# Instantaneous Collision and Interference Detection for Reliable Wireless Communication

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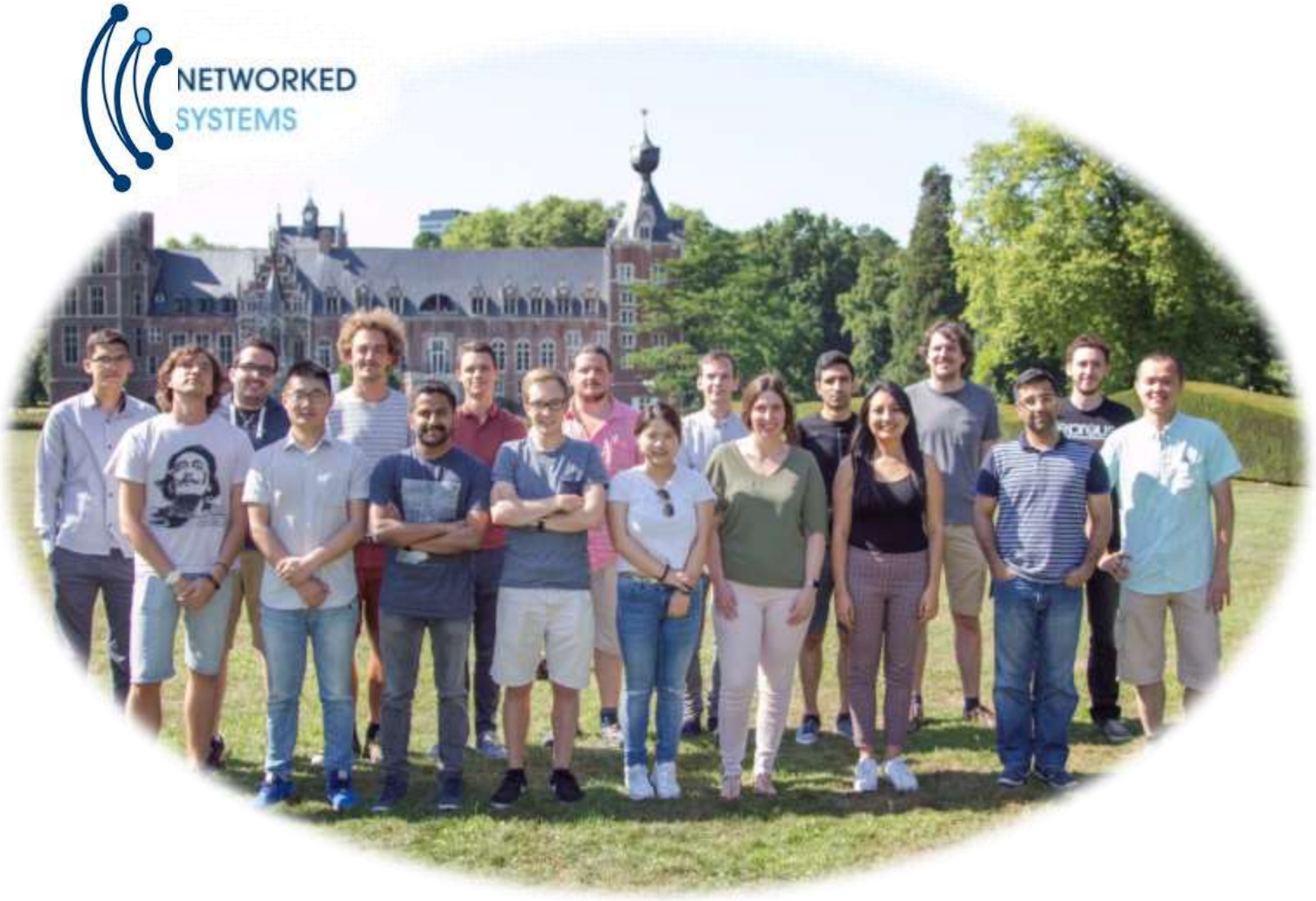
NETWORKED SYSTEMS

