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Towards an Automated Monitoring of RF Activity in Low-Power Wireless Testbeds

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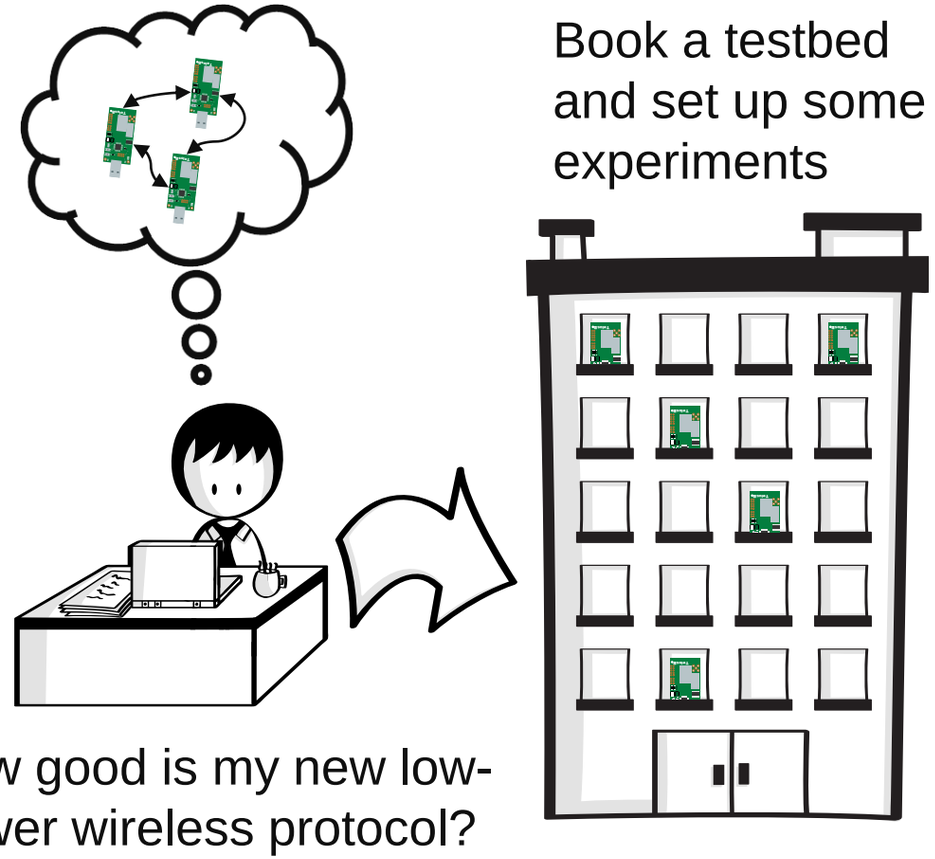
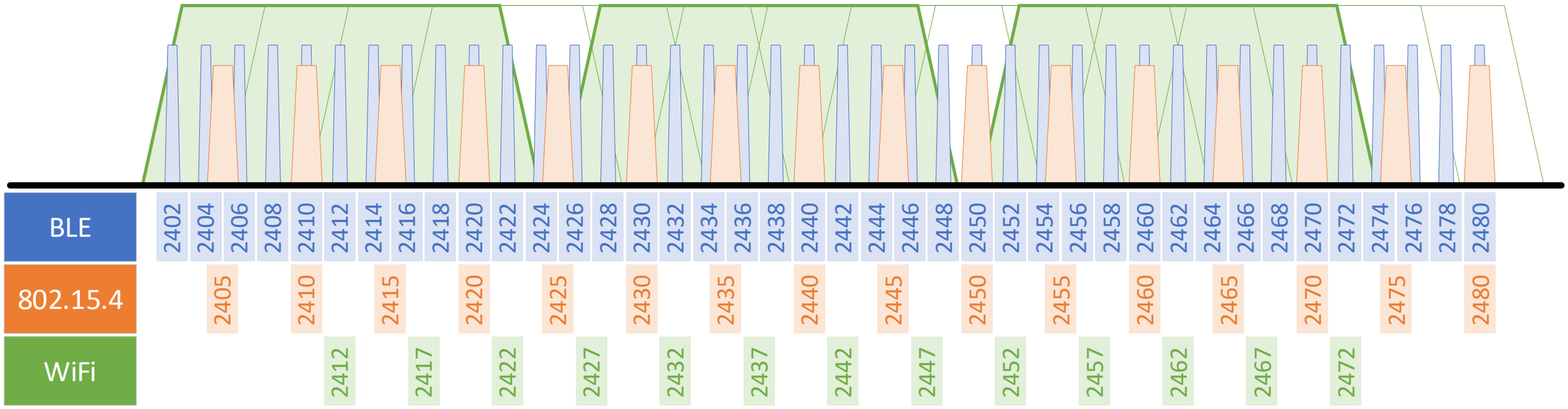
How we compare low-power wireless protocols today

