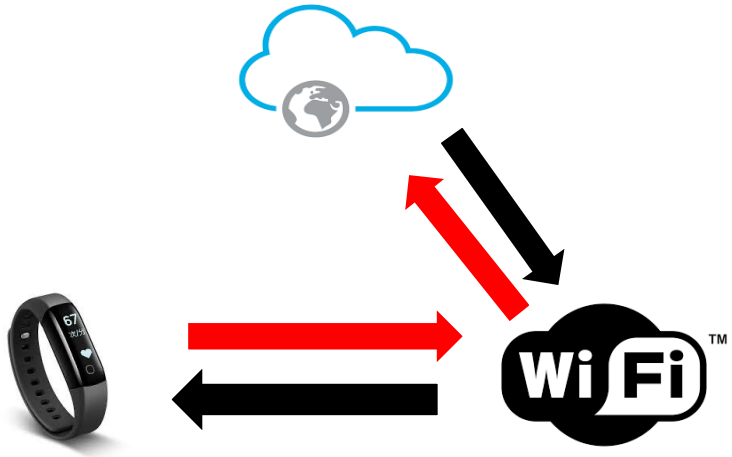
Link Quality Estimation of Cross-Technology Communication

Jia Zhang[1], Xiuzhen Guo[1], Haotian Jiang[1],

Xiaolong Zheng[2], Yuan He[1]

Cross-Technology Communication



Smart Health

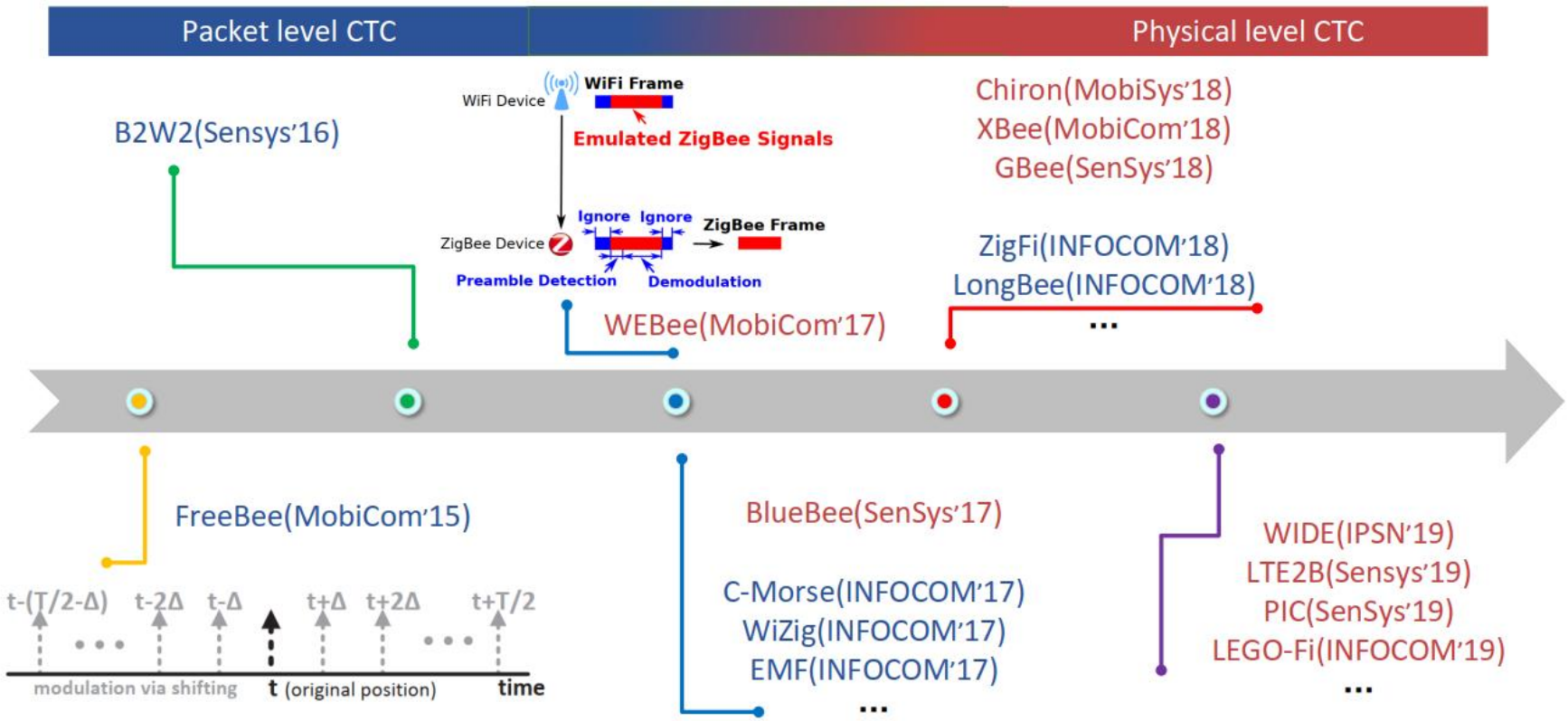
Smart Factory

Smart Home

- No gateway required
- Direct data exchange
- Hybrid network
- …

Development of CTC

- Early work：Packet level CTC
- The state of the arts：Physical level CTC



Development of CTC

- The state of the arts：Physical level CTC

Sender-Based	Receiver-Based	Both-Based
WEBee [Mobicom'17] PMC [ICNP'17] LTE2B [Sensys'19] Passive-ZigBee [Sensys'18] WIDE [IPSN'19] BlueBee [Sensys'17]	XBee [Mobicom'18] LEGO-Fi [Infocom'19] XFi [ICNP'20]	LongBee [Infocom'18] TwinBee [Infocom'18] Chiron [Mobisys'15] PIC [Sensys'19] Symphony [ICNP'19]

Link quality estimation of CTC

- The quality of CTC link concern:
  - Link selection, transmission strategy and routing structure.