KU LEUVEN

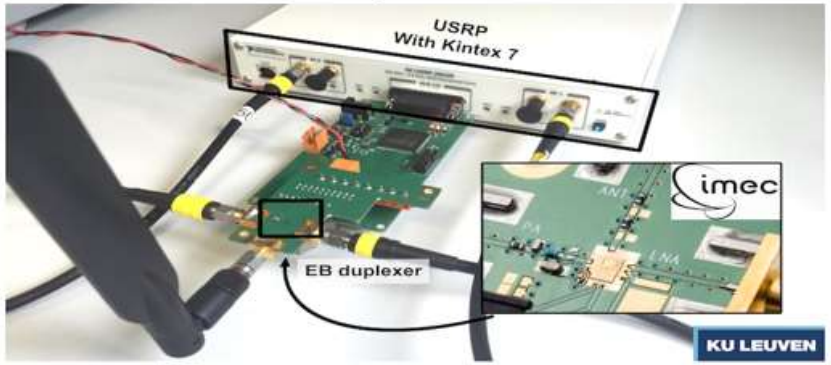
# KU Leuven Networked Systems Group




*https://www.esat.kuleuven.be/telemic/research/NetworkedSystems*

# KU Leuven Networked Systems Group

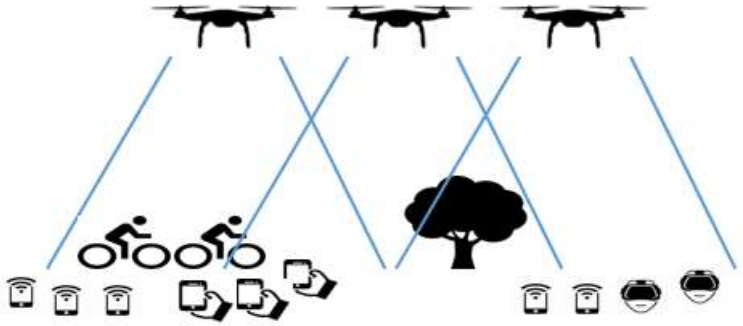
Full Duplex




Many SDR platforms

Massive MIMO

Aerial Cells

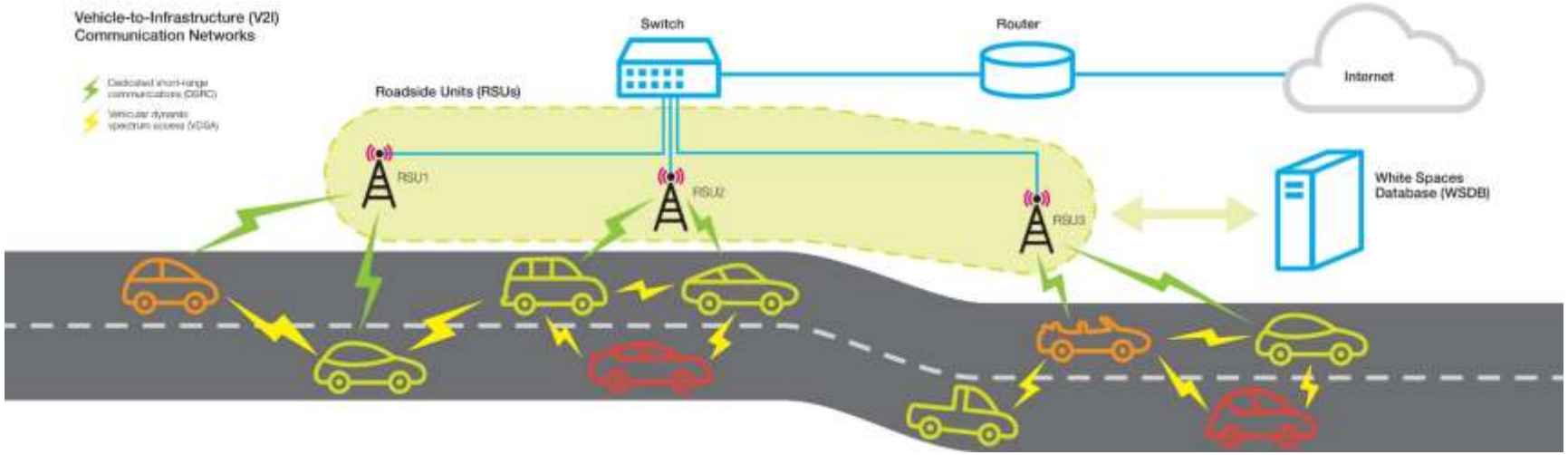


