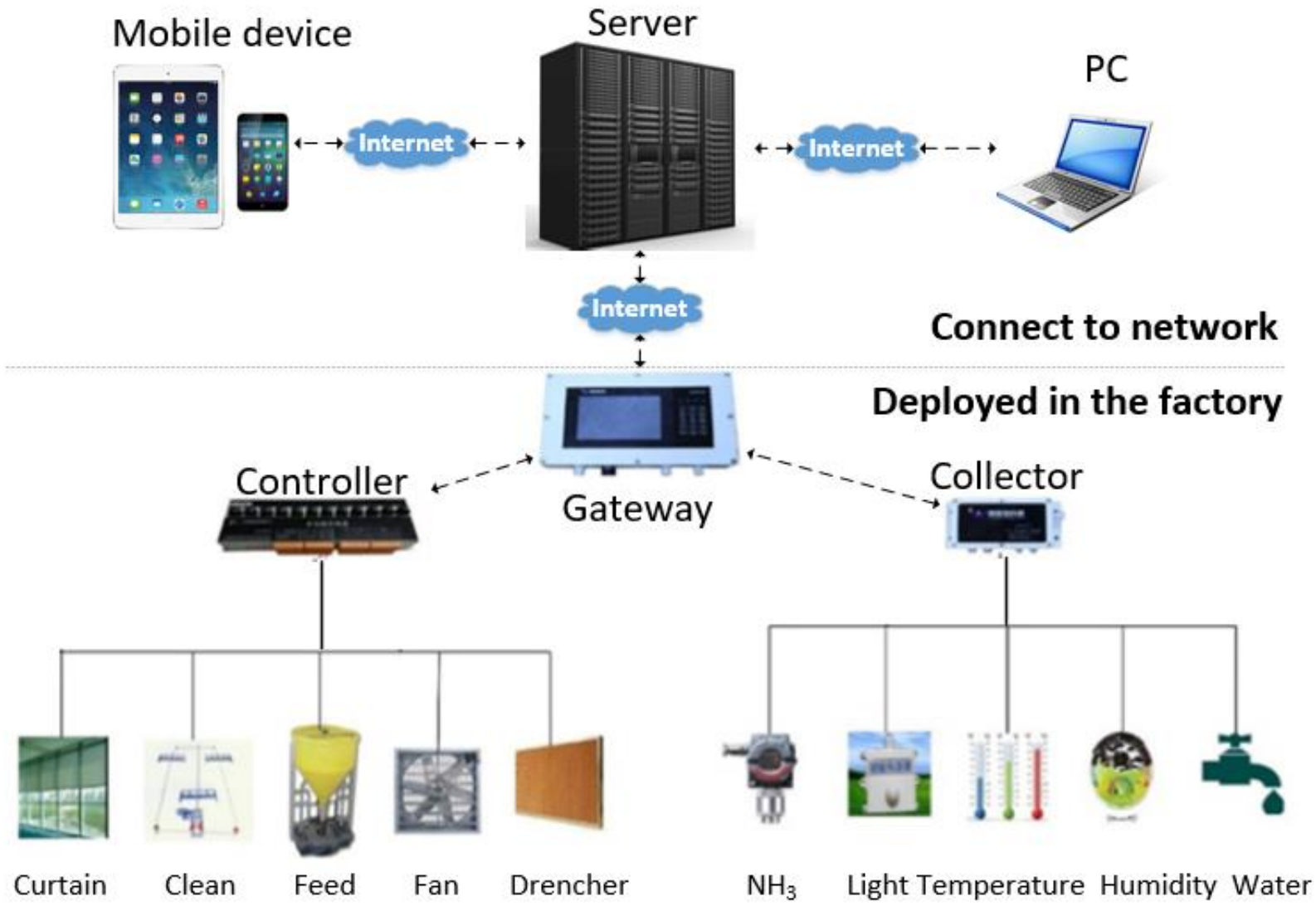
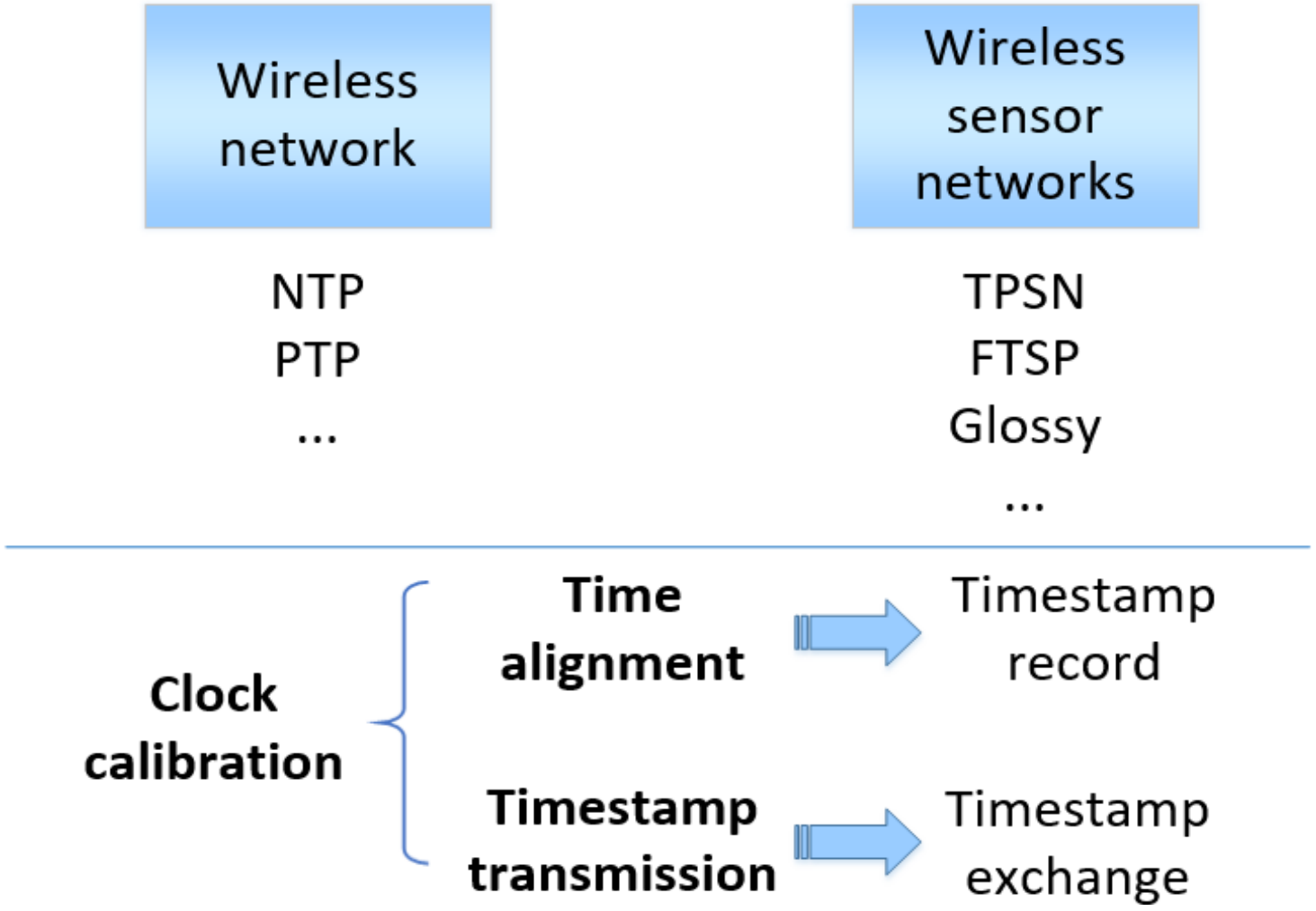
Crocs:
Cross-Technology Clock Synchronization for WiFi and ZigBee

