DEPENDABLE INTERNET OF THINGS
IN ADVERSE ENVIRONMENTS

ENABLING RUNTIME ADAPTATION OF PHYSICAL LAYER SETTINGS FOR DEPENDABLE UWB COMMUNICATIONS

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Motivation

In UWB research focus on localization. Maximizing dependability for UWB communications, instead, is still unexplored

- Energy-efficiency: UWB radios are more energy-hungry than narrowband IoT transceivers
- Reliability: essential to reliably acquire and share the timestamps in the network

Characterization of the numerous 802.15.4 UWB PHY settings is missing

- PHY settings have huge impact on dependability
- Changing them helps to overcome a degrading channel

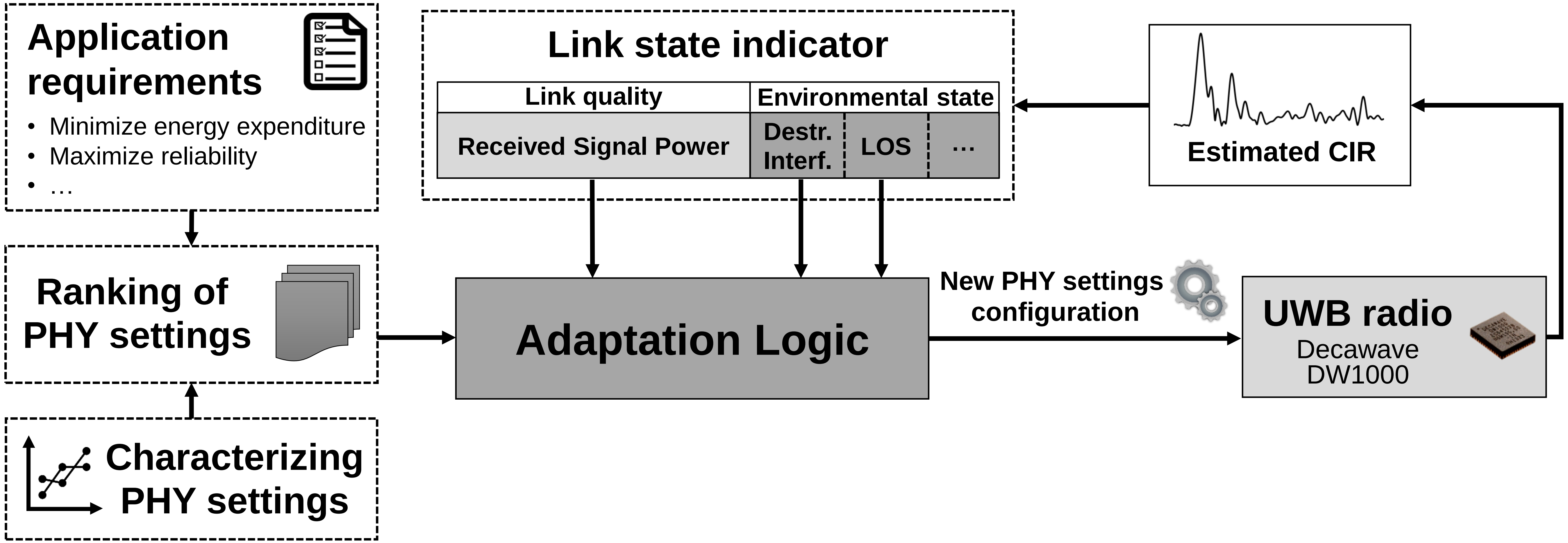
Need for runtime adaptation

- To date, UWB systems make use of static PHY settings independent on dynamic environment

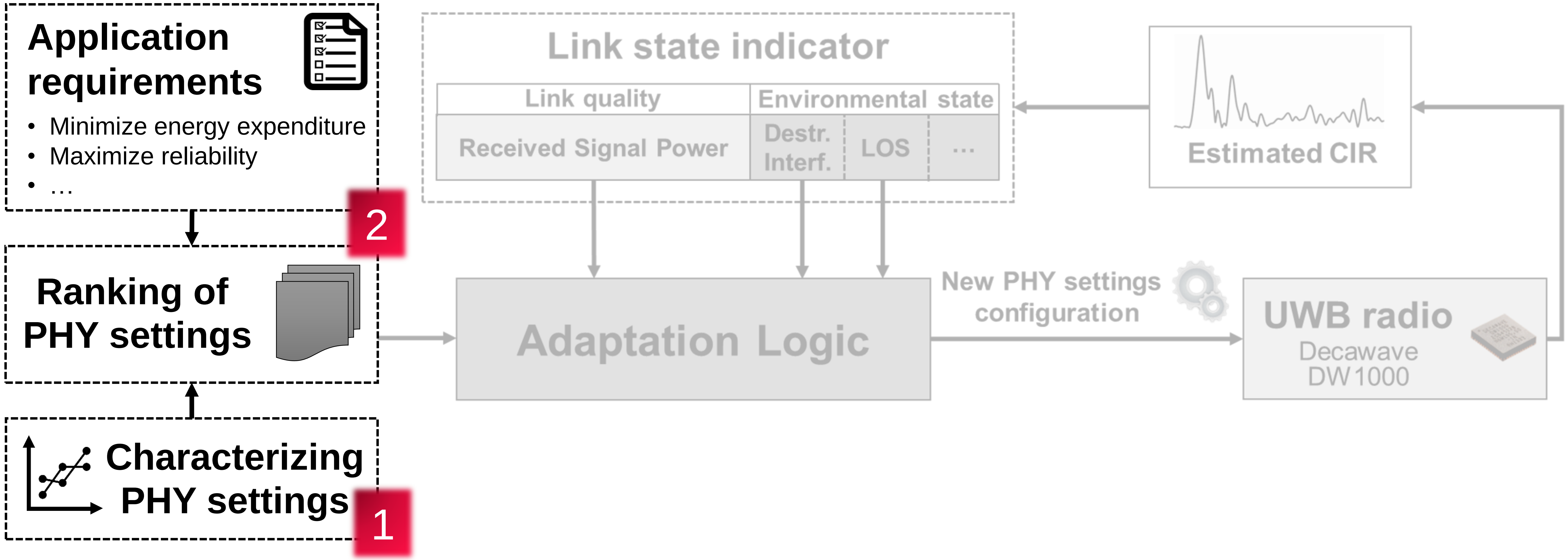
Estimating the link quality for UWB not thoroughly investigated

- Link quality estimation is required to trigger the adaptation of the PHY settings