- Public testbeds are often used to validate the performance of protocols
  - These testbeds are often set up in regular office buildings
- Hard to ensure that RF conditions are the same across experiments
  - Even when running experiments at night or over weekends



The RF environment is messy

- There are a lot of technologies in the 2.4GHz ISM band
- They do not use the spectrum equally (bandwidth, channel hopping)



How does this affect benchmarking?

- Efforts have been made to improve the rigor of experimenting
- There is no method to quantify or compare RF
- Automatic testing has been shown to enable fair comparisons
  - E.g. Demonstrated during EWSN dependability competition enabled by D-Cube

Can we mitigate the lack of control?

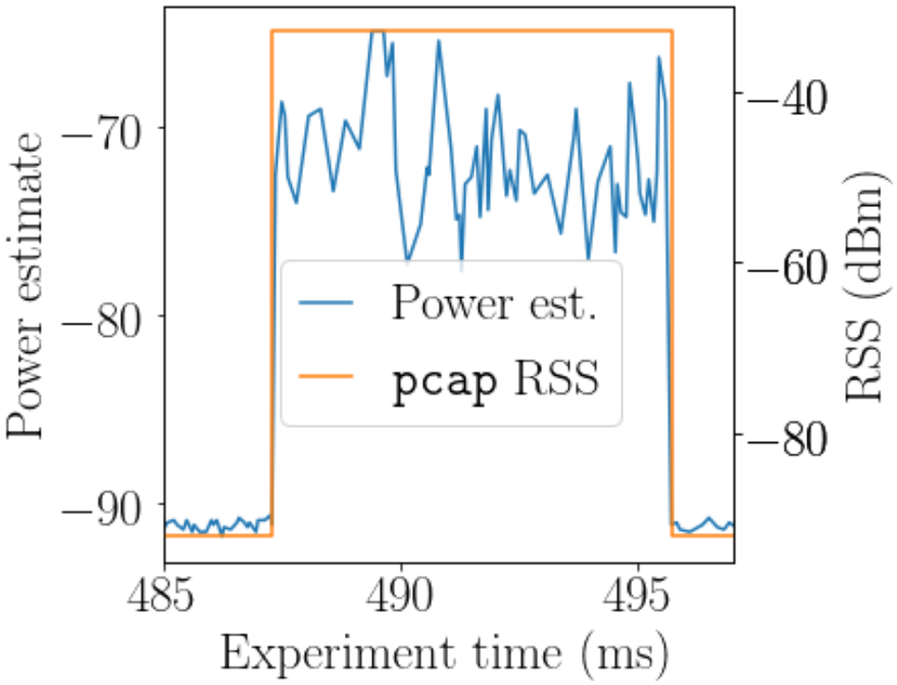
- Using off-the-shelf devices to monitor the RF environment
  - Monitor the entire 2.4GHz ISM band
- Distinguish different kinds of interference
  - Detect events only a few hundreds of µs long
- Quantify the interference present
- Compare interference between experiments

Tools to monitor RF interference

- Many low-power nodes can sniff the RF power
  - They still operate in a very in a narrow band
- ATH9K WiFi cards can report if the RF power is above a threshold
  - While programmable, the information is only binary and much nuance is lost
- SDRs or dedicated spectrum analysers can monitor a wide band
  - Due to their cost they scale poorly across an entire testbed

