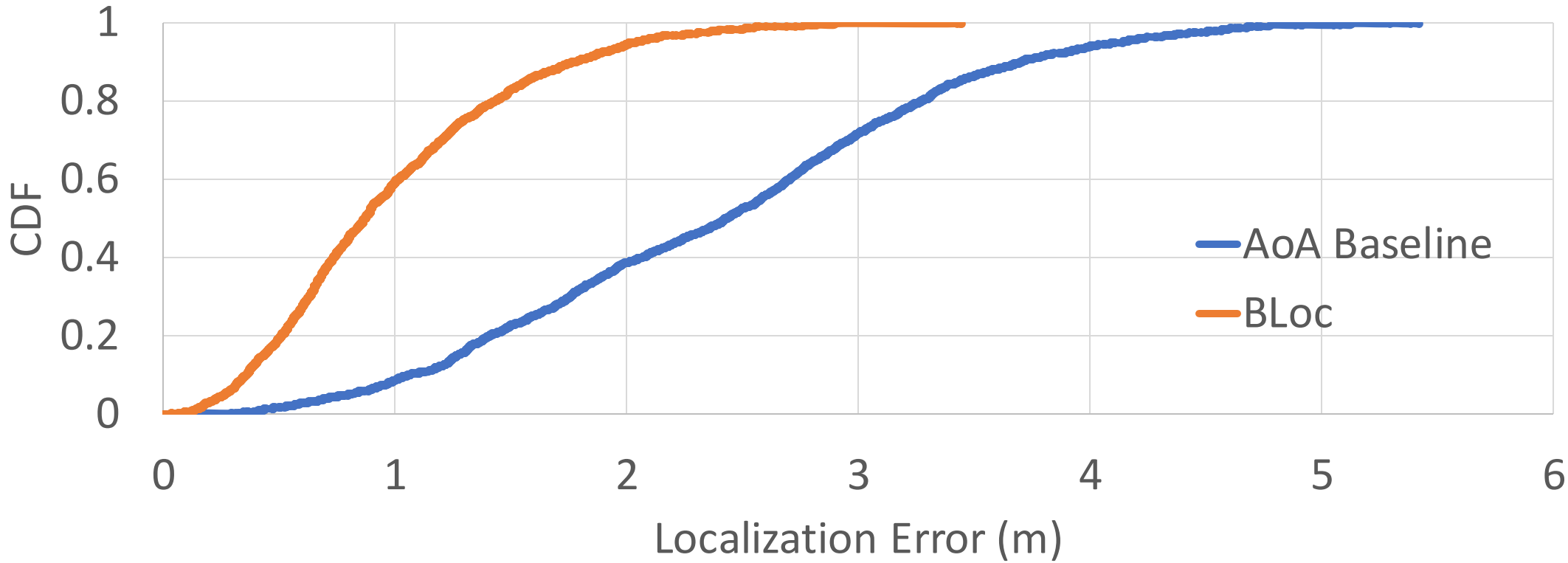


Experimental Evaluation

Setup

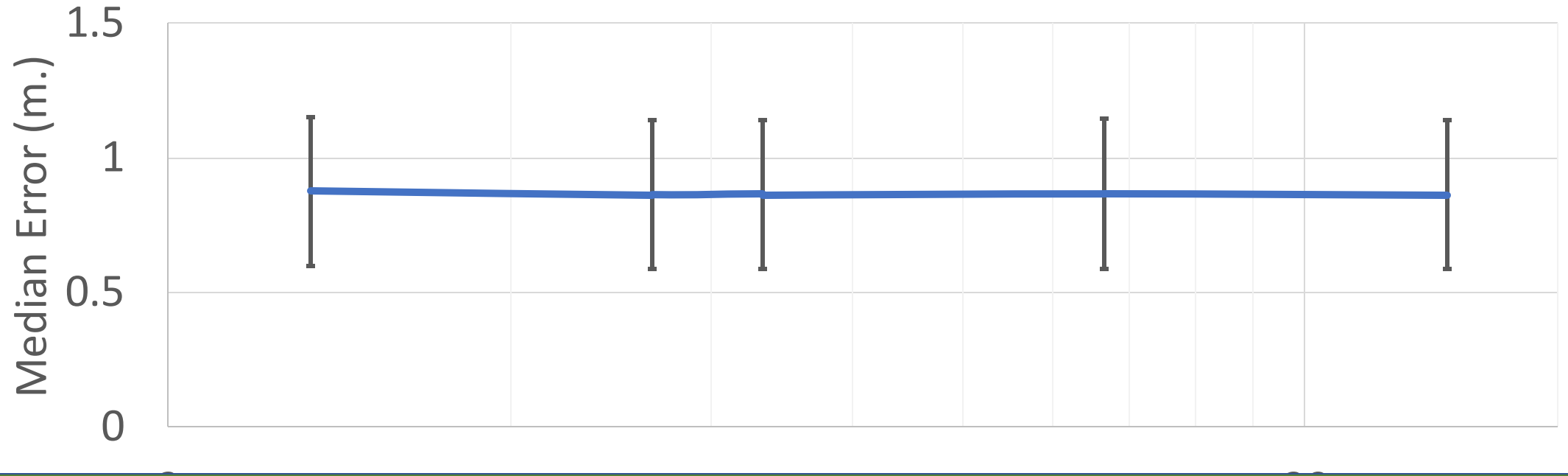

AP3
AP4
AP2
AP1
3
2
1
0
-1
-2
-3
-2
-1
0
1
2
3
BLE Tag Locations
Anchor Points

Localization Accuracy



Bloc achieves 86cm median error

Dependence on Number of Sub-bands



In BLoc, BLE tag needs to just hop across 4 bands

Related Work

- BLE Localization
  - RSSI-based bluetooth indoor localization [MSN'15]; Locating and tracking BLE beacons with smartphones [CoNEXT'17]
- RF-based Localization
  - Multipath triangulation[MobiSyS'18]; Chronos[NSDI'16]; SpotFi[Mobicom'15]; Witrack [NSDI'14]; WiSee[Mobicom'14], ArrayTrack[NSDI'13]; PinPoint[NSDI'13]; PinIt[SIGCOMM'13]; Zee[MobiCom'12]; PinLoc[MobySys'12]; FM-based[MobySys'12]; EZ[MobiCom'10]; ...

Conclusion

- BLoc: the first CSI based indoor-localization algorithm for BLE
- Achieves BLE sub-meter(86cm) median error indoor localization
- Enables sub-meter localization for IoT