Outline & Contributions



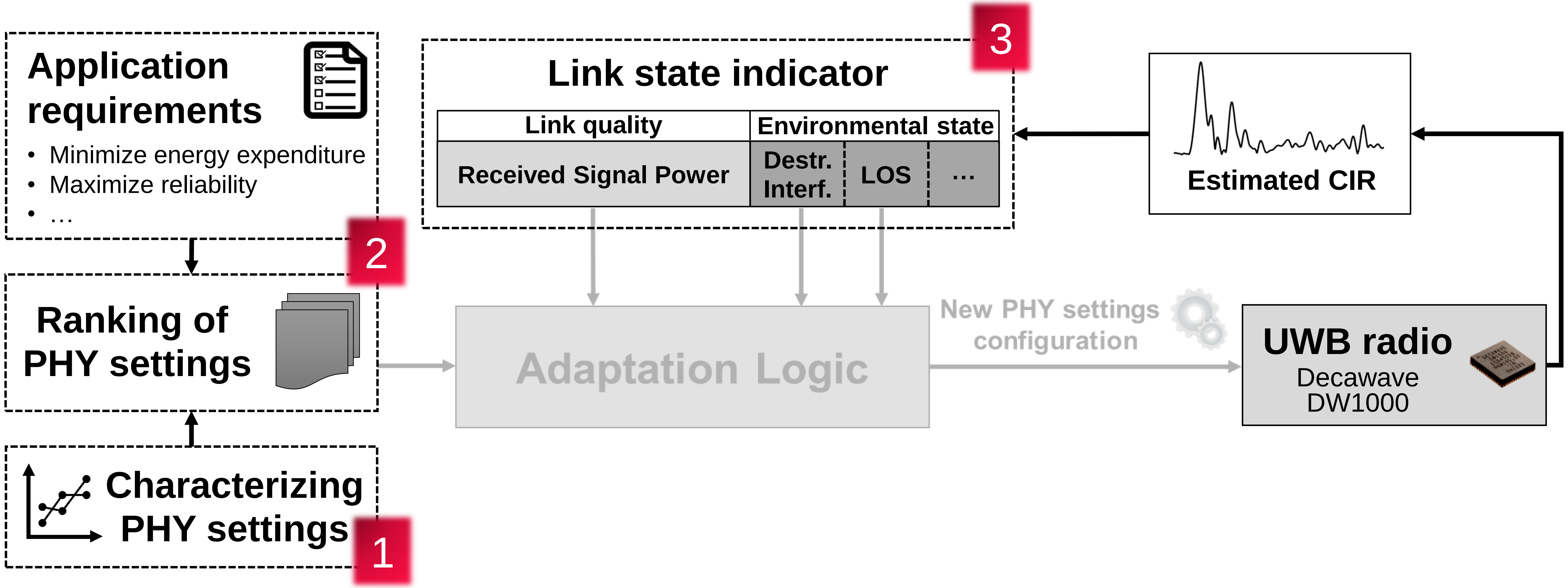
Outline & Contributions



(1) Characterize and quantify the impact of the different PHY settings on the dependability of UWB transceivers

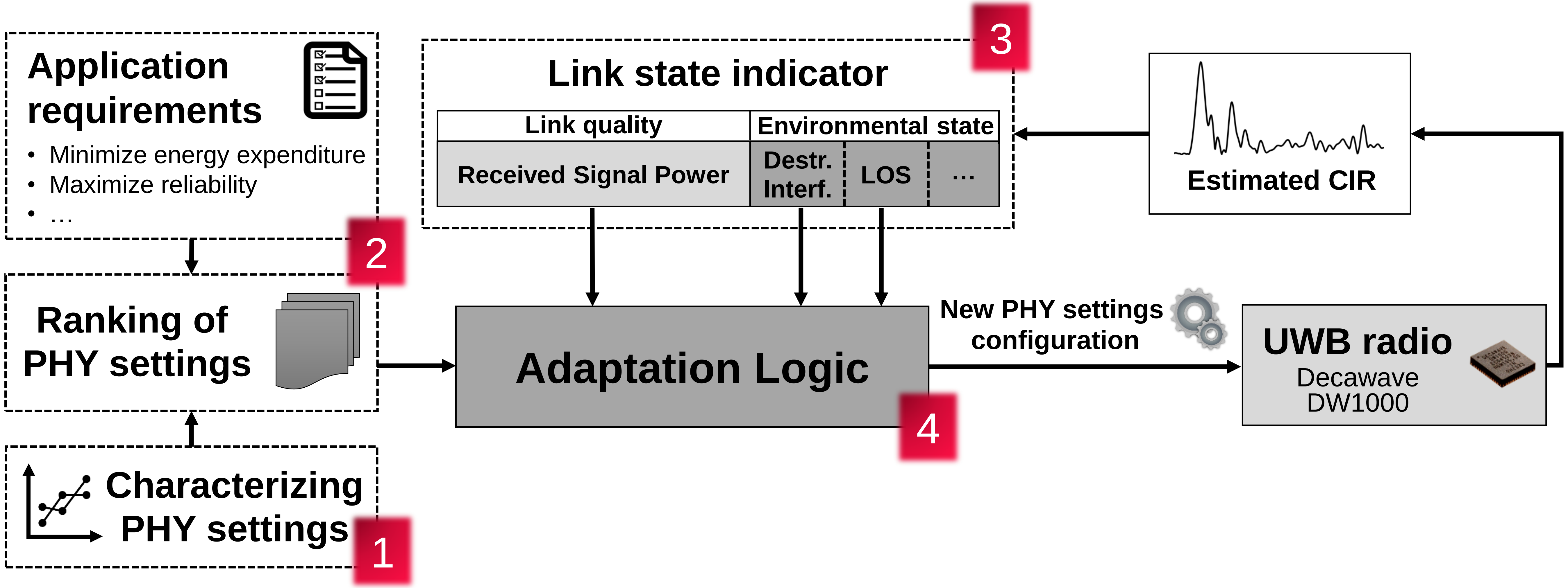
(2) Rank PHY settings depending on characterization and application requirements

Outline & Contributions



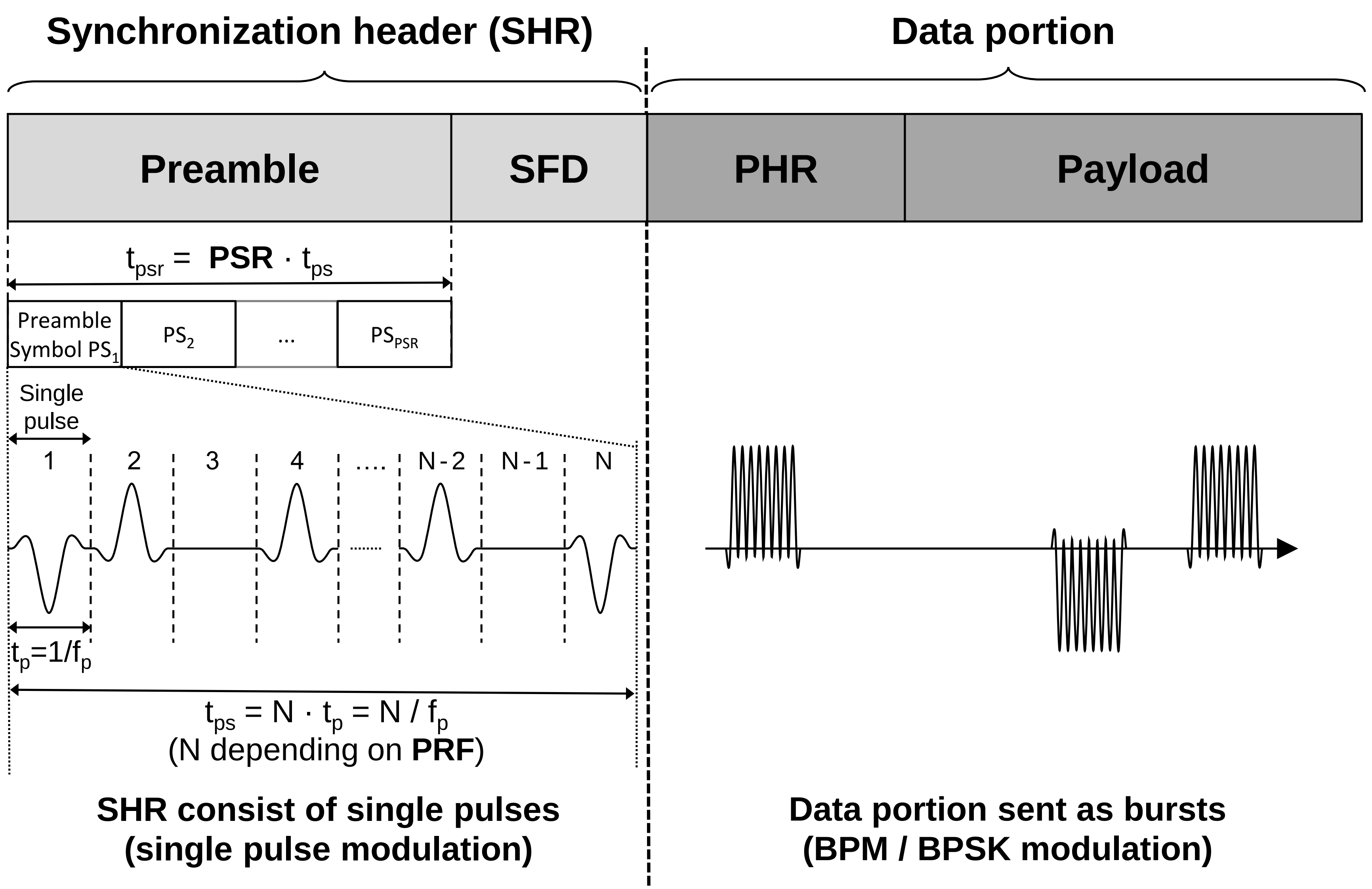
(3) Use PHY information to estimate link quality and extract information about the surrounding environment