Zihao Yu, Chengkun Jiang, Yuan He,
Xiaolong Zheng, Xiuzhen Guo
Tsinghua University

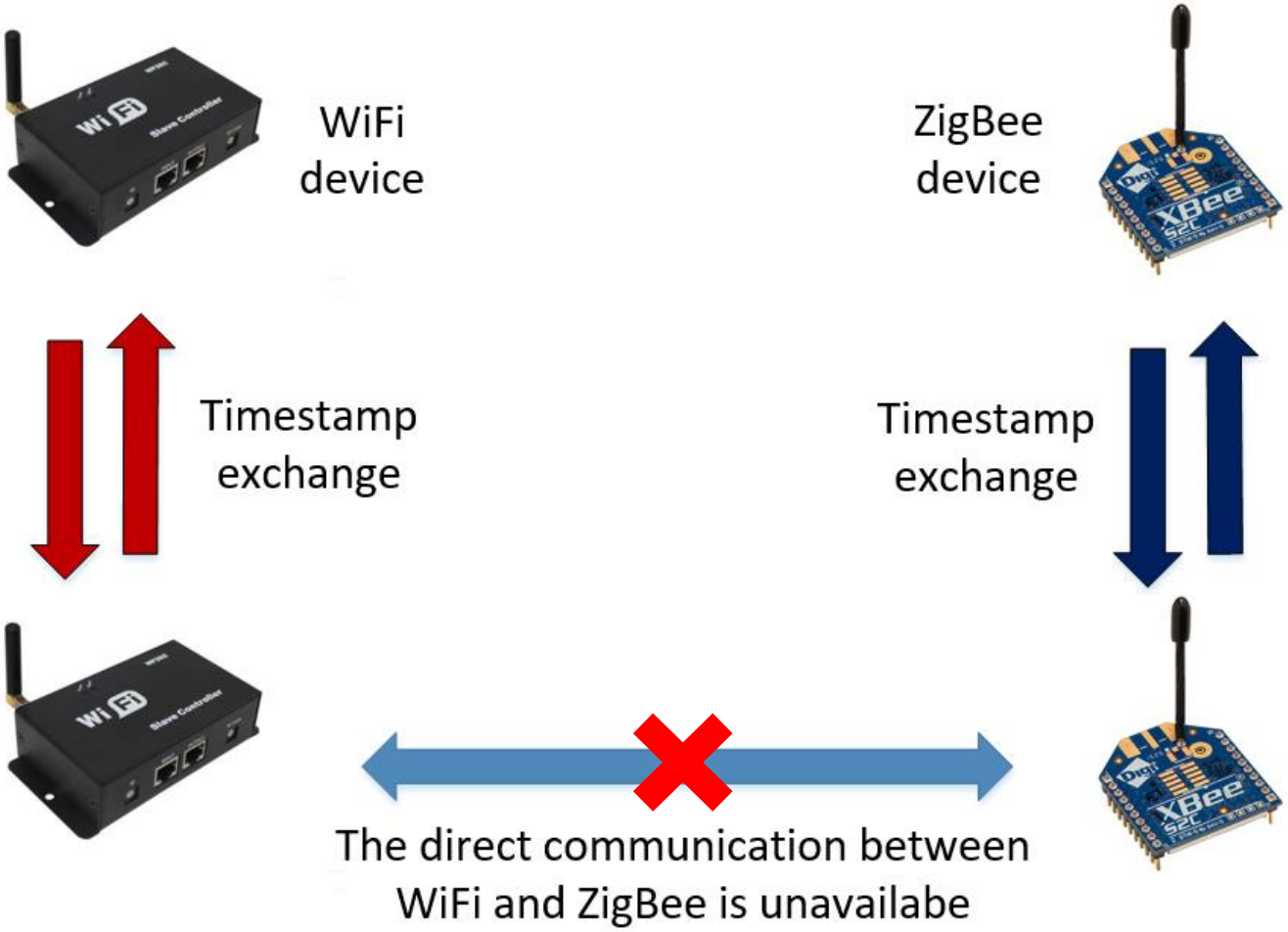
A scenario of Industrial IoT



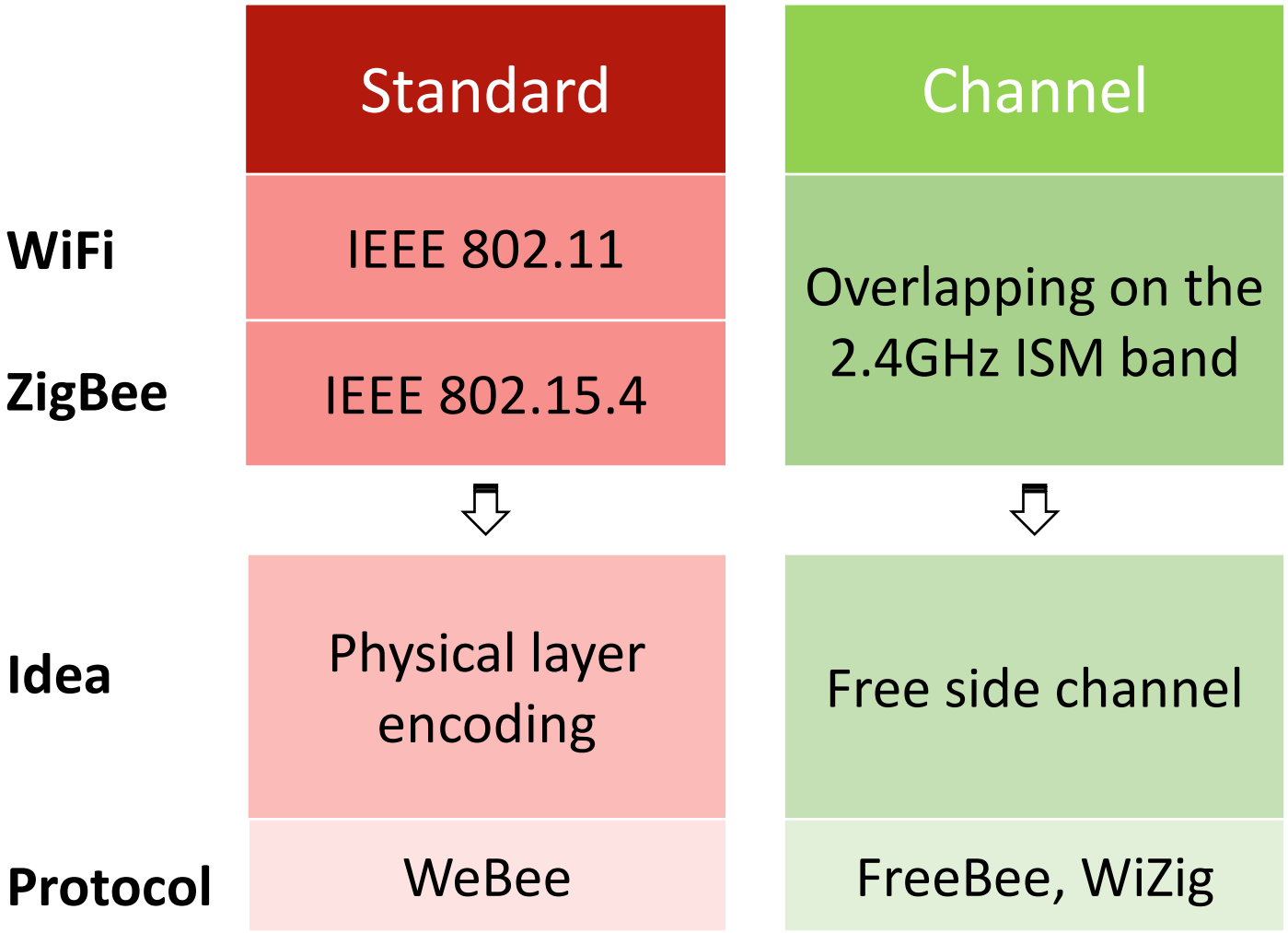
Clock synchronization in different networks