- A cornerstone of hybrid networking:
  - Allocation of link resource
  - Network QoS
  - Network structure optimization

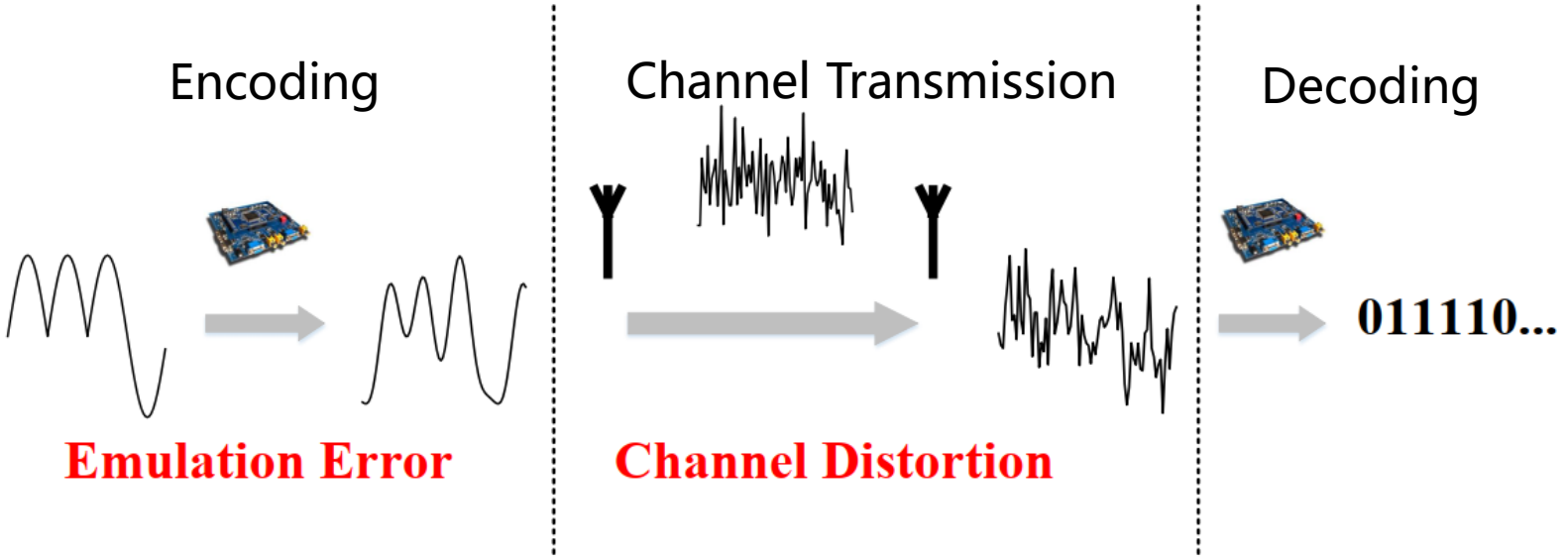
- Link quality estimation is a building block!

Metrics of link quality estimation

- Raw physical-level indicator
  - RSSI，SNR…
- Metrics derived from physical-level measurement
  - LQI，CSI…
- Packet-level indicators
  - PRR，ETX…

Mismatch of metrics and the CTC link

- CTC link is jointly affected by two factors:
  - **The emulation error** and **the channel distortion**



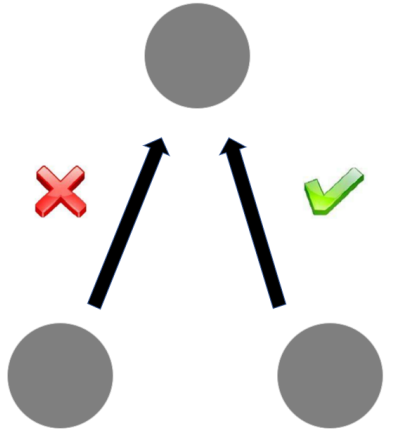
The process of CTC

Mismatch of metrics and the CTC link

- CTC link is jointly affected by two factors:
  - **The emulation error** and **the channel distortion**
- Raw physical-level indicator & Metrics derived from physical-level measurement
  - Both of them can not characterize the process of CTC
- Packet-level indicators
  - Overlook the differences at the lower layers of the protocol stack