Outline & Contributions



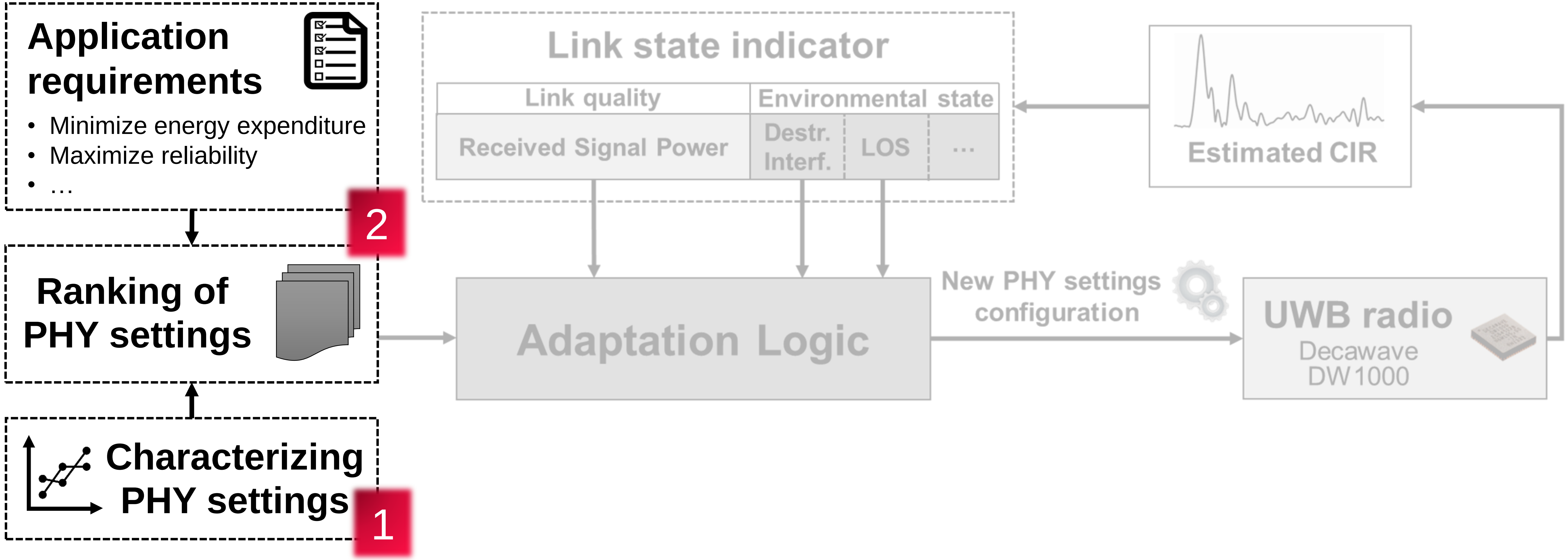
(4) Design an adaptive scheme that derives an optimal set of PHY settings at runtime.

Background: IEEE 802.15.4 UWB PHY



- Different modulation schemes
- Configurable PHY Settings
  1. Pulse Repetition Frequ. (PRF)
  2. Preamble Symbol Rep. (PSR)
  3. Data Rate
  4. Channel
  5. Bandwidth

Reminder: Outline & Contributions



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Characterizing UWB performance

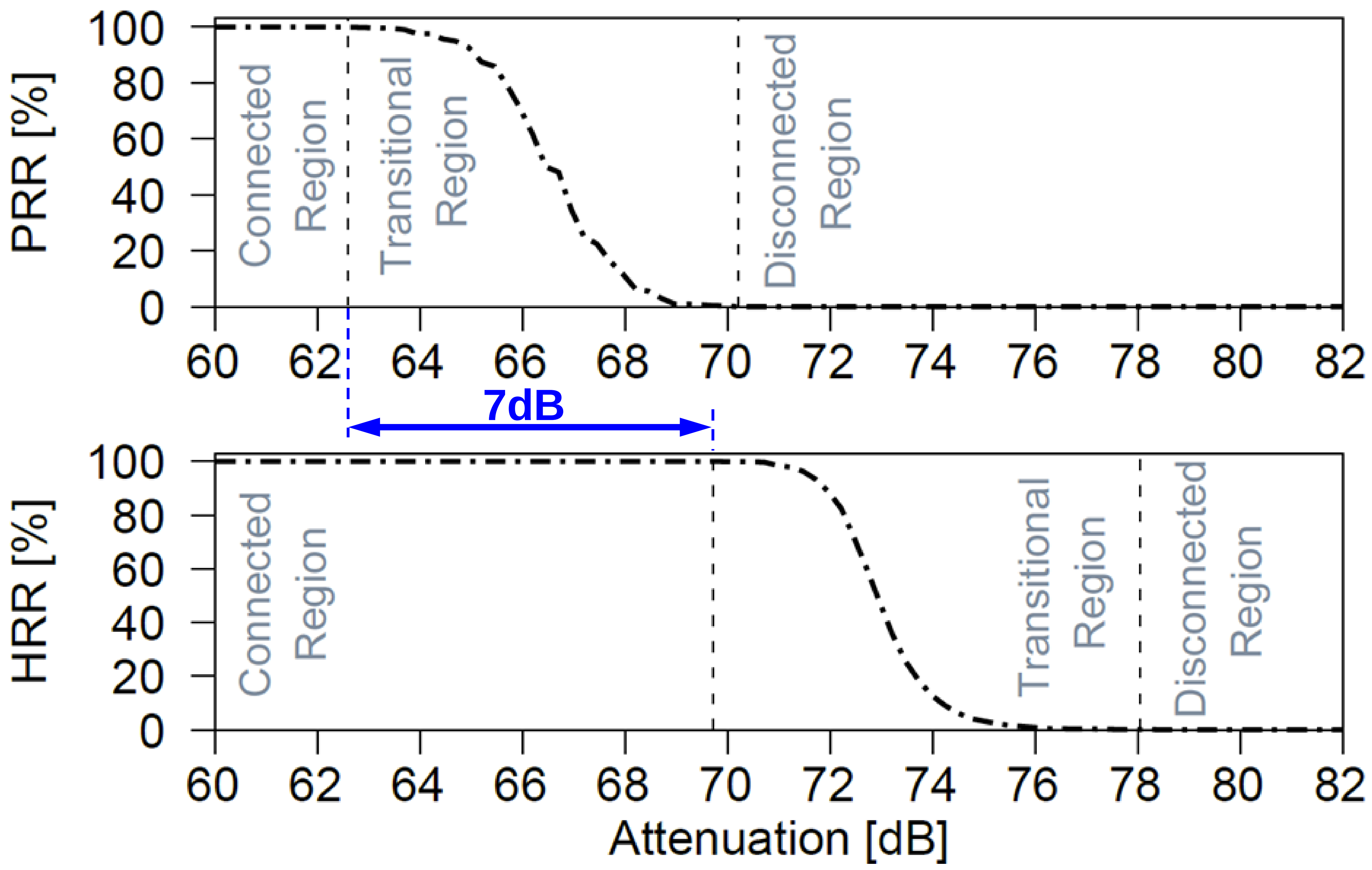
Experimental setup:

- Decawave DW1000 UWB transceiver (EVB1000 boards)
- Cable-based single link setup (TX, RX)
- Used programmable attenuator in between to simulate a degrading channel in a reproducible manner
- 1000 packets per attenuation and setting