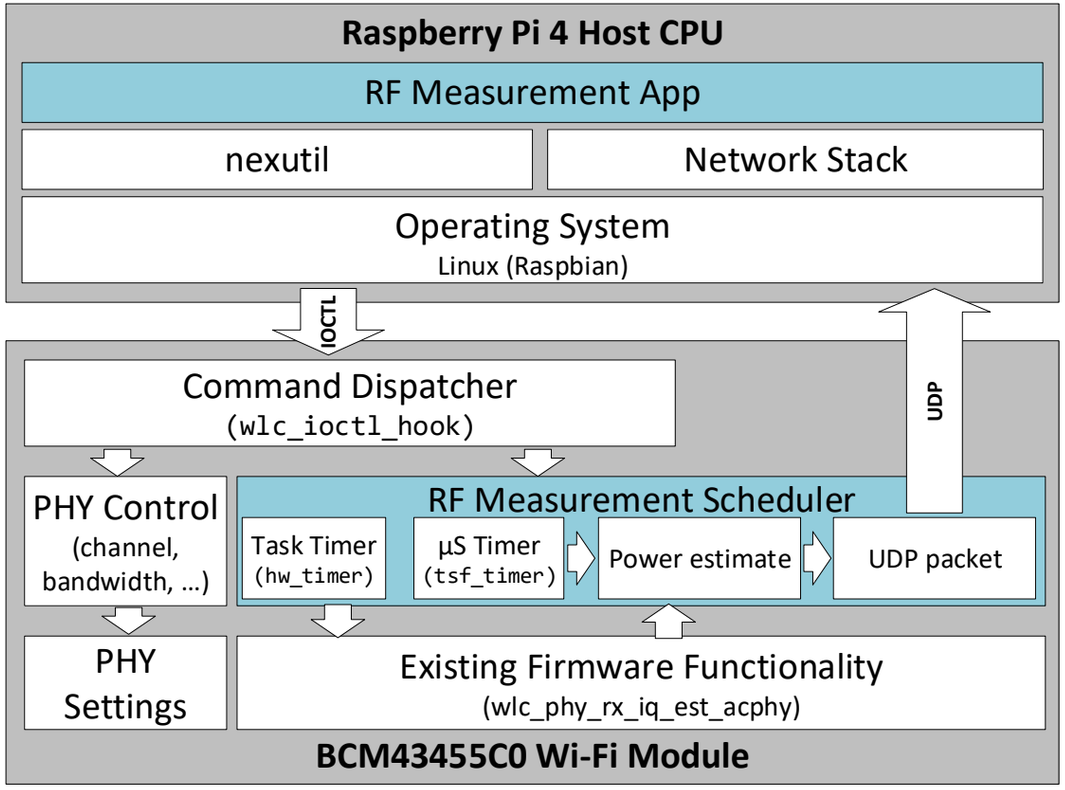
Monitoring the RF environment using off-the-shelf hardware

- A special monitor mode can often be used to capture WiFi packets
  - Even when not connected to the access point
- Captured packets contain RSS information and packet length to compute channel use
- The real interference looks different though



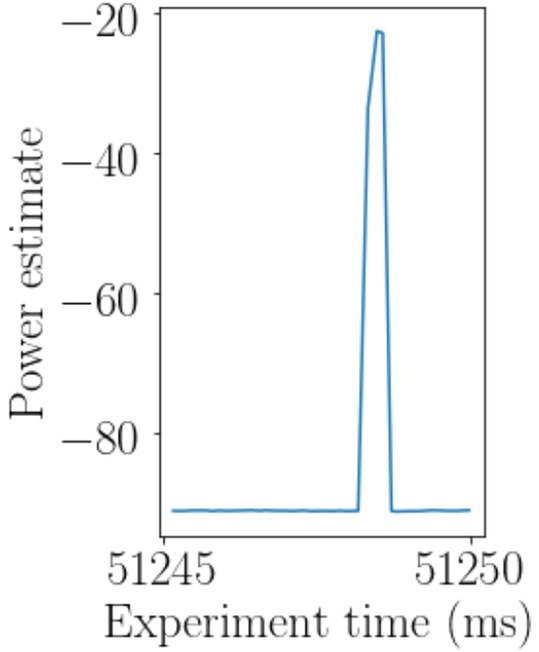
Monitoring the RF environment using off-the-shelf hardware