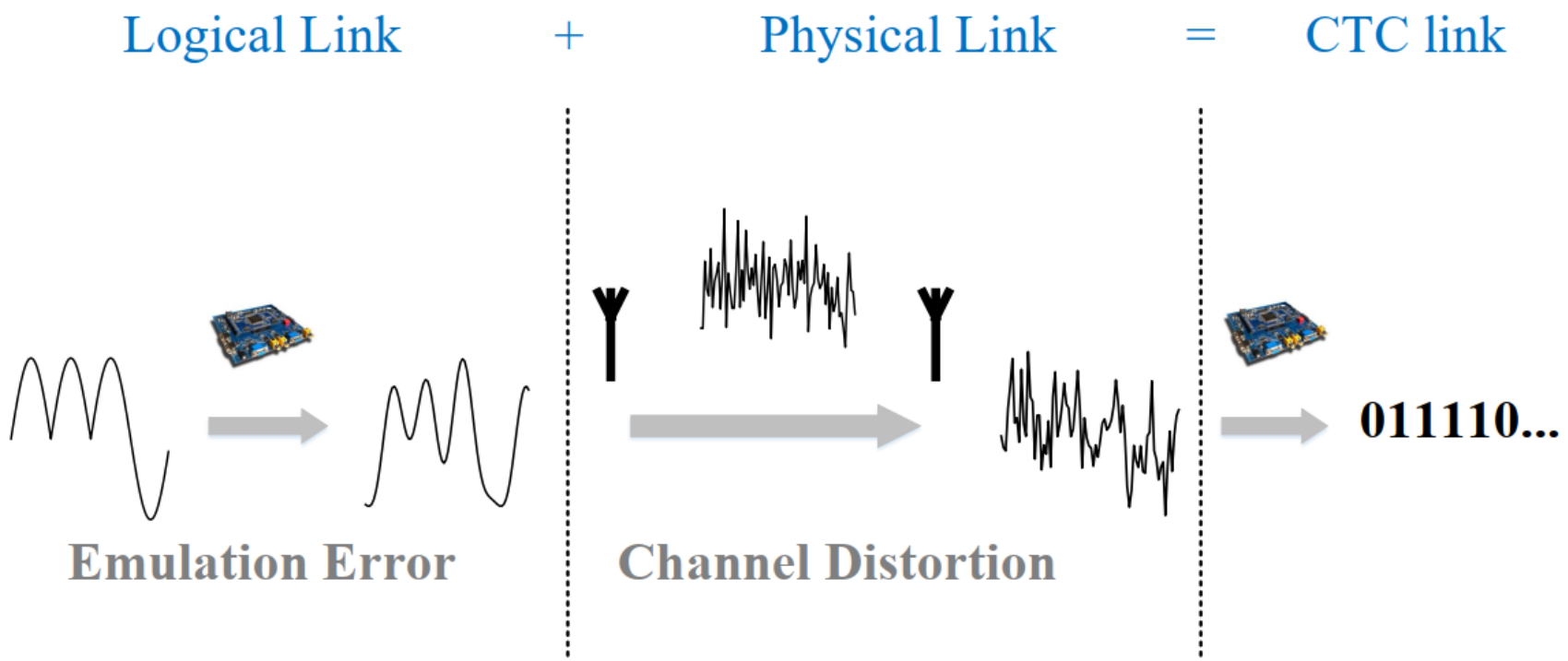
Design goals of the new metric

- Can fully characterize CTC link characteristics
  - Consider both the emulation error and the channel distortion
- Easy to measure
- Easy to use on commercial devices



Understanding the CTC link

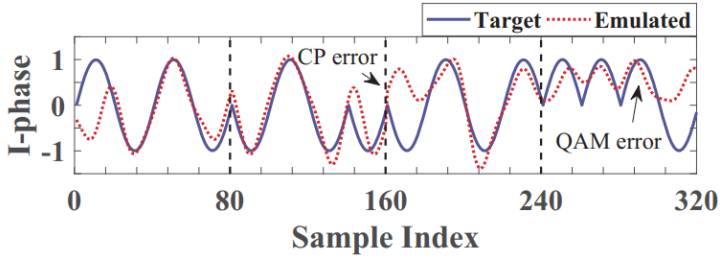
- The CTC link



The entire CTC link

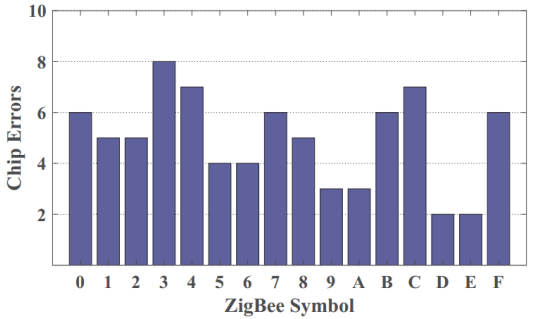
Two factors

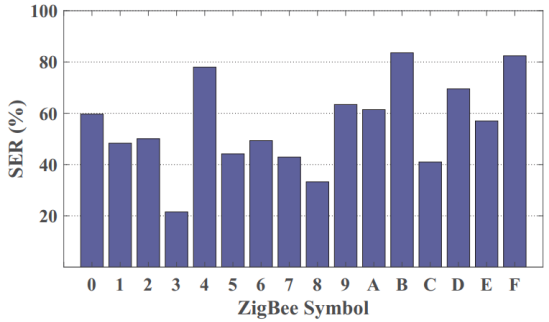
- Channel distortion is uncertain and affects the link performance