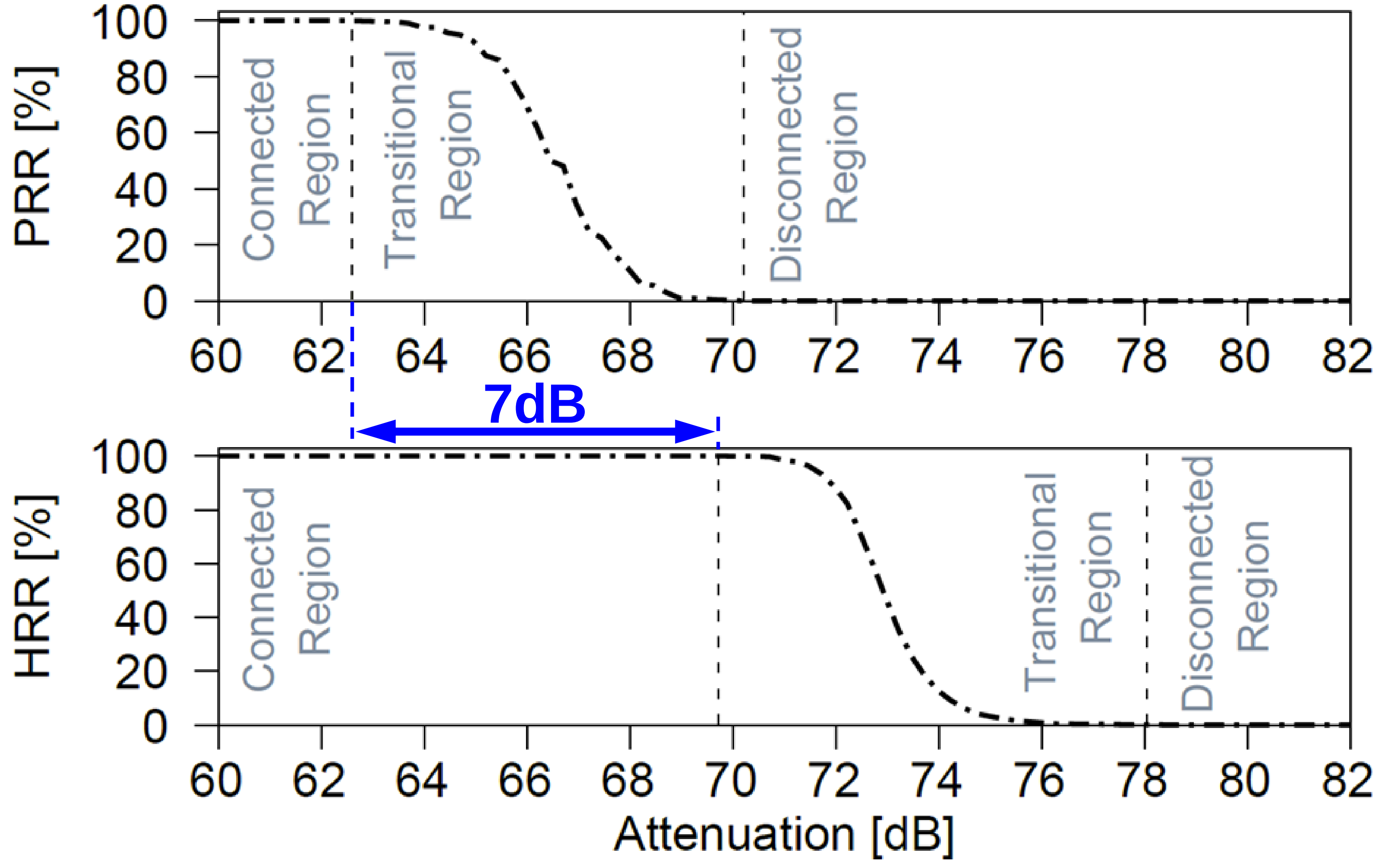
$$Packet\ Reception\ Rate\ (PRR) = \frac{\#\ of\ received\ packets}{\#\ of\ sent\ packets}$$

$$Header\ Reception\ Rate\ (HRR) = \frac{\#\ of\ valid\ SHR\ received}{\#\ of\ sent\ packets}$$