- Implemented on the BCM43455C0 WiFi module of the the Raspberry Pi 4
- Using Nexmon new functionality can be added to the radio firmware
- RF samples are sent to the OS using UDP messages
- A scheduler is used to trigger periodic measurements

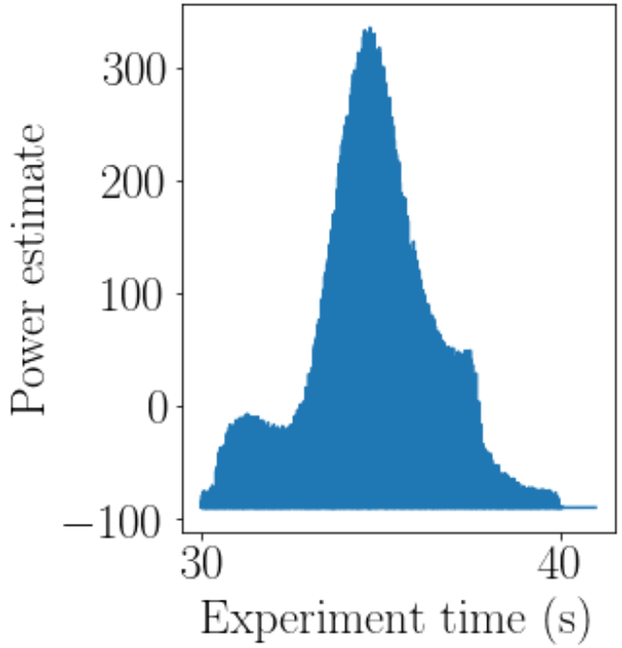


Monitoring the RF environment using off-the-shelf hardware

Ephemeral events such as Bluetooth Low Energy advertisements

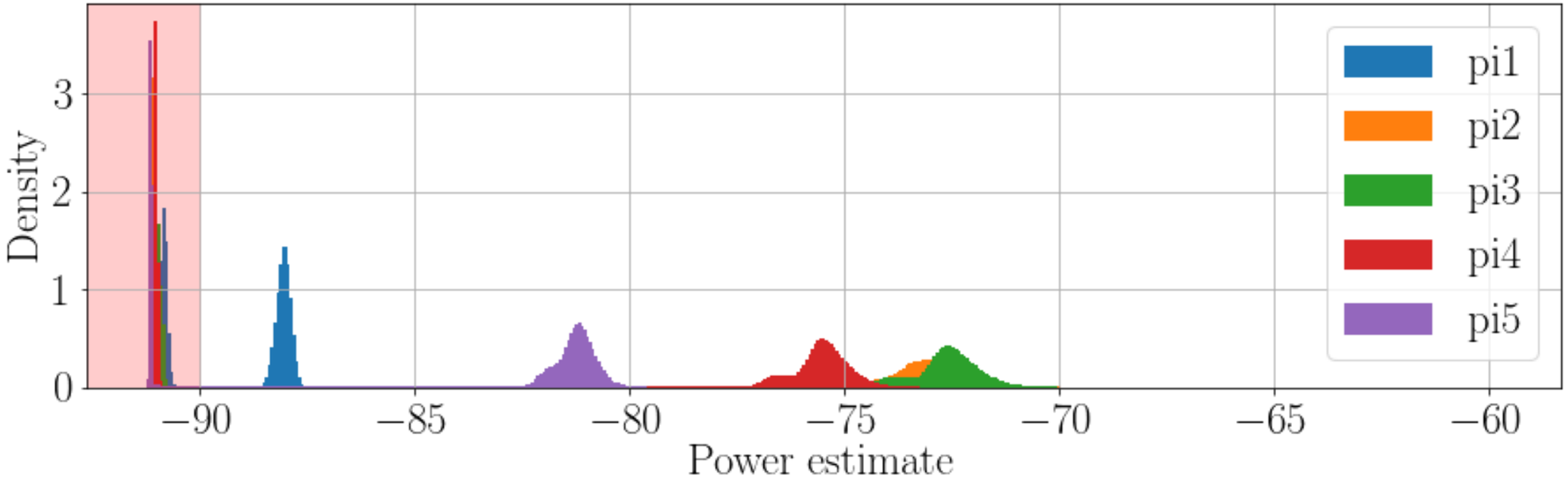


Interference caused by devices not actually communicating (e.g. a microwave oven)