Indoor Distributed Antennas

IoT Nodes

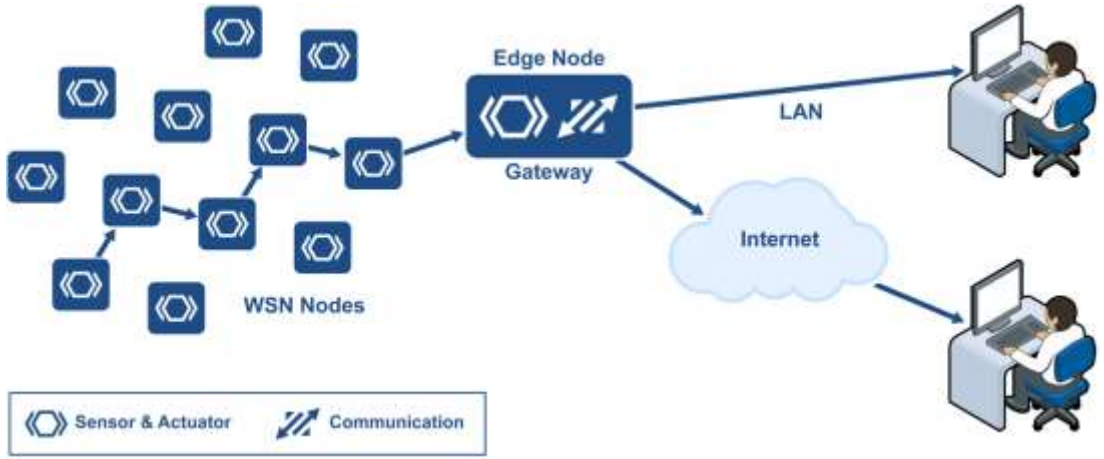
# Wireless networks, every where!

- Mobile Robots in factory, …
- Vehicular Networking for safer roads

# Wireless networks, every where!

- Wireless network of sensors, IEEE 802.15.4 (ZigBee)
- Swarm drones
- Thousands-robot swarm