Characterization: Impact of modulation schemes



Characterization: Impact of modulation schemes

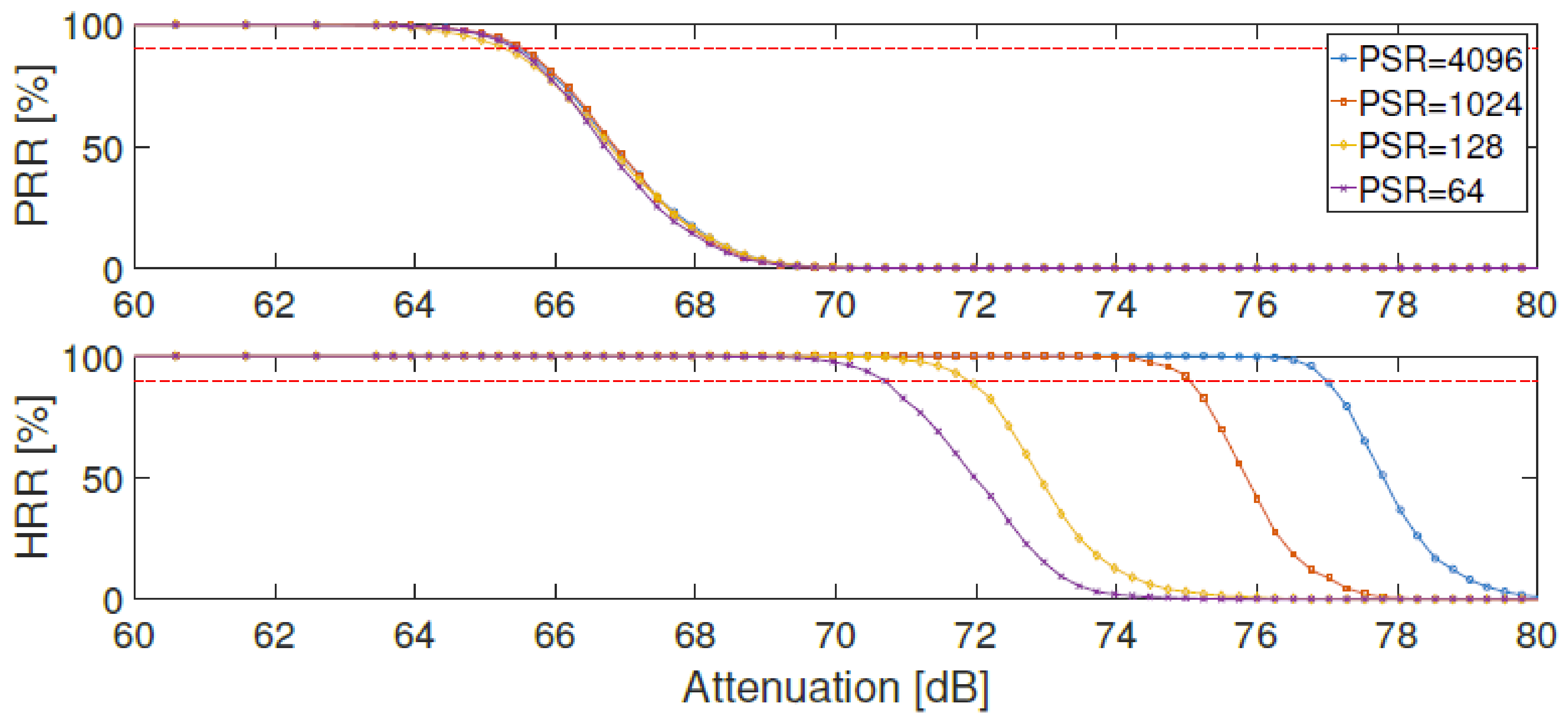


(1) Link quality available in absence of complete packet reception

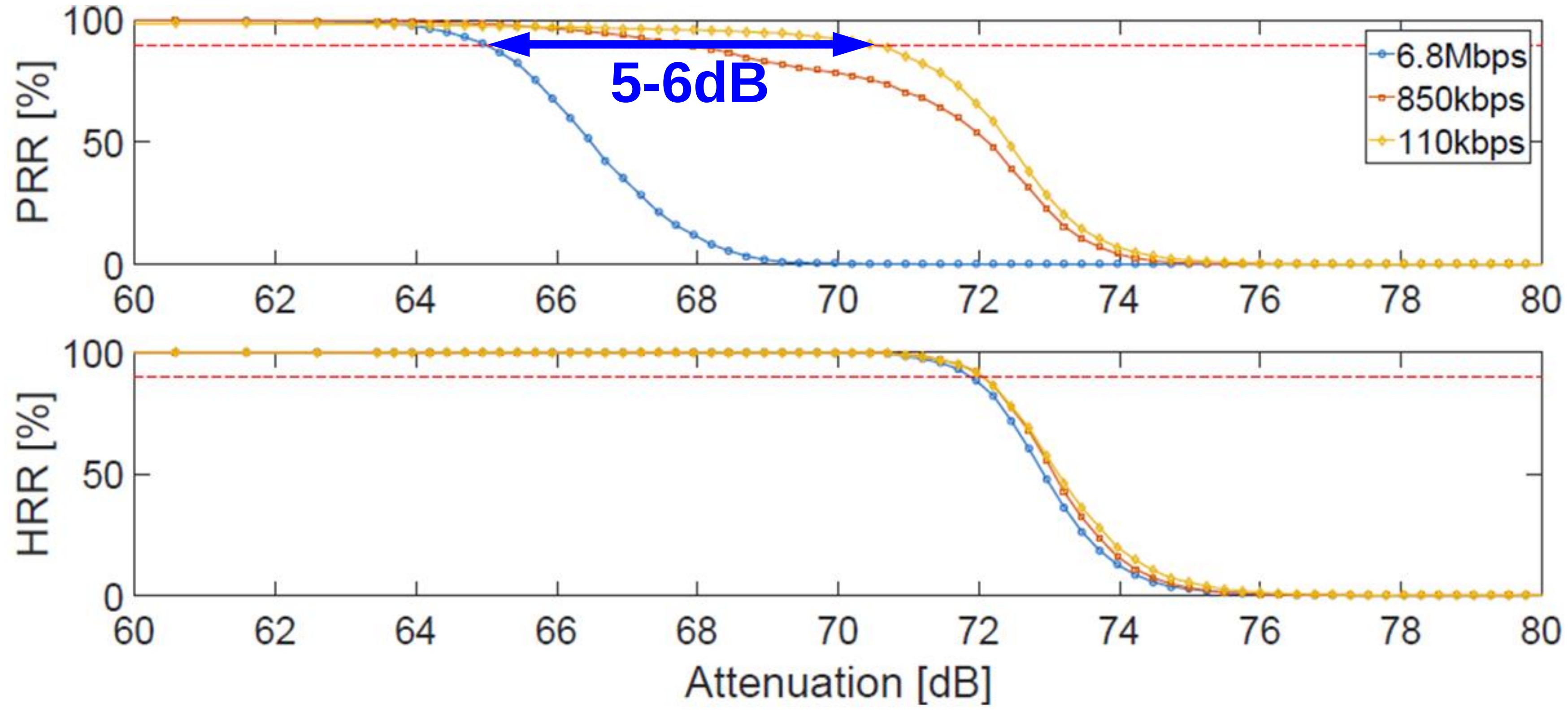
(2) Preamble detection as binary ACK

Impact of PHY settings (e.g., PSR, DR)

Preamble Symbol Repetitions (PSR)



Data Rate

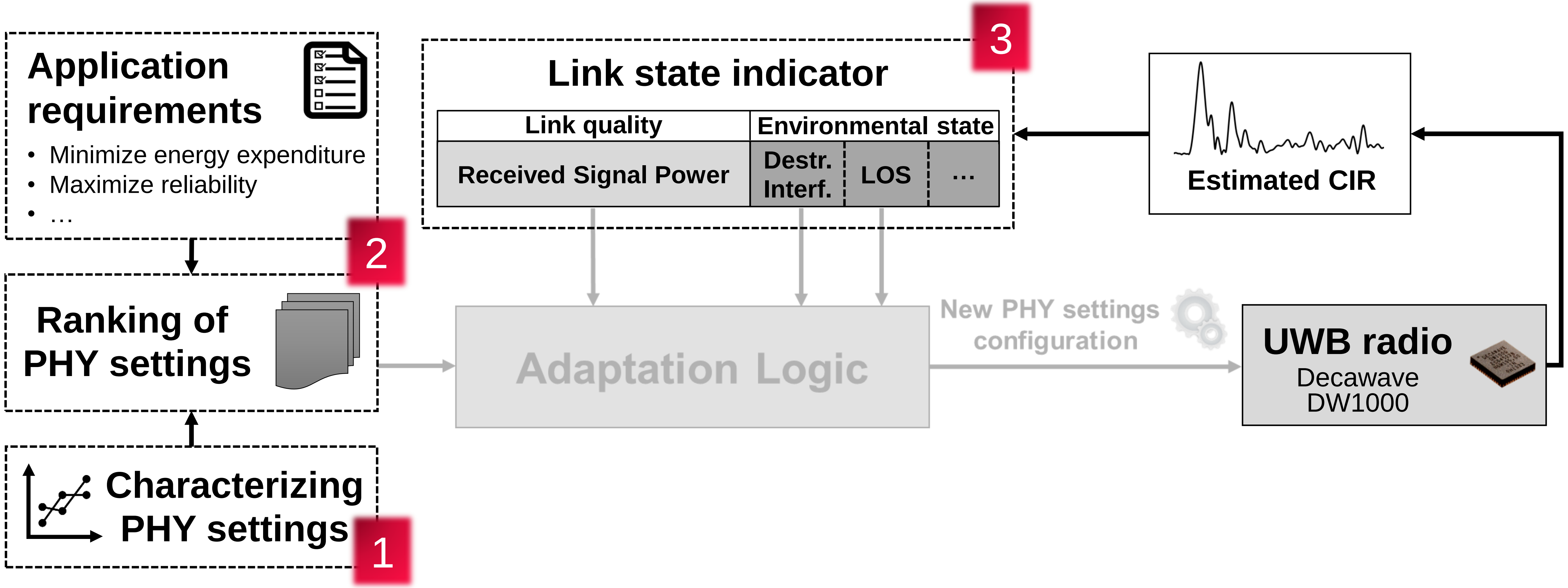


- Energy efficiency (TX+RX SHR):
  - PSR=4096: 30.2x less efficient
  - PSR=1024: 7.6x less e

- Energy efficiency (TX+RX):
  - DR=850kbps: 1.55x less efficient

Based on characterization we can derive a rank of settings in order to satisfy the application requirements.