The emulated signal waveform

- Emulation error is certain and affects the link performance

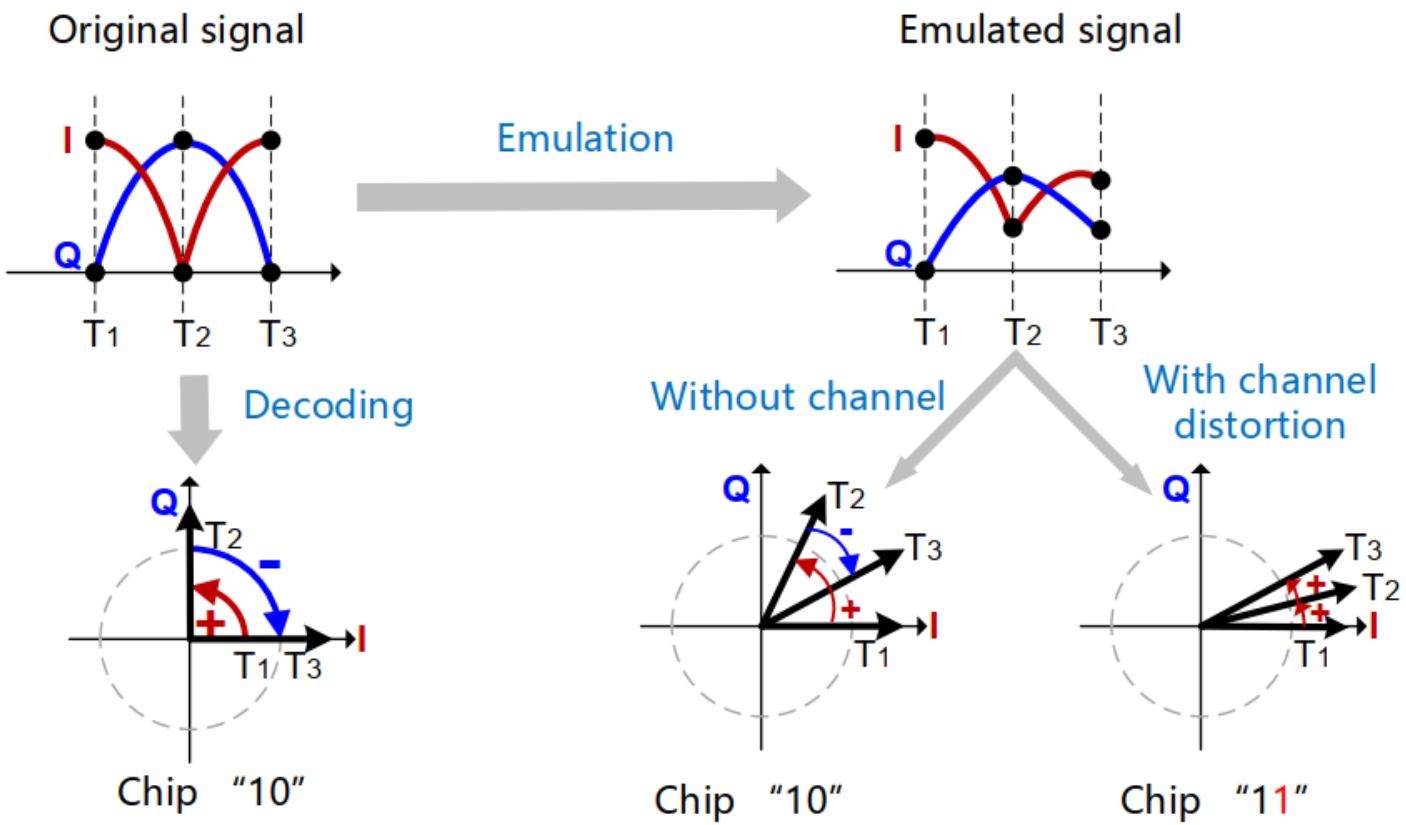




The chip error and the SER of each symbol

Link model

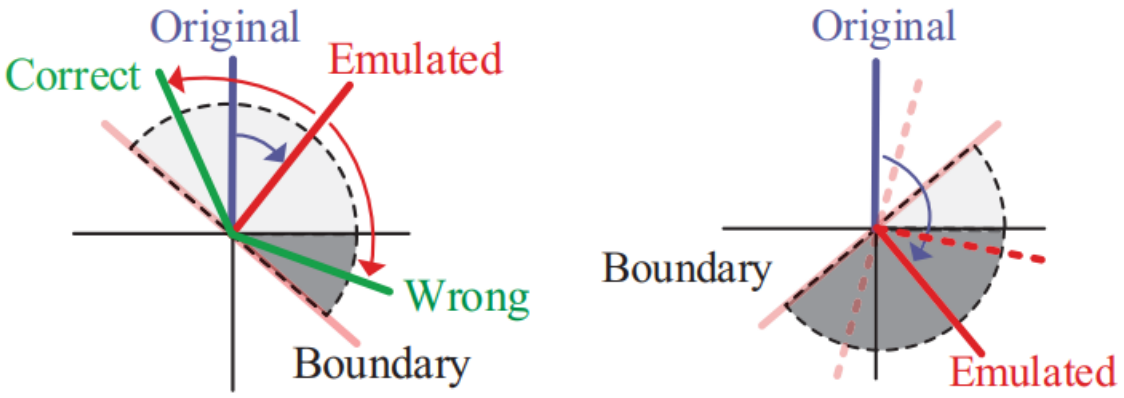
- Decoding error



The appearance of decoding error

Link model

- Variation of phase shifts
  - Phase changes on the sampling points: a random variation within the range of $[-x,\ x]$
  - Emulation phase shifts can be obtained in advance



The phase shift change model

C-LQI

- C-LQI is defined as **the expected probability for a symbol to be correctly decoded by the receiver of a CTC link**

$$C - LQI = \frac{the\ same\ symbols\ correcty\ decoded}{all\ the\ same\ symbols}$$