Clock synchronization between heterogeneous devices

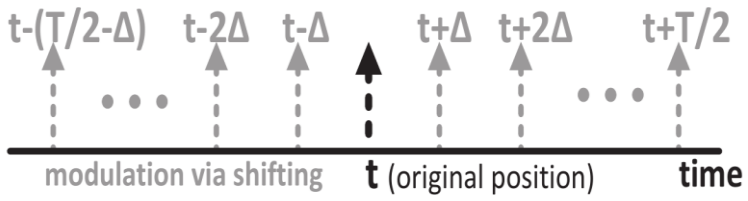


Cross-technology communication

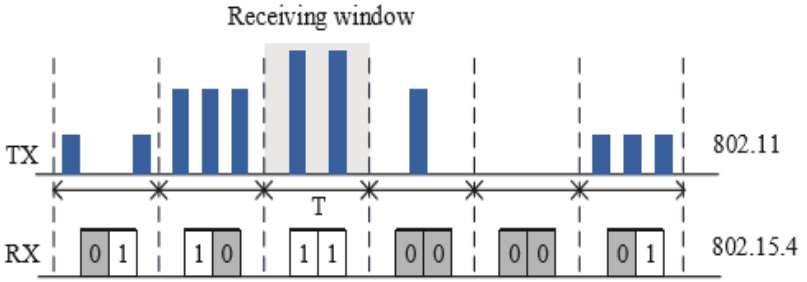


Cross-technology communication

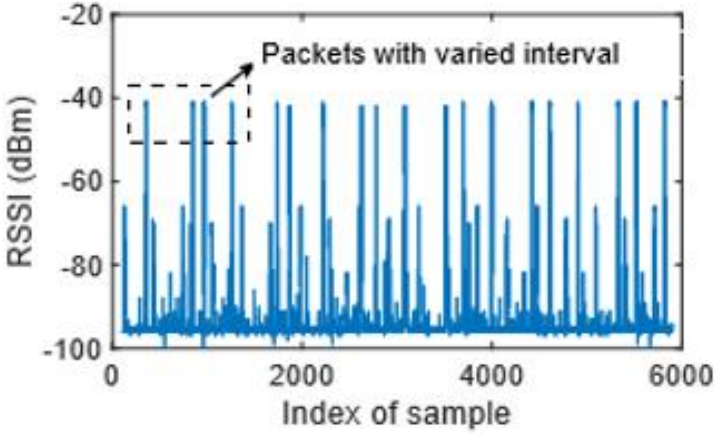
Time modulation (FreeBee)