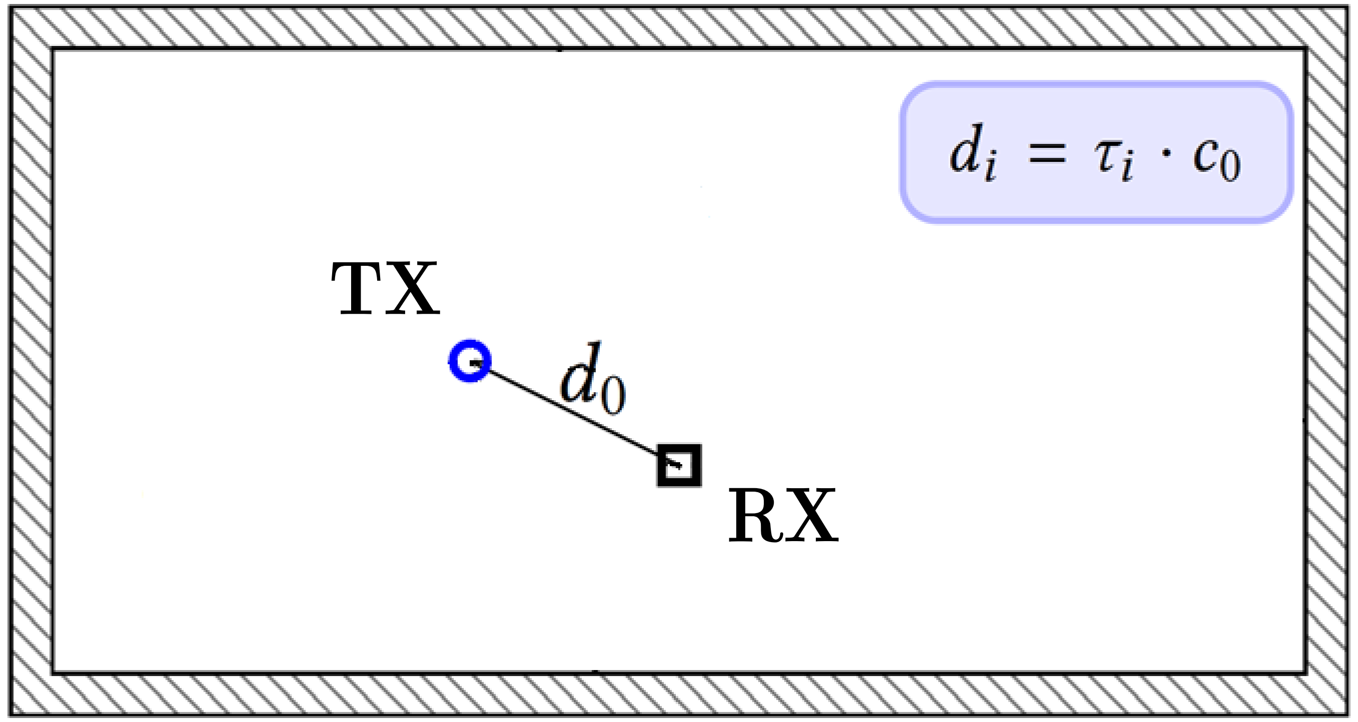
Reminder: Outline & Contributions

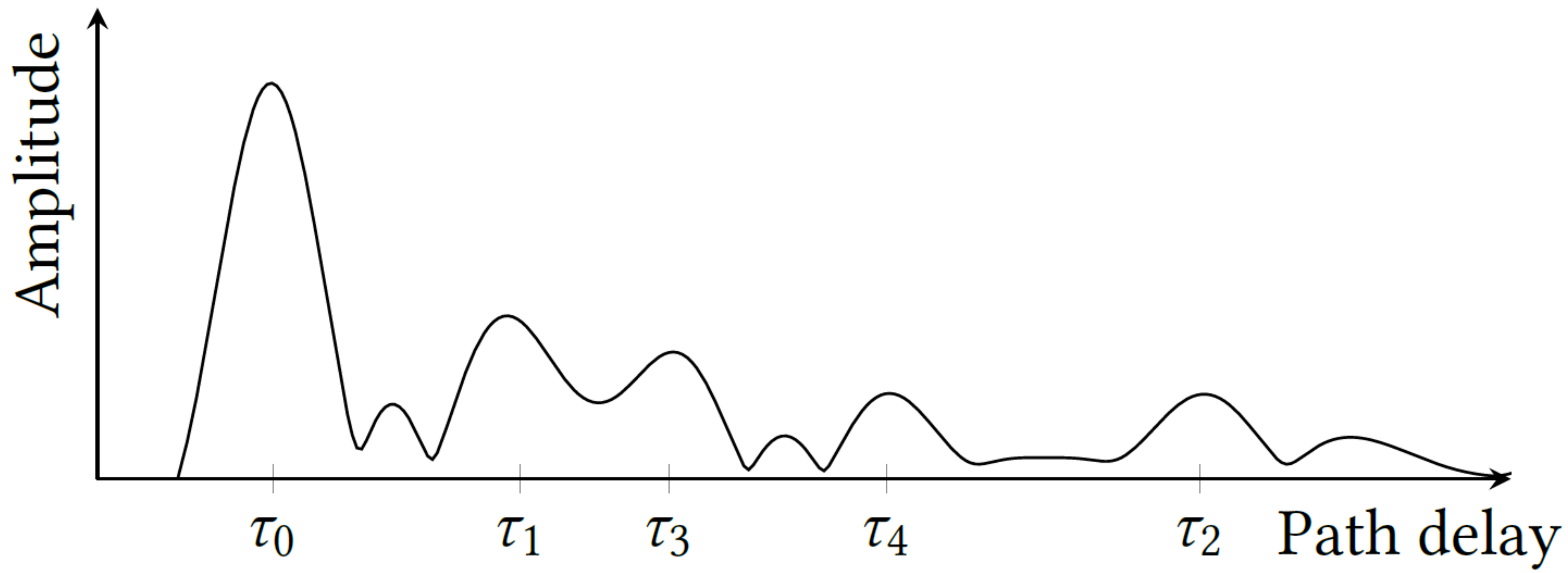


(3) Use PHY information to estimate link quality and extract knowledge about surrounding environment

Background: Channel impulse response

- UWB transceivers provide an estimate of the channel impulse response; derived from the preamble in the SHR
- Provides information about the multipath propagation and, thus, the environment

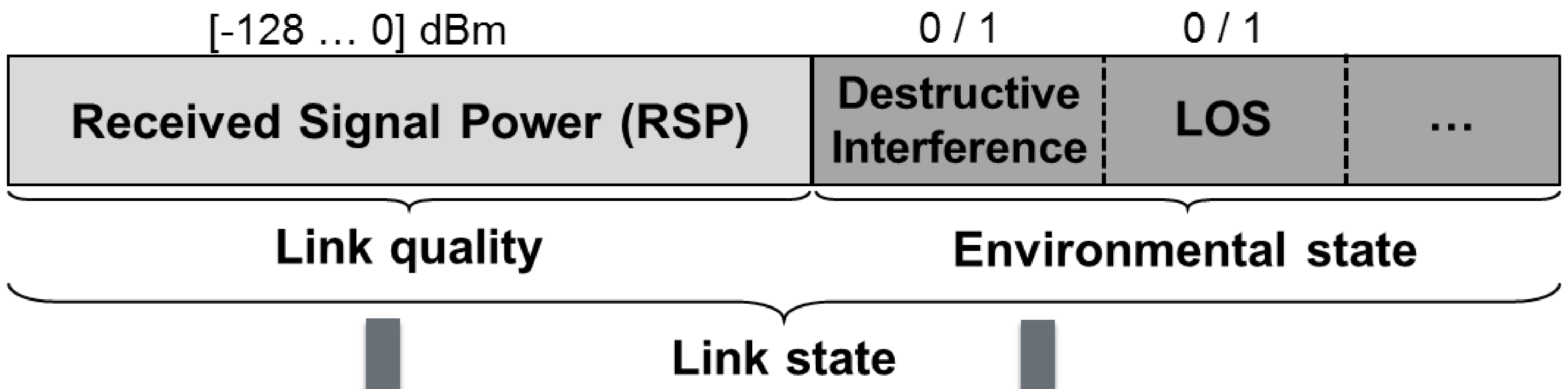




- Used to precisely estimate the arrival time of a packet

Estimating the link state

- We use CIR to estimate the link quality and extract environmental info
- UWB link state indicator (Link quality + environmental state = link state)