✔ Can fully characterize CTC link characteristics

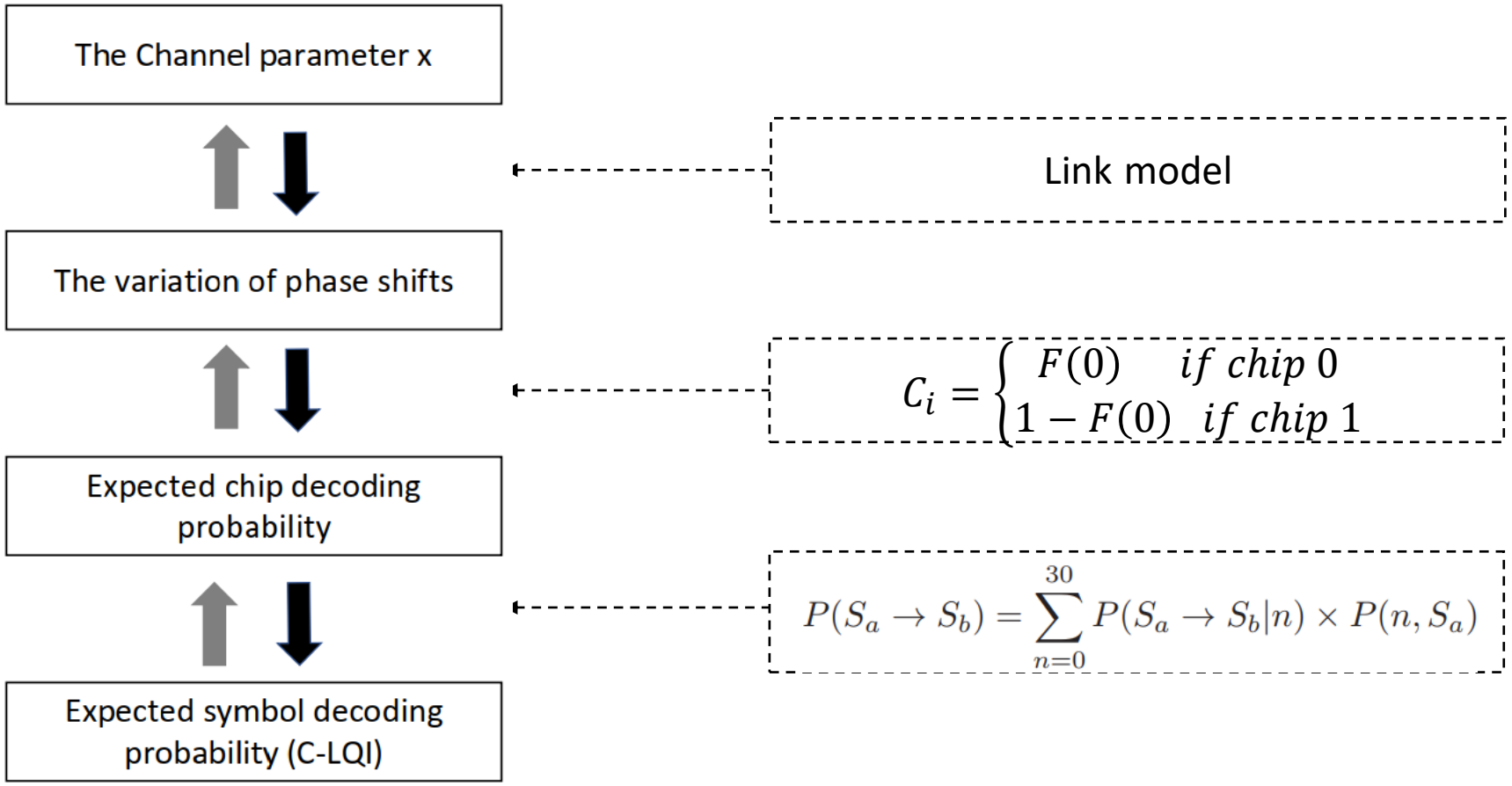
✔ Easy to measure

✔ Light-weight

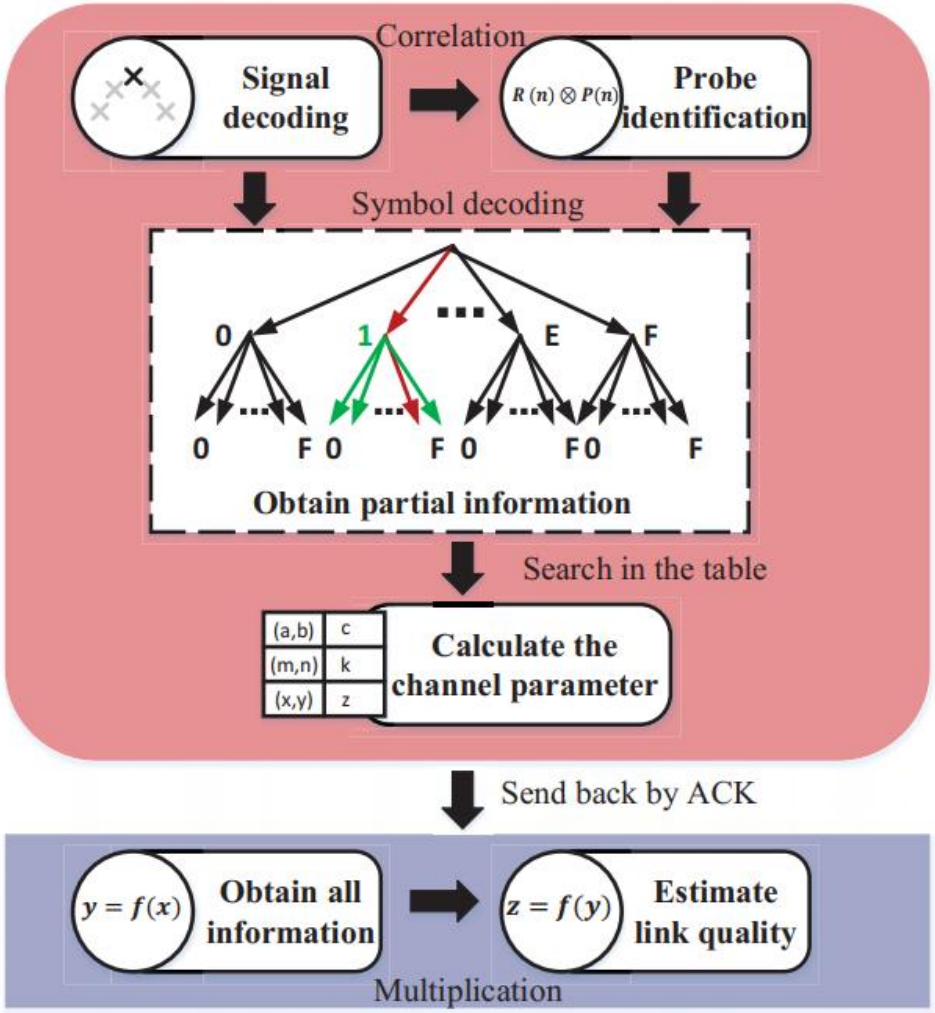
Calculation of C-LQI

- The calculation process

$$C - LQI = \frac{the\ same\ symbols\ correcty\ decoded}{all\ the\ same\ symbols}$$