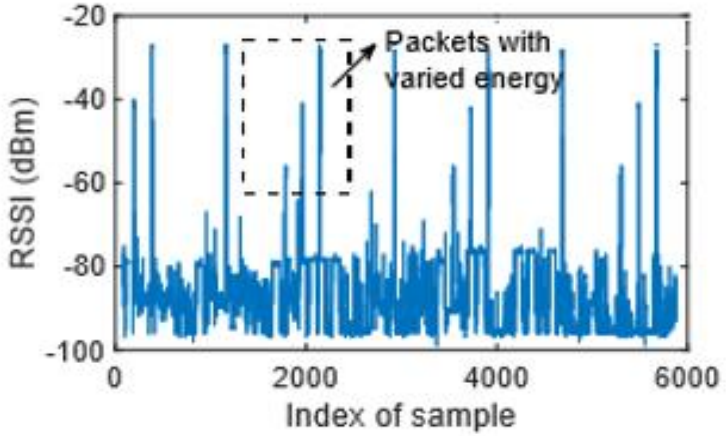


Energy modulation(Wizig)



The timing of packets | Side channel | The energy of packets





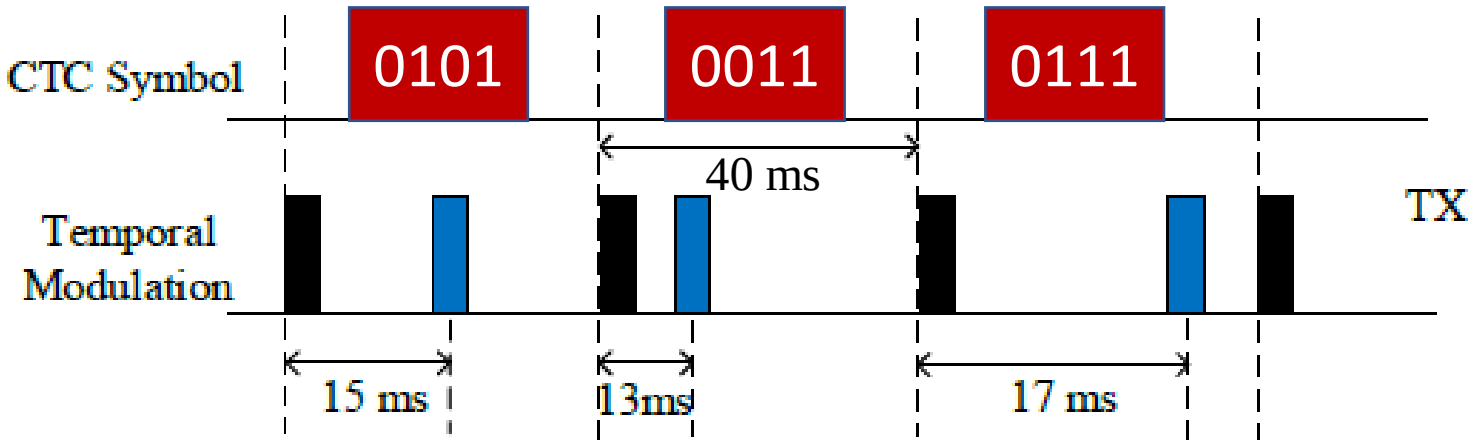
Timestamp transmission

Timestamp: XXXX…0101 0011 0111 1011

Divided by group of bits

X X … 0101 0011 0111 1011

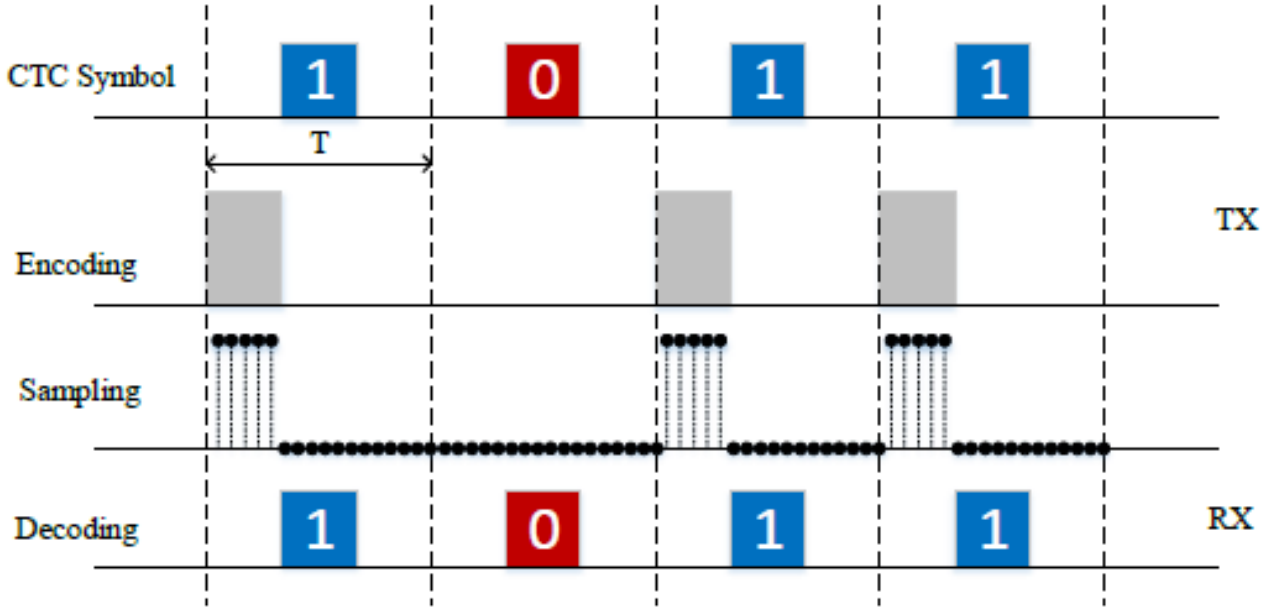
Encode the digits sequentially