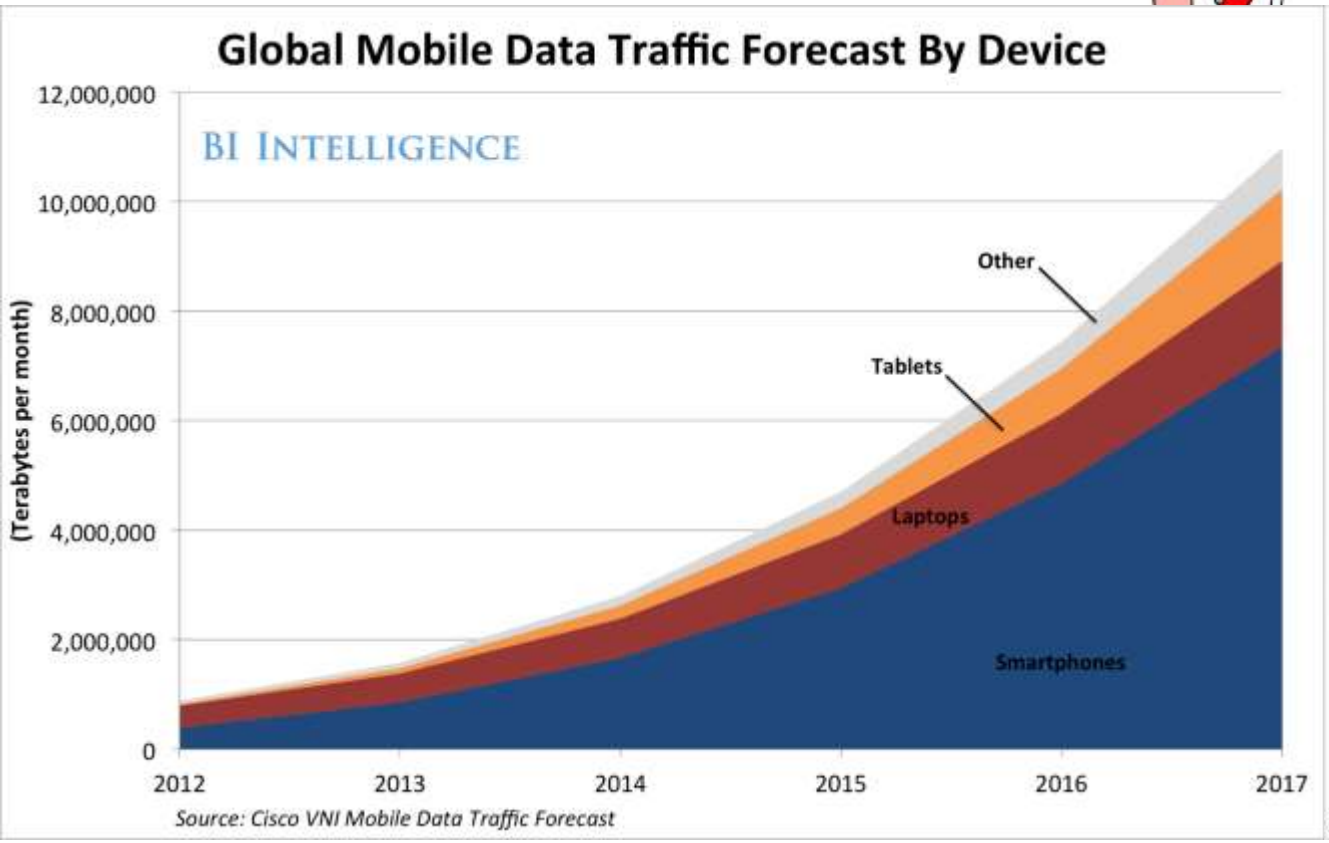

# Key requirements for wireless networking

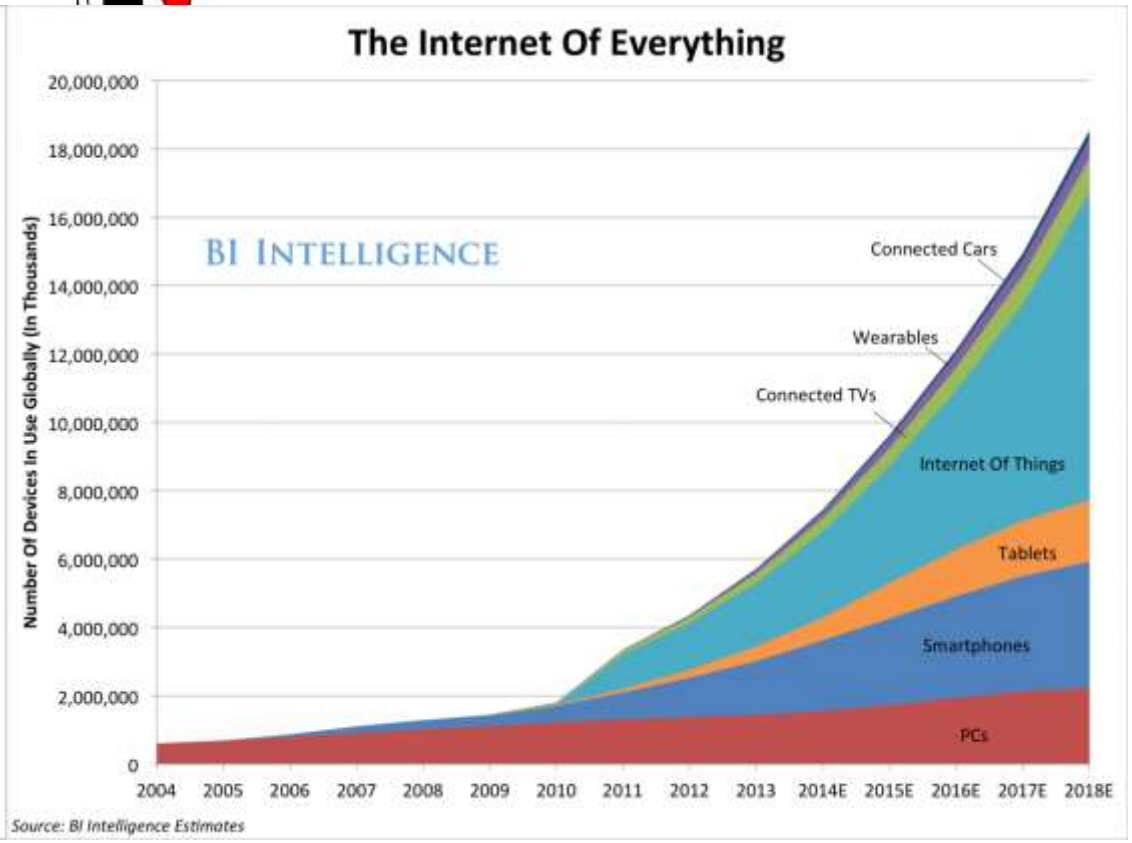
Energy efficiency


Throughput

Reliability

# Scarcity of Spectrum




*http://uk.businessinsider.com/the-internet-of-everything-2014-slide-deck-sai-2014-2?r=US&IR=T*