The protocol design



$$C - LQI = \frac{the\ same\ symbols\ correcty\ decoded}{all\ the\ same\ symbols}$$

- How to design the probe frames
  - Choosing the two highest decoding probability symbols
- How to calculate the channel parameter
  - Utilizing a mapping table between the parameter and the decoding probability
- How to estimate the link quality
  - Calculating packet reception rate using C-LQI or making a judgment

Evaluation(selection)

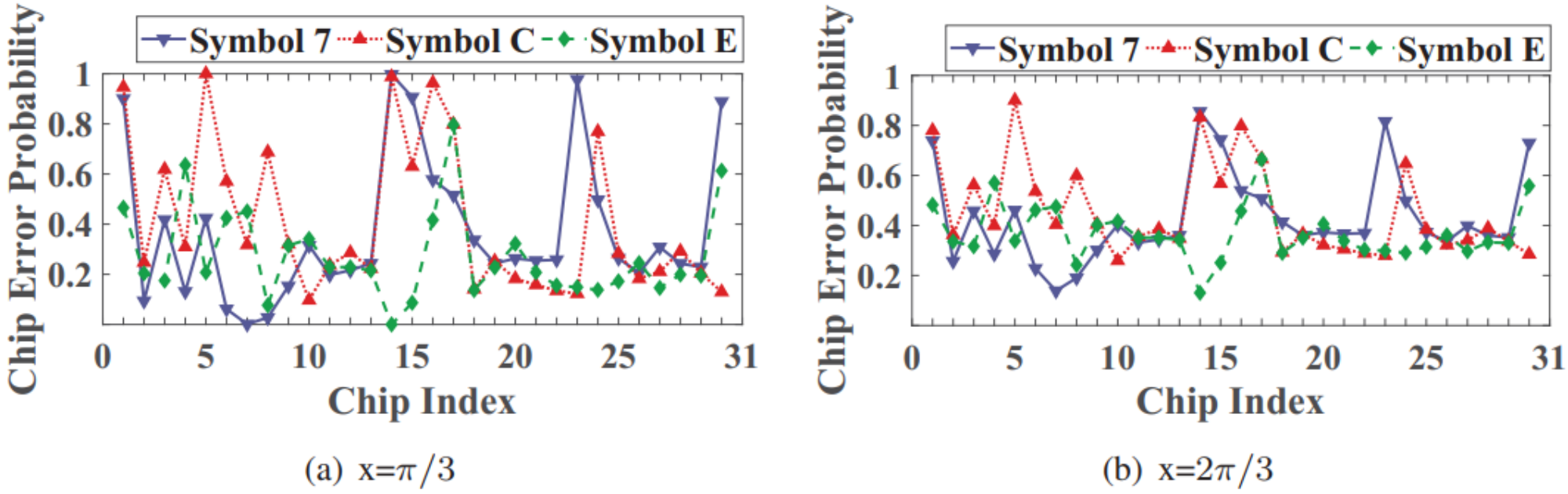
- WEBee-based implementation
  - Tx : 802.11a/g, 2440 MHz
  - Rx : 802.15.4, channel 19

- Performance metric: Relative errors

- Compare with s-PRR(the previous PRR in a short period) and EWMA(Exponentially Weighted Moving-Average)
  - Probe num : 100
  - The previous weight of EWMA : 0.2