Timestamp transmission

The example of energy modulation

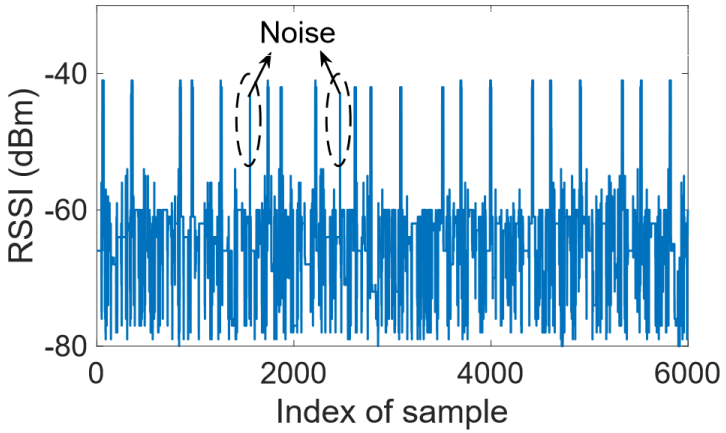
1011



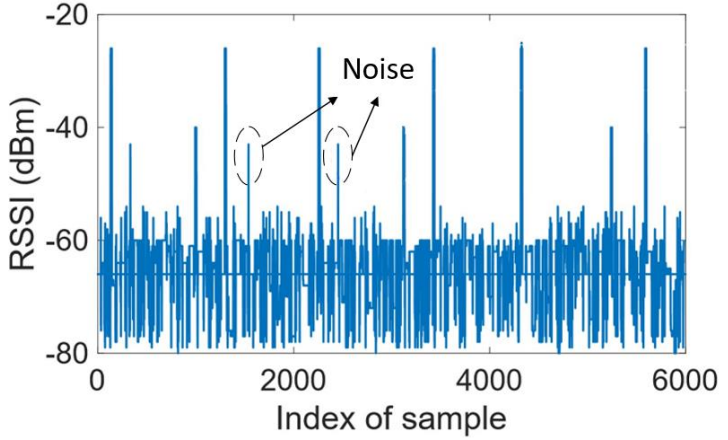
‘1’: packet presence ‘0’: packet absence

Observation of cross-technology communication

- Low throughput
- Limited robustness



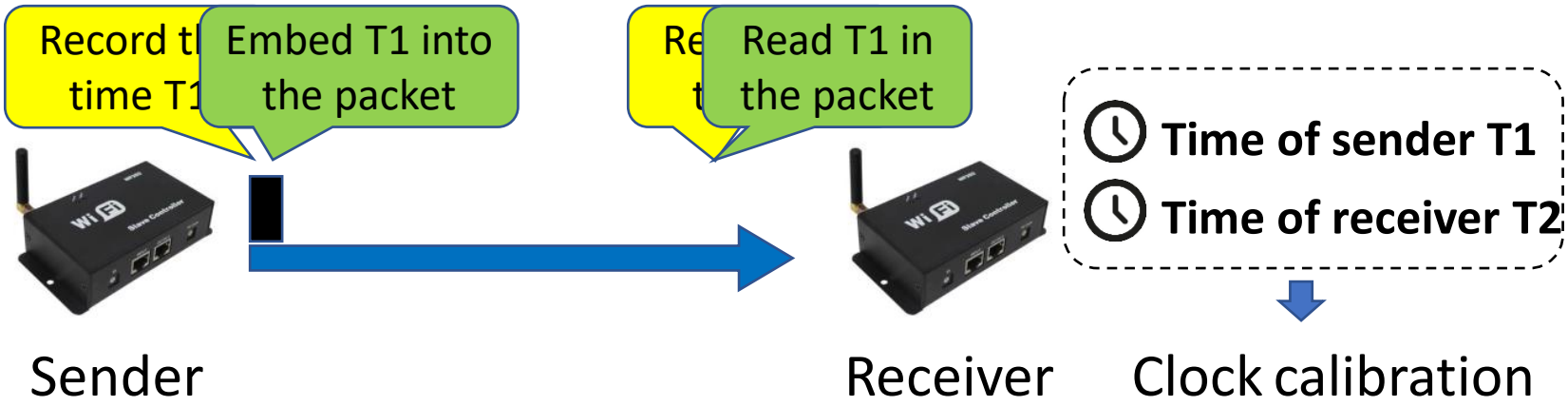
Three packets with a fixed time interval pattern