# High chance of collision

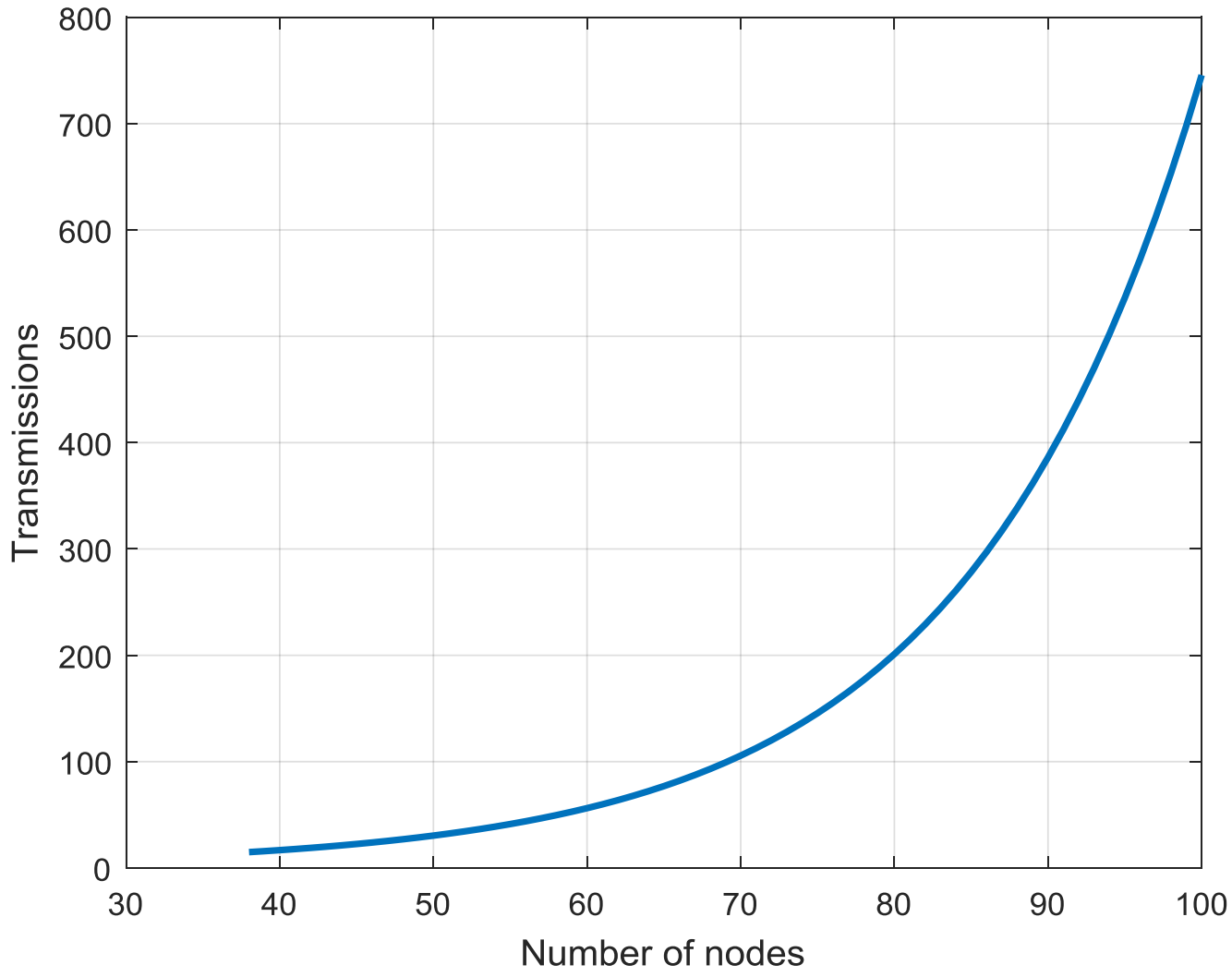
More nodes

↓

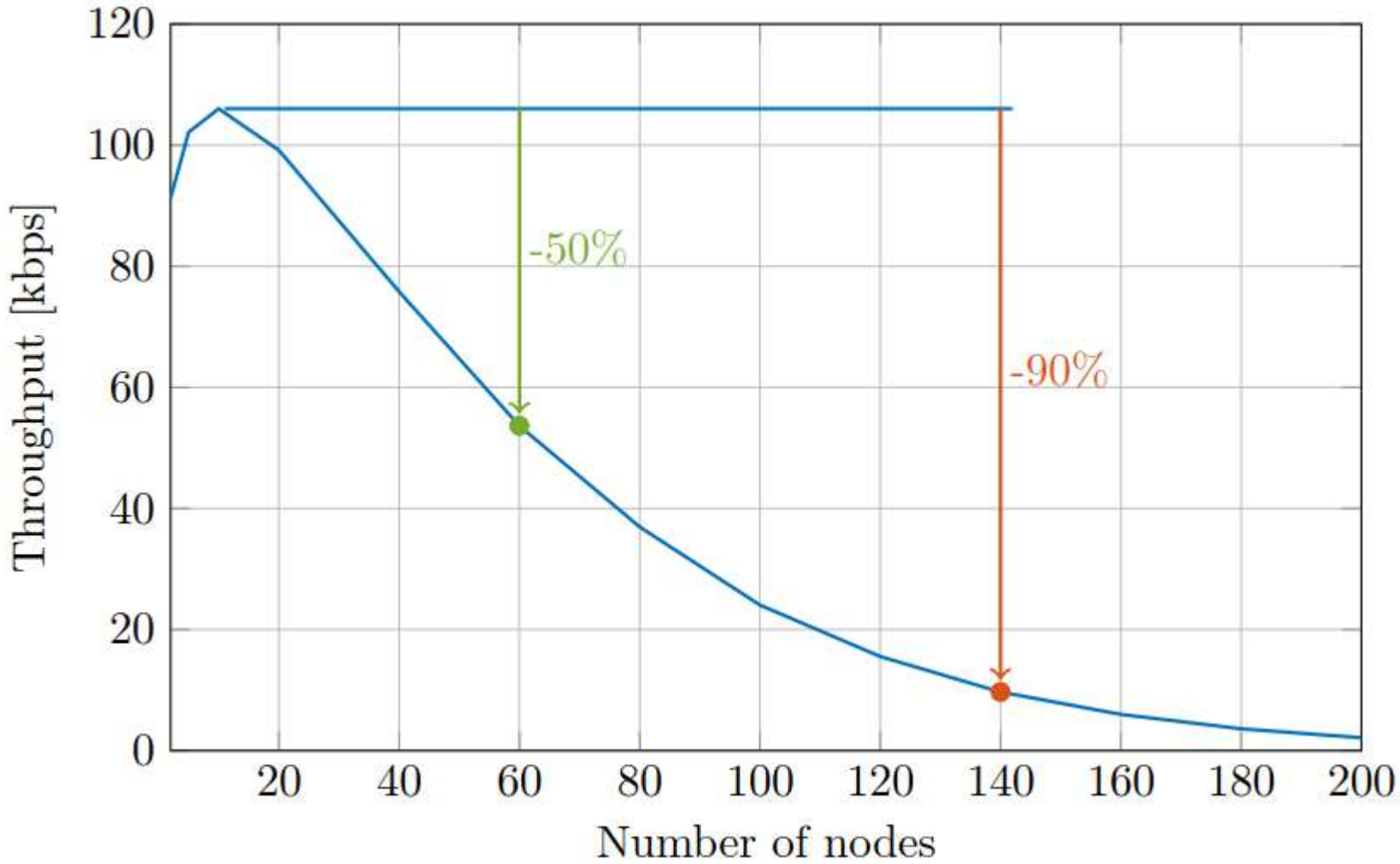