Evaluation

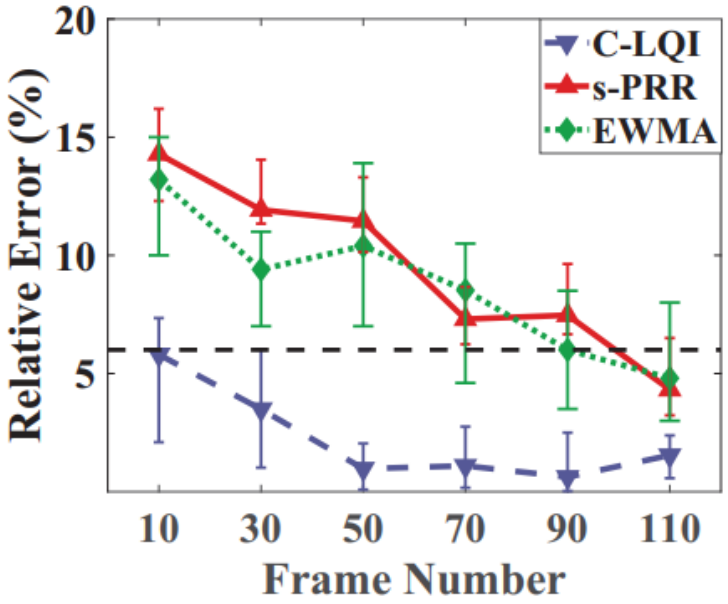
- Chip error probability

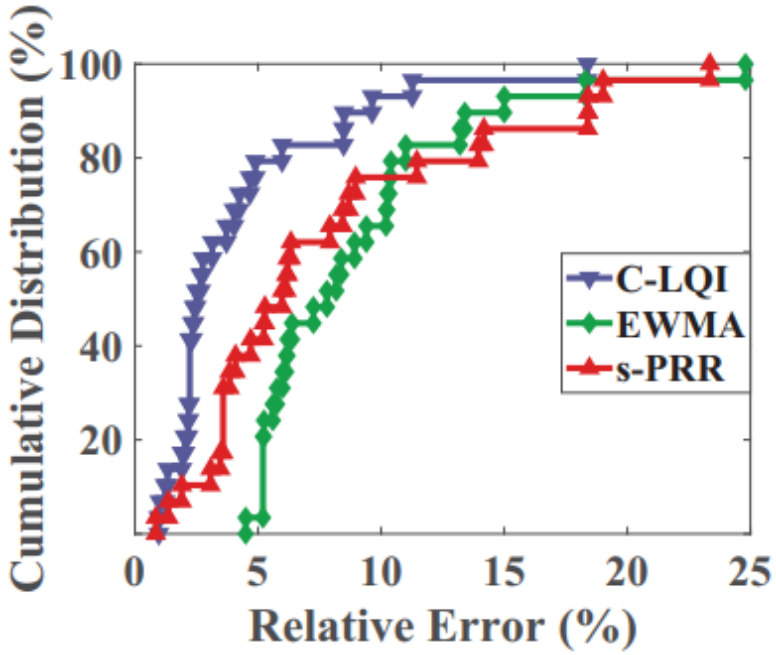


Different channels or different symbols have different chip error probabilities

Evaluation

- Overall performance comparison

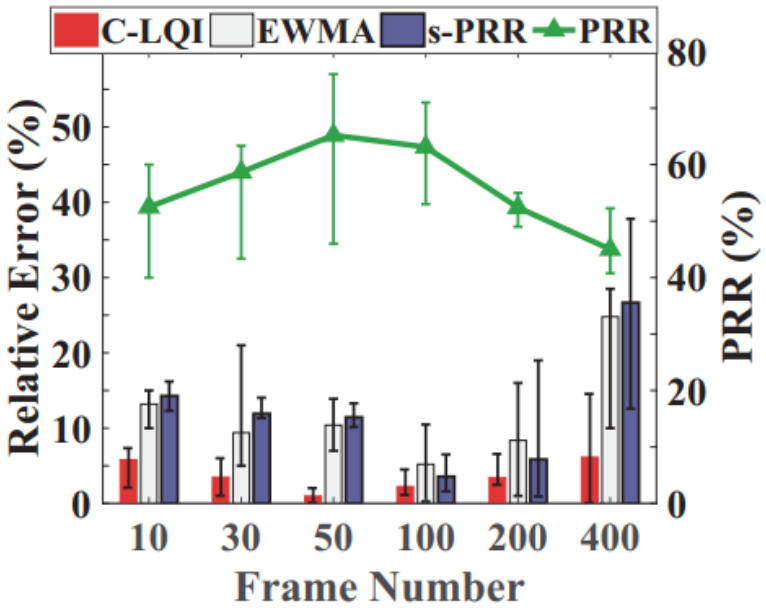


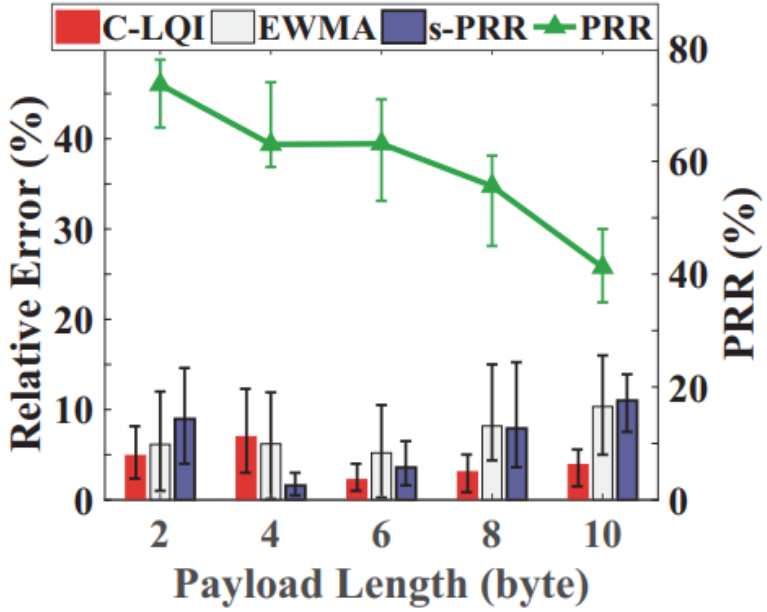


C-LQI is more accurate than others as it has more decoding information

Evaluation

- Frame number & Payload length

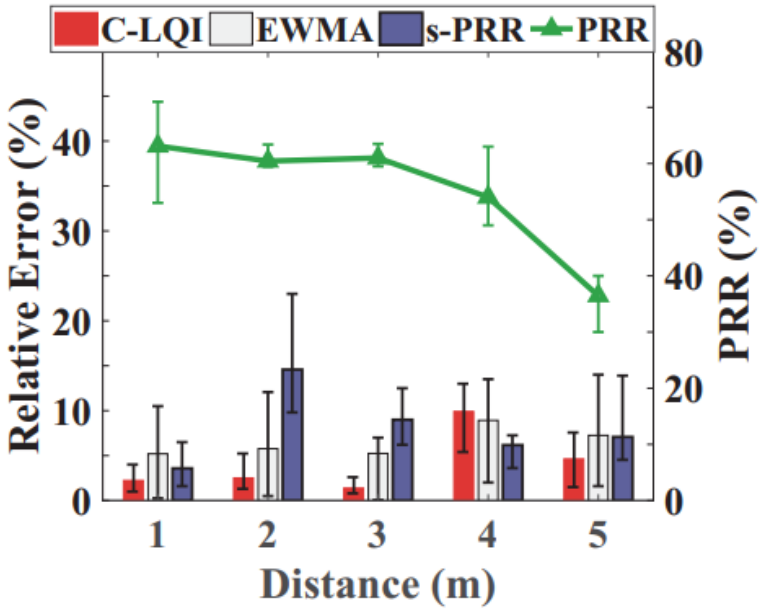


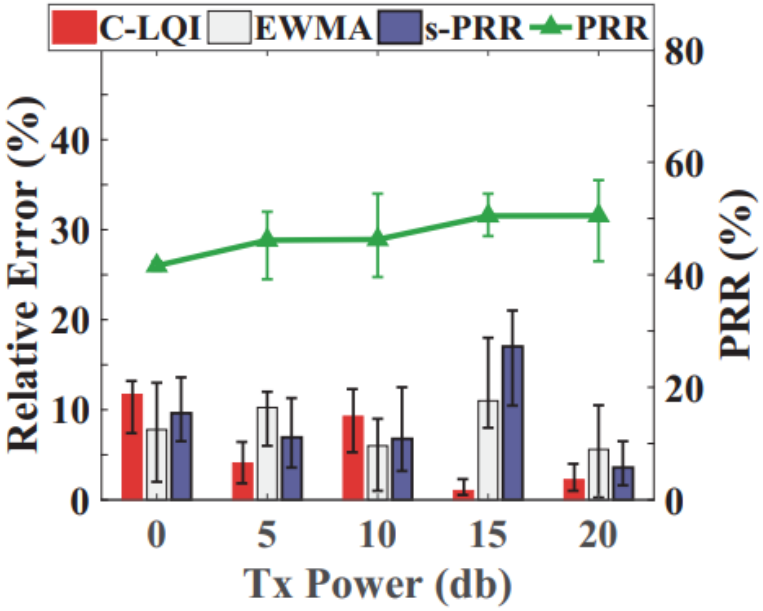


Appropriate parameters make C-LQI perform better

Evaluation

- Distance & Tx Power

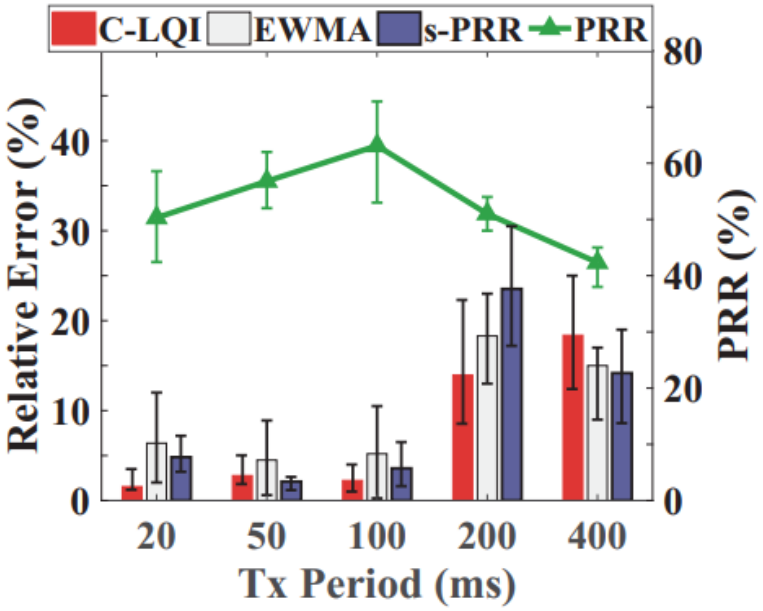