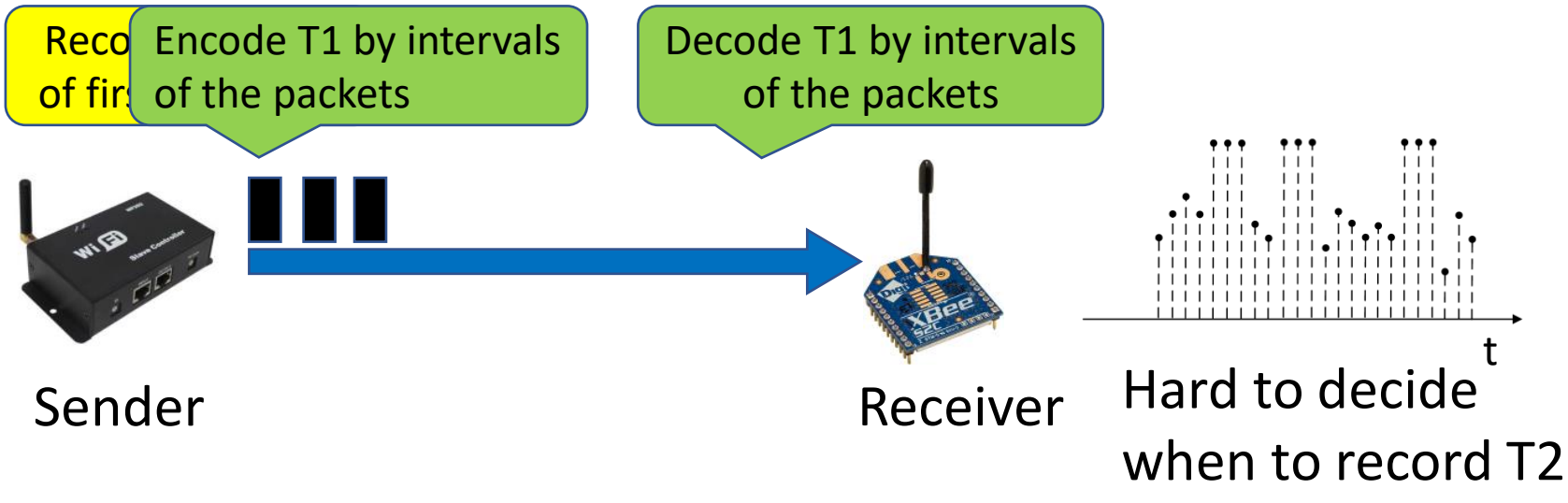


Three packets with a fixed energy pattern

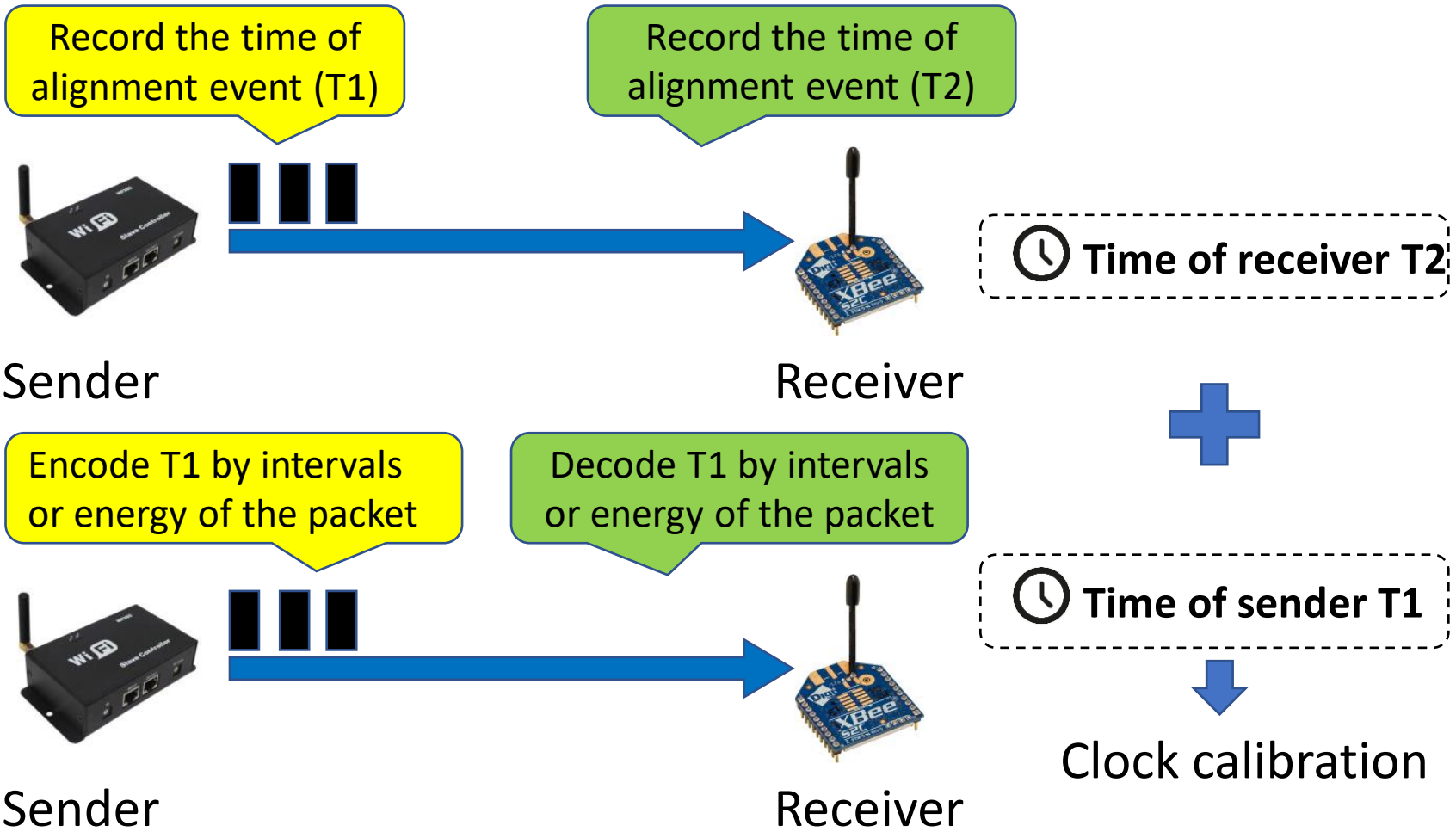
The simple pattern of packets may be destroyed by noise

Time alignment





Decoupled synchronization



Crocs beacon

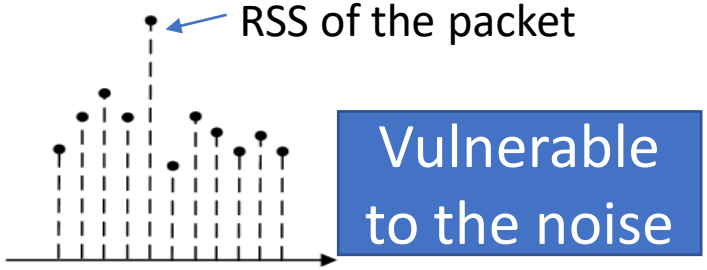
Record the time of alignment event (T1)

Record the time of alignment event (T2)

Sender

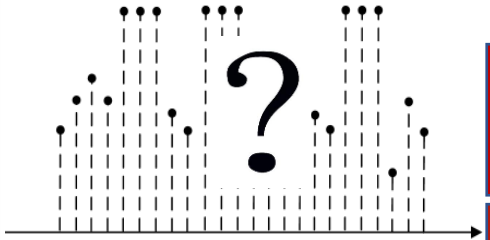
Crocs beacon: A special sequence of packets