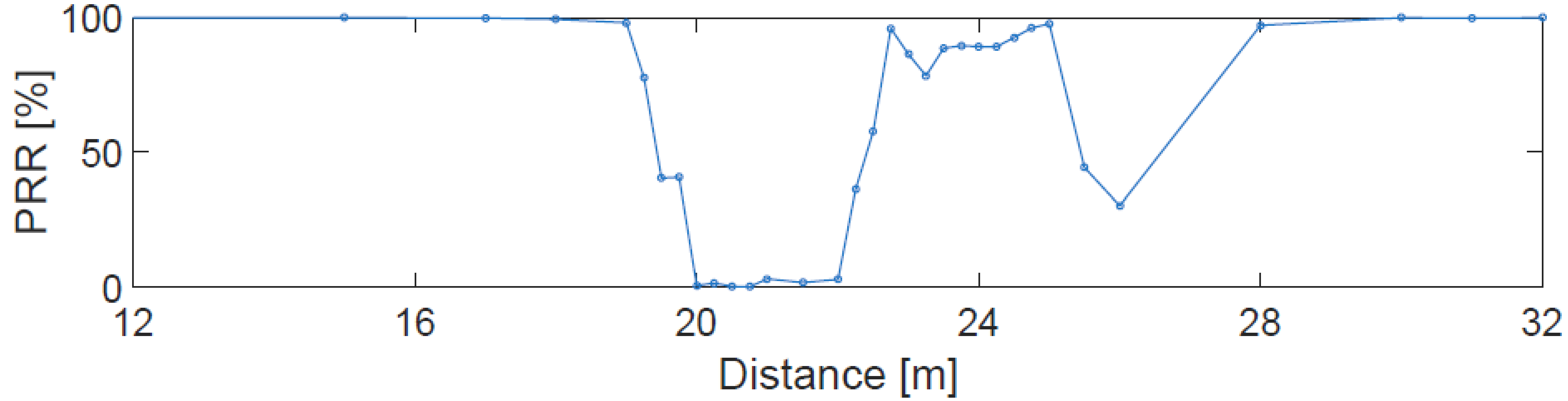


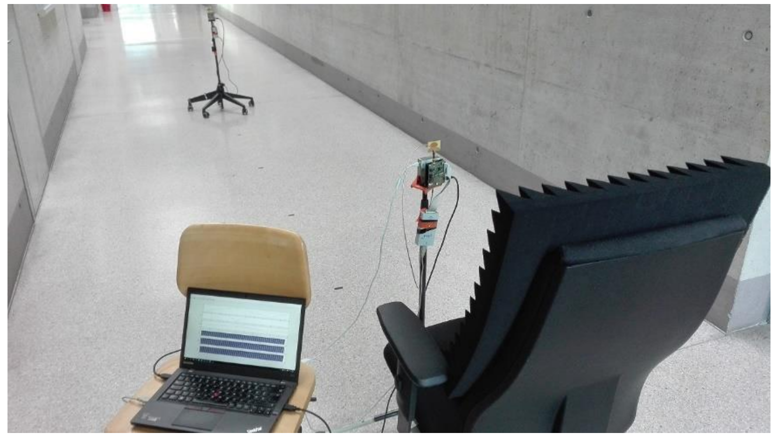
- Binary values
- LOS/NLOS, destructive interference,...
- Detect the cause of a degrading channel

- Derived from the integral of the channel impulse response
- Estimator of the received signal power / PRR

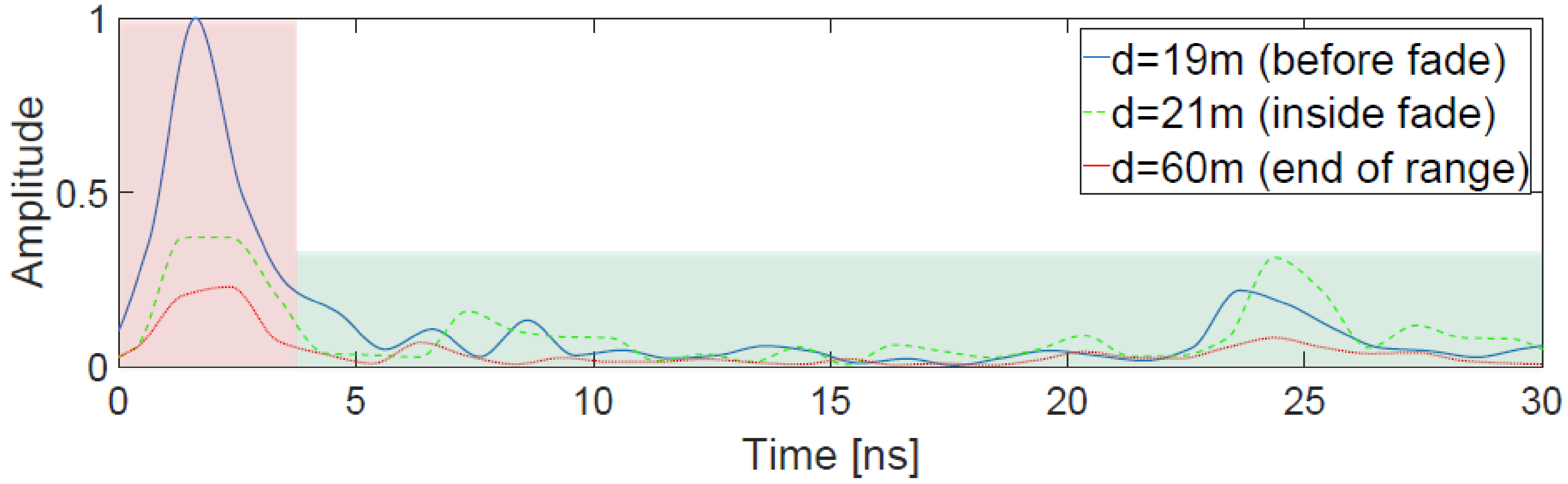
Detecting destructive interference

- Measurement campaign in corridor at campus
- PRR shows deep fades





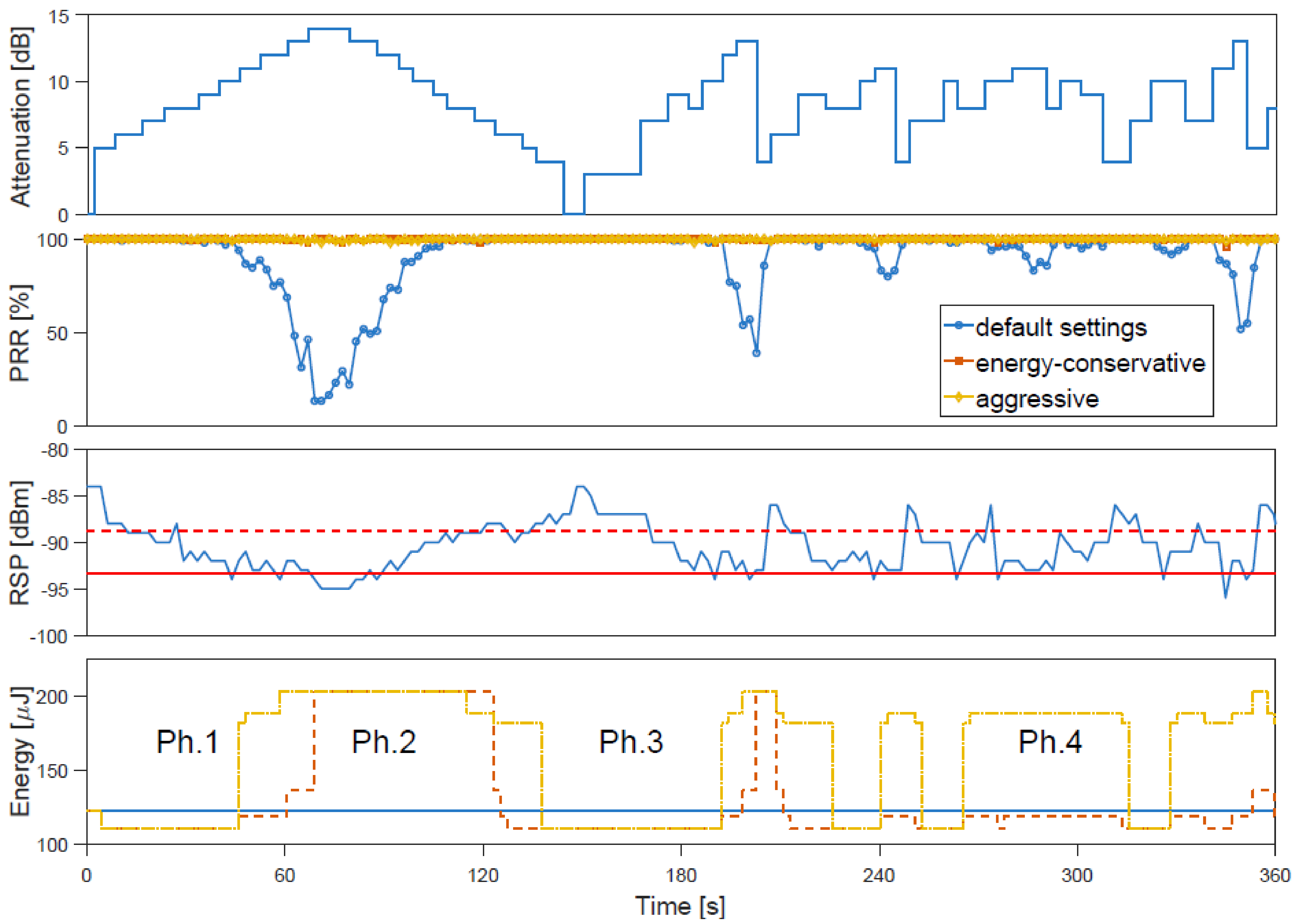
- CIR used to detect the cause of degraded channel