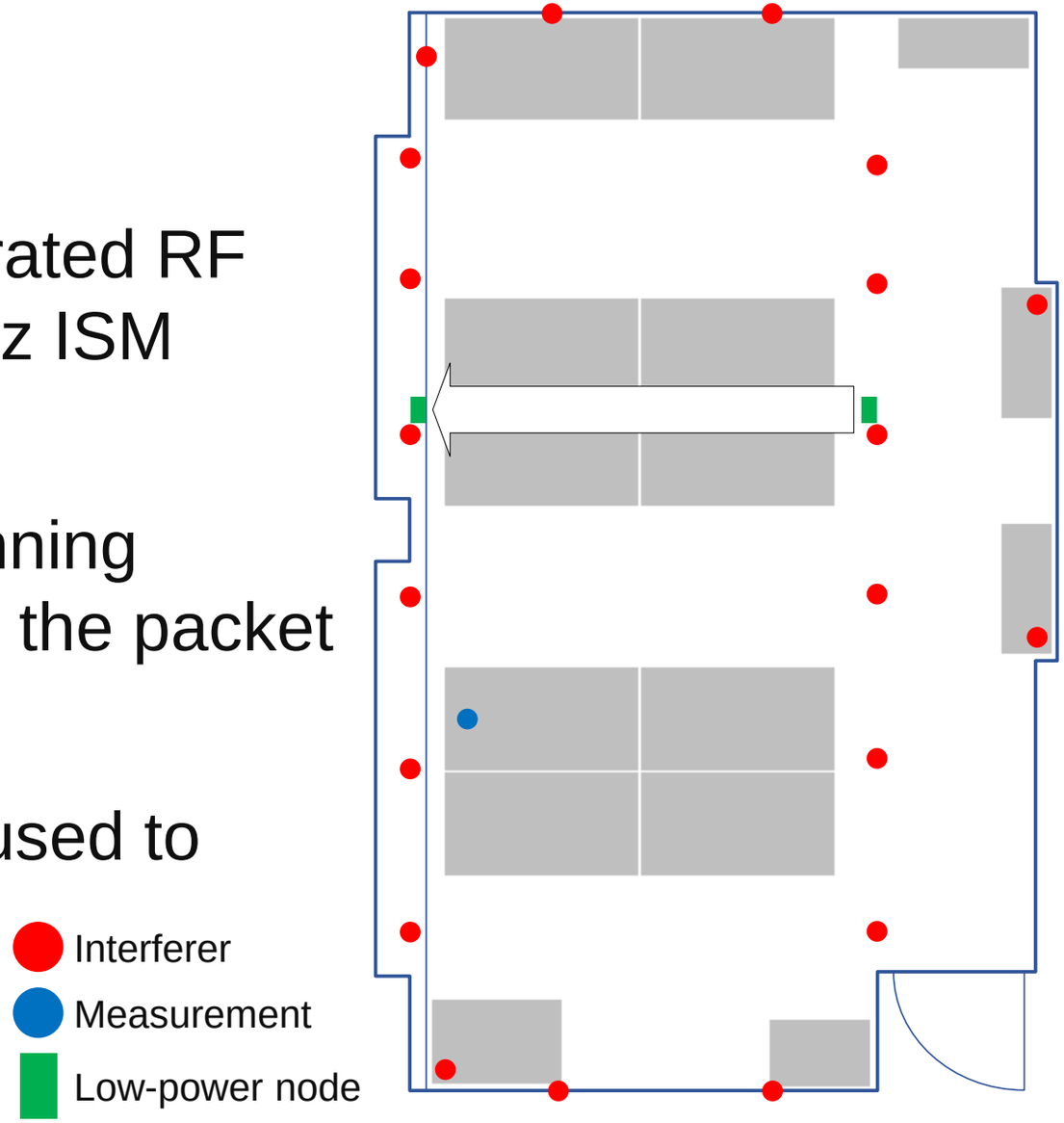
Quantifying the difference in RF

- We reduce the power estimates to a probability density function
  - To enable real-time decisions the whole experiment is split into windows