Receiver



Vulnerable to the noise

RSS sample of only one packet



Unique to distinguish

Robust to noise

RSS sample of Crocs beacon

Barker code

A finite sequence of N values of +1 and -1: a_j for $j = 1, 2, \ldots, N$

Property:

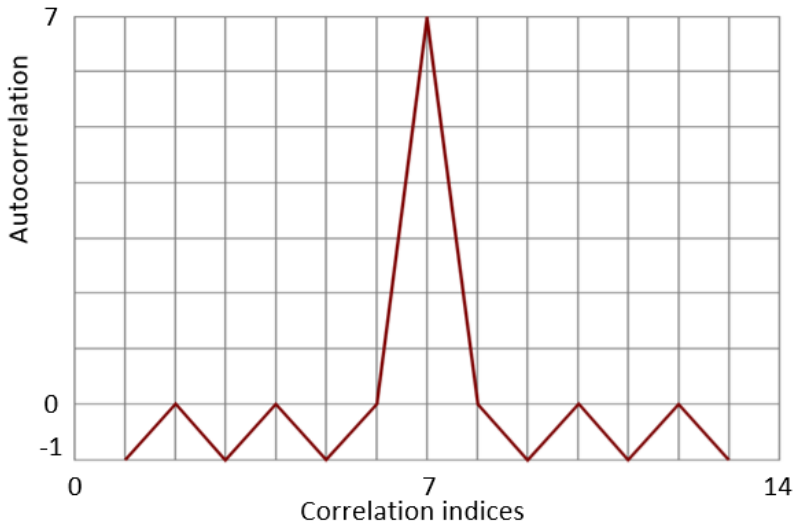
$$c_v = \sum_{j=1}^{N-v} a_j a_{j+v}$$

$$|c_v| \leq 1$$

for all $1 \leq v < N$.

No of panels	Barker Code	
2	+1 −1	+1 +1
3	+1 +1 −1	
4	+1 +1 −1 +1	+1 +1 +1 −1
5	+1 +1 +1 −1 +1	
7	+1 +1 +1 −1 −1 +1 −1	
11	+1 +1 +1 −1 −1 −1 +1 −1 −1 +1 −1	
13	+1 +1 +1 +1 +1 −1 −1 +1 +1 −1 +1 −1 +1	

Barker code with different length



Autocorrelation function of Barker-7 code

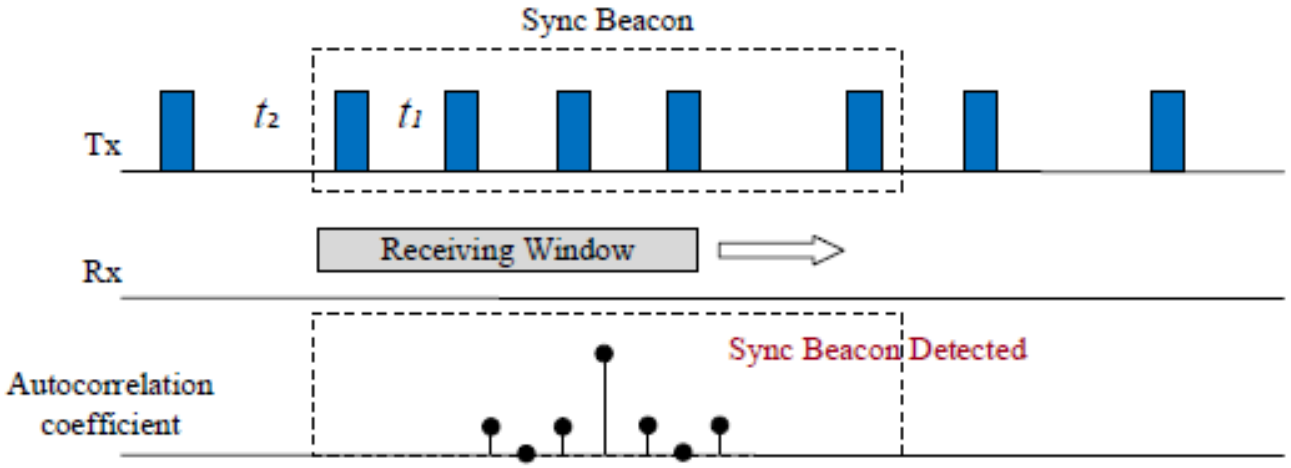
Time alignment design

How to encode the Barker code:

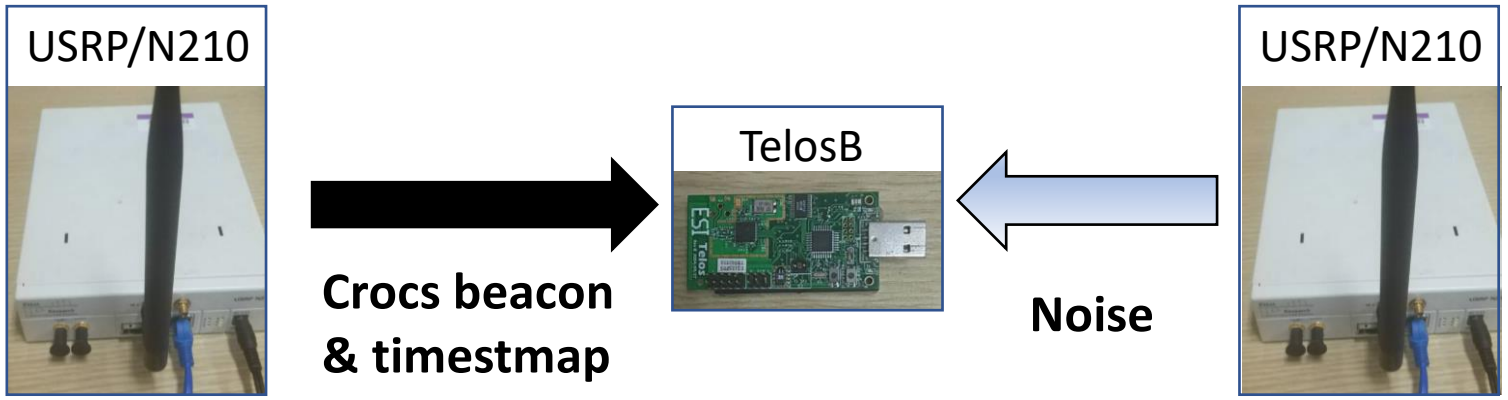
Energy ✗ Not robust to noise

Interval ✓ Use two unit intervals, t_1 and t_2 to create the Barker code

Realization:

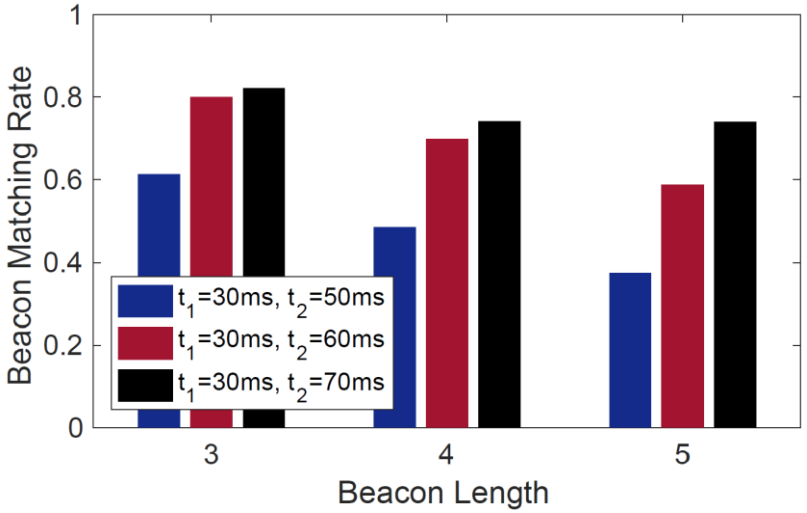


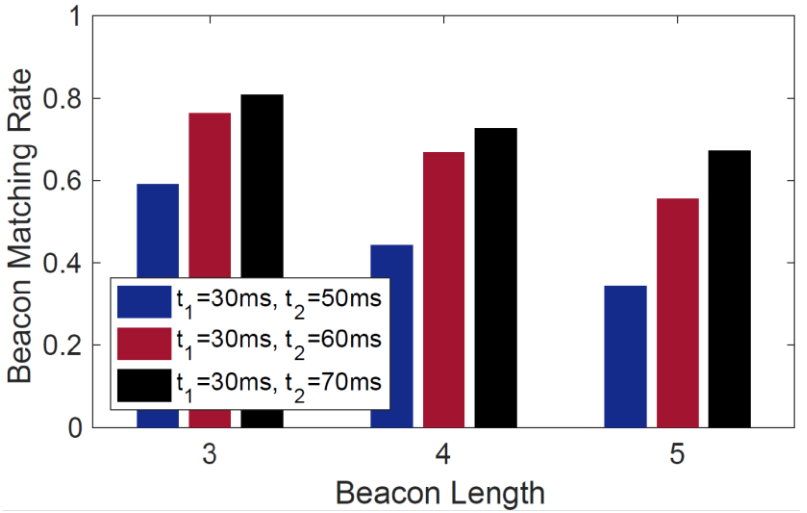
Evaluation



- One USRP acts as WiFi sender
- Another USRP generates noise
- TelosB mote is used as ZigBee device

Beacon matching rate

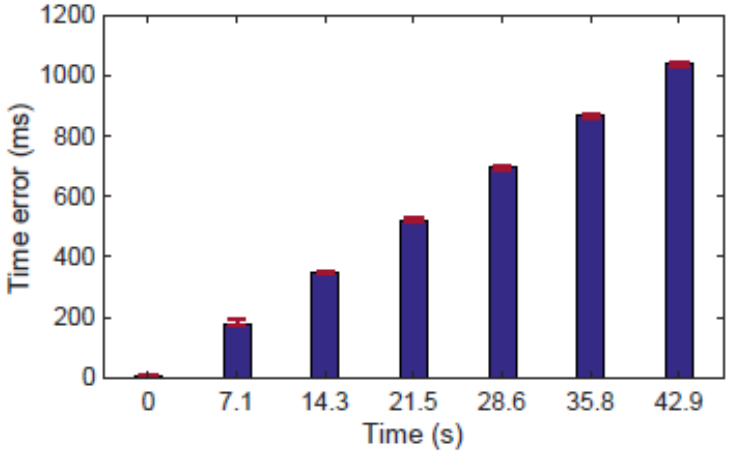




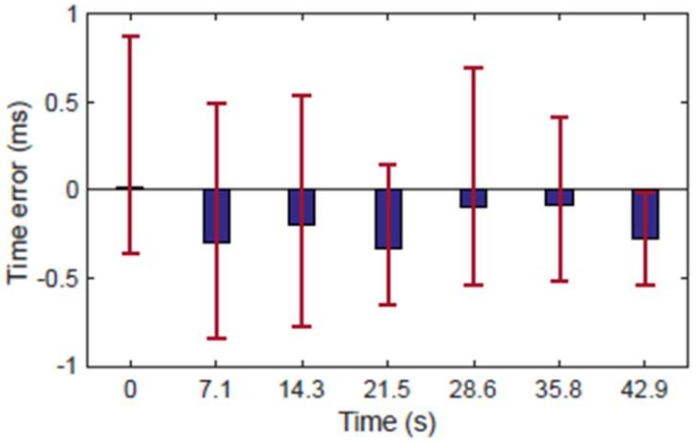
The beacon matching rate with relatively low noise

The beacon matching rate with relatively high noise

Time error



Time error without clock calibration



Time error with clock calibration

Summary

- We design Crocs, the first cross-technology clock synchronization protocol that works for WiFi and ZigBee.

- We design a Barker code based beacon to trigger the event of synchronization.