More transmissions

↓

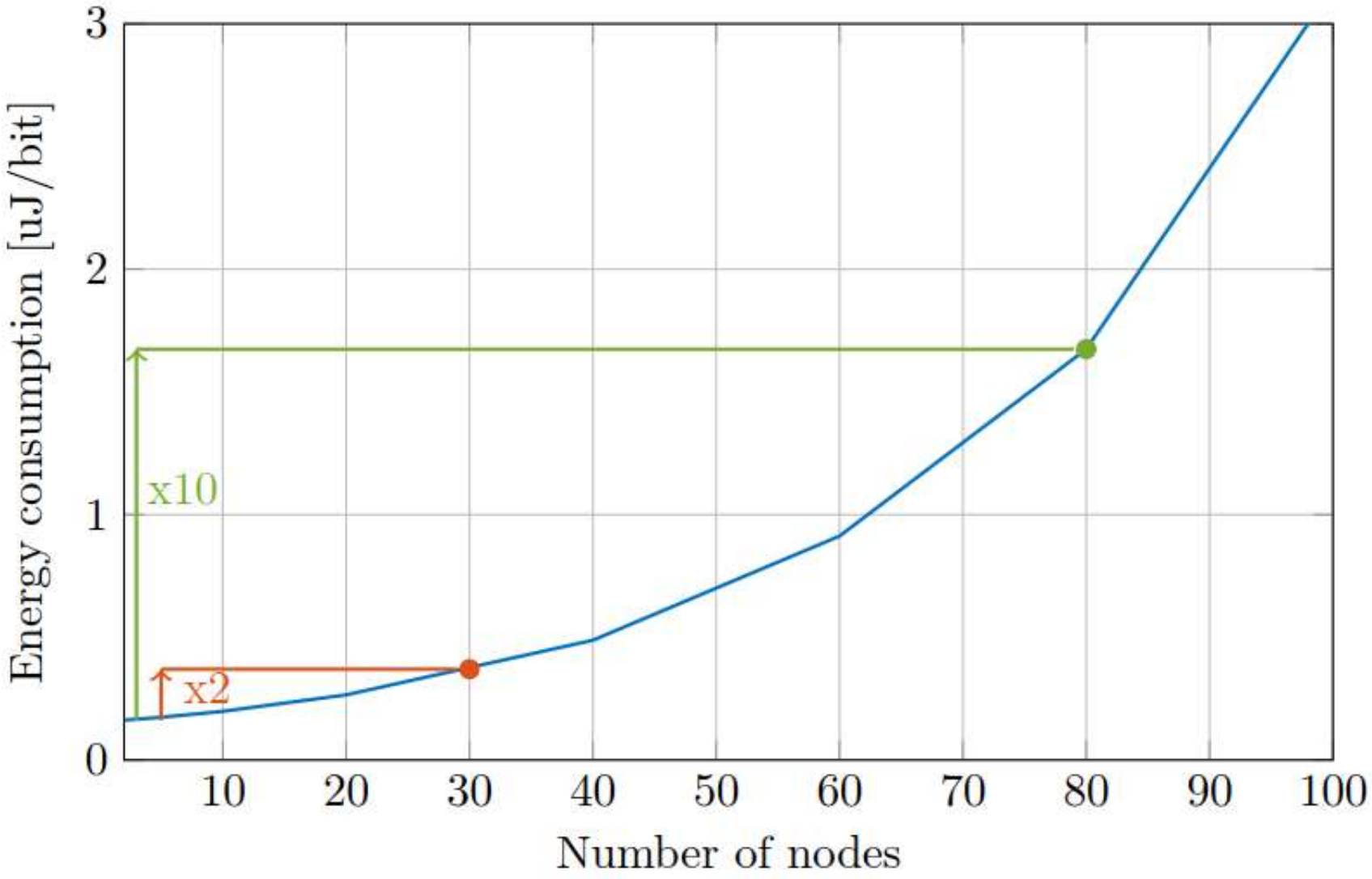
Higher chance of collision



# Collision reduces the throughput