$$PR = \frac{P_{FP}}{\sum_{i=1}^{N_{MPC}} P_{MPC,i}}$$

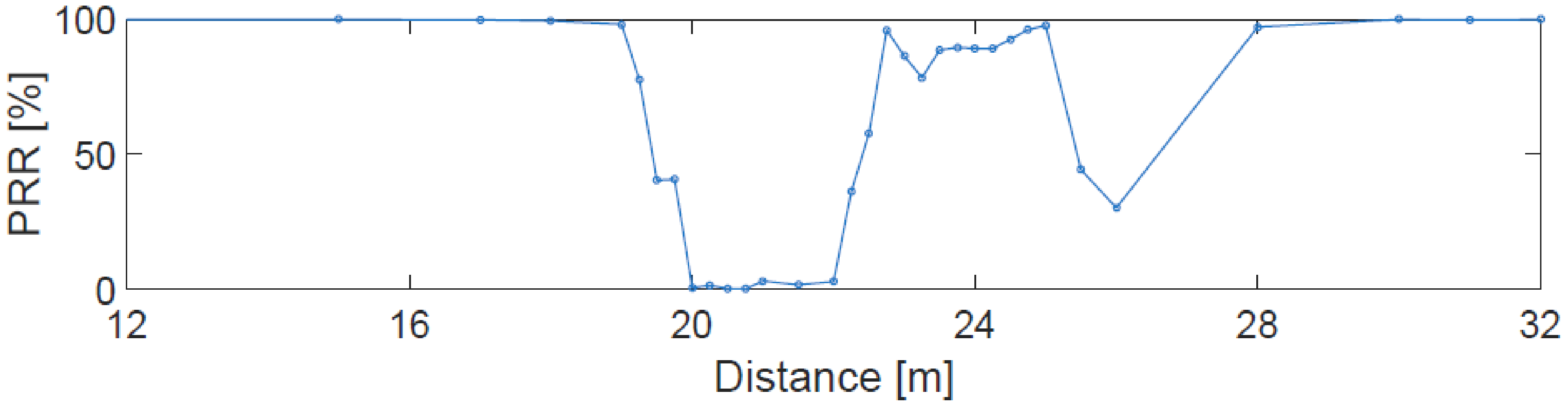
→ Huge impact on adaptation logic

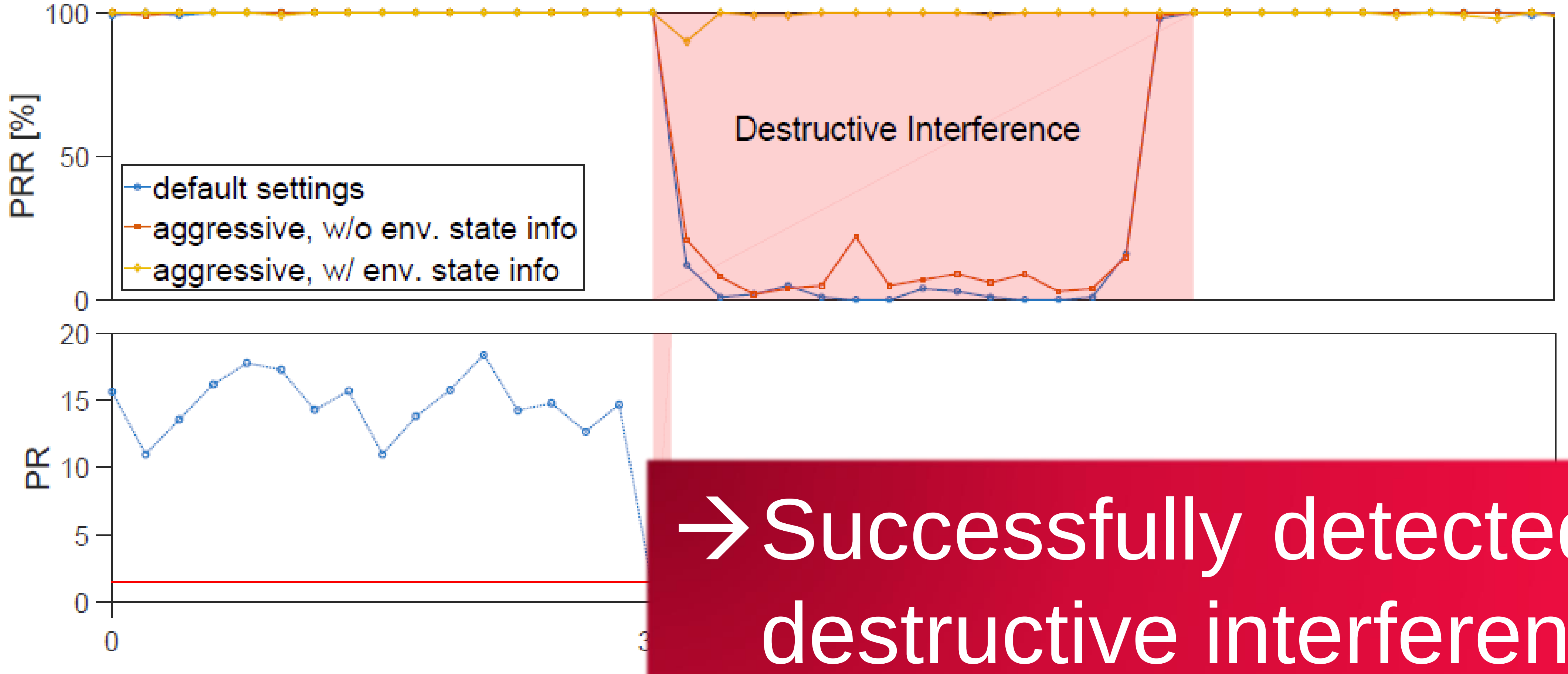
Evaluation I – Irregular fluctuations



→ PRR > 95%!!!

Evaluation II – Destructive interference





→ Successfully detected and tackled destructive interference

Conclusions

- We have exploited UWB PHY settings as tuning knobs to increase the dependability of communications
- We quantified the reliability and energy cost of each setting to know which one(s) to privilege depending on the application requirements
- We used the CIR to estimate the link quality and extract information about the environment
- Designed an adaptation scheme that adapts UWB PHY settings at runtime
- Evaluated the performance of the adaptation scheme in a real-world experiment

Thanks.