Proof of concept

- Using our in house testbed we generated RF interference across the whole 2.4GHz ISM band using JamLab-NG
- We set up a pair of TelosB nodes running Contiki to pass messages and report the packet reception ratio (PRR)
- One collocated Raspberry Pi 4 was used to record power estimates

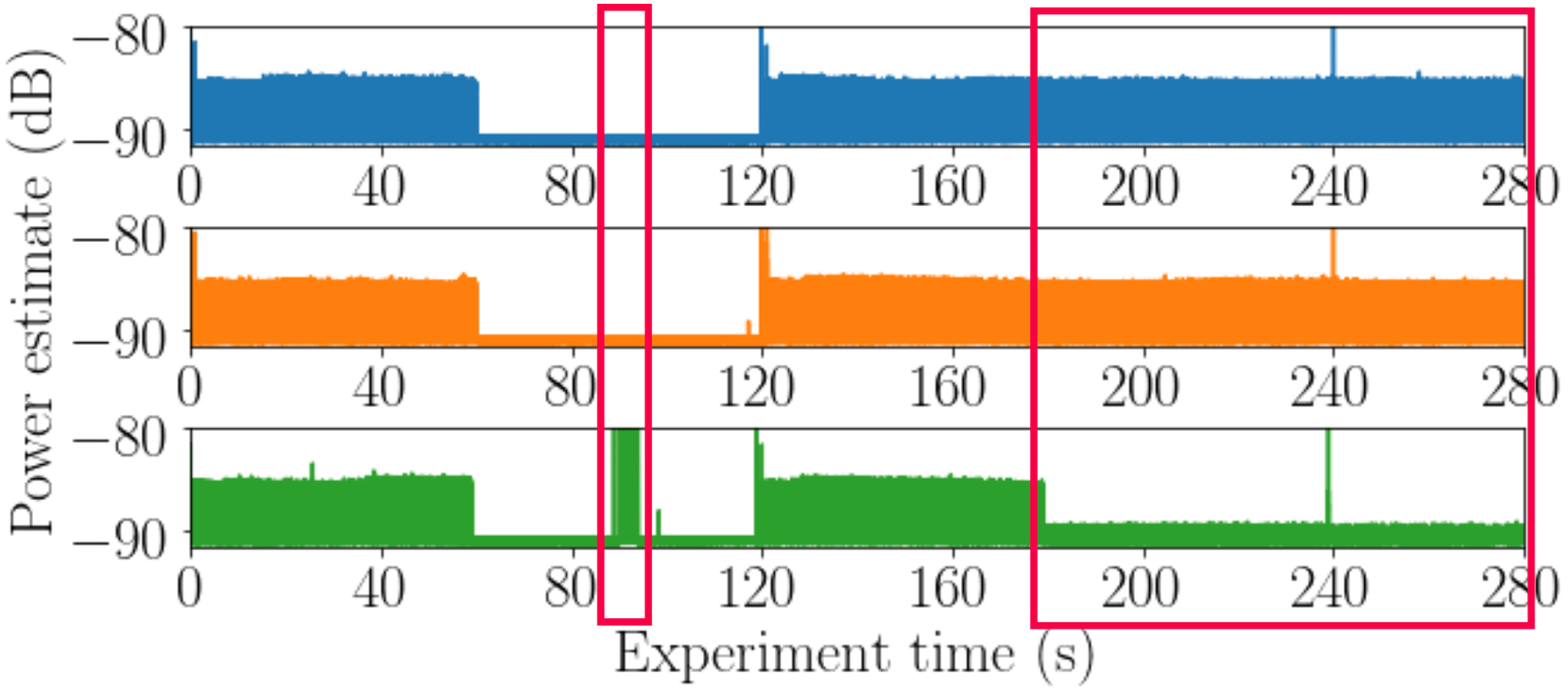


Proof of concept

- In the first two runs we generated interference using the same settings

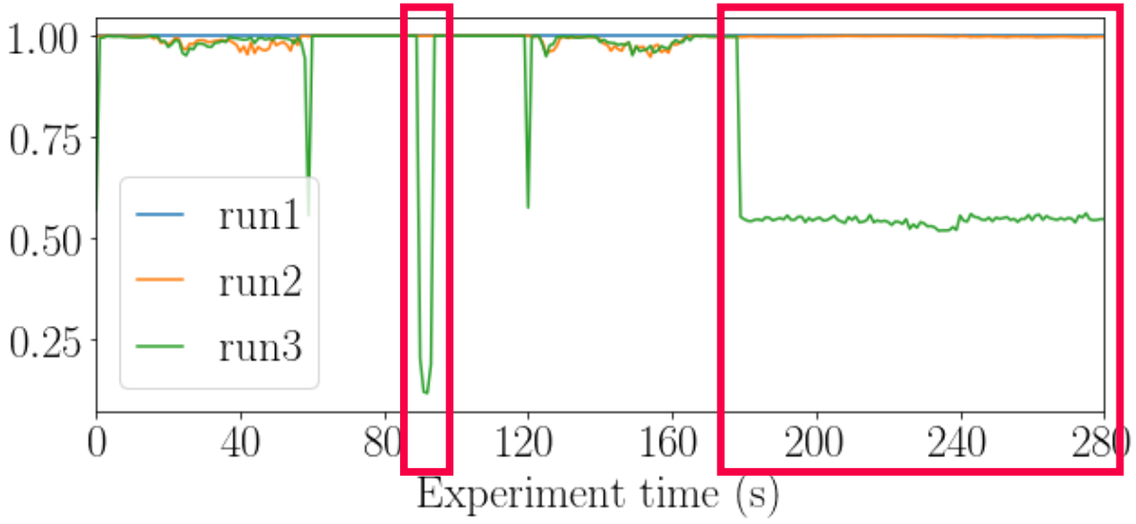
Run 3 deviates in two places from the first two:

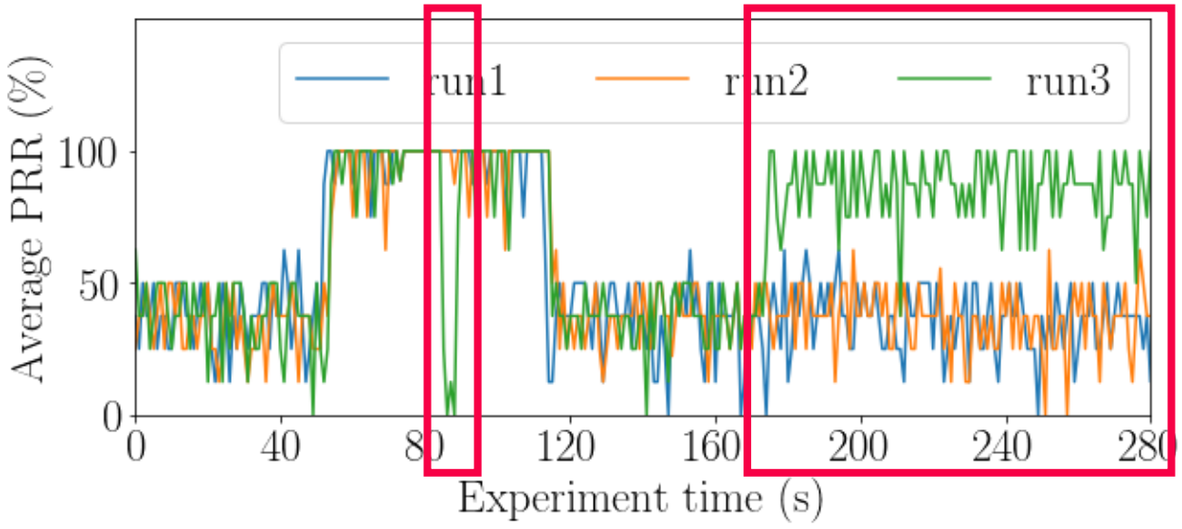
1. A spike when there should be no interference
2. Lesser interference for at the end of the experiment



Proof of concept

- Correlation will have a value of 1 for identical interference patterns
- The deviations in the pattern can be easily detected
  - They have clearly altered the resulting PRR of the low-power nodes





Conclusion

- Off-the-shelf hardware can be used to monitor RF environment
- A PDF still holds sufficient information to make decisions on similarity
- Distance functions for histograms can be used to compare experiments
- Little computational power is required, allowing real-time decisions
- We are now ready to scale these results up to the full testbed