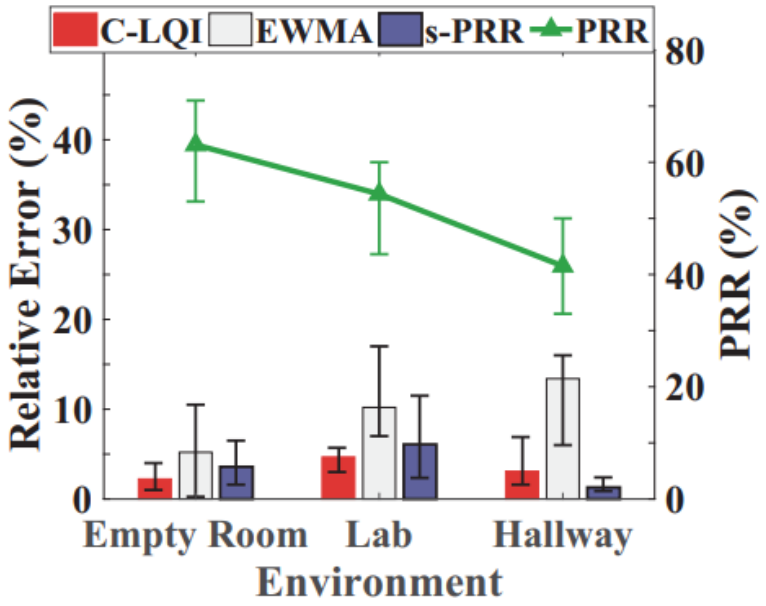


Higher received signal strength makes C-LQI perform better

Evaluation

- Tx Period & Environment





Appropriate parameters make C-LQI perform better

Conclusion & future work

- We propose C-LQI, the first metric of the CTC link quality, which takes both the emulation error and the channel distortion into account.

- Future work
  - Hybrid network building
  - Scheduling
  - Concurrent transmission
  - Link allocation
  - …

Shared resources

- Our resource sharing URL :

http://tns.thss.tsinghua.edu.cn/sun

Q&A

Thanks

j-zhang19@mails.tsinghua.edu.cn

http://tns.thss.tsinghua.edu.cn/sun