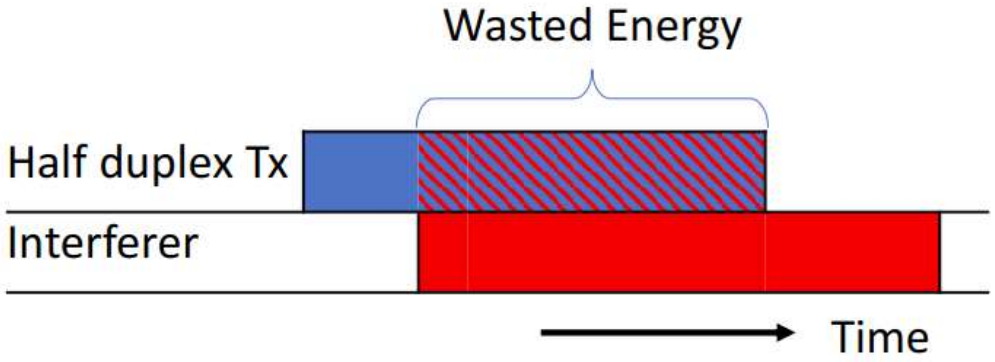


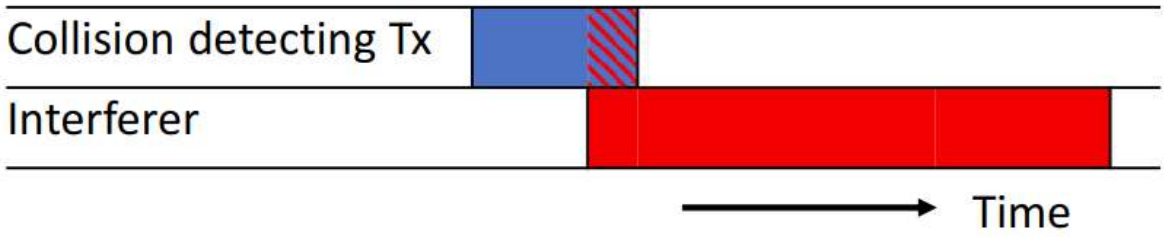
# Collision degrades energy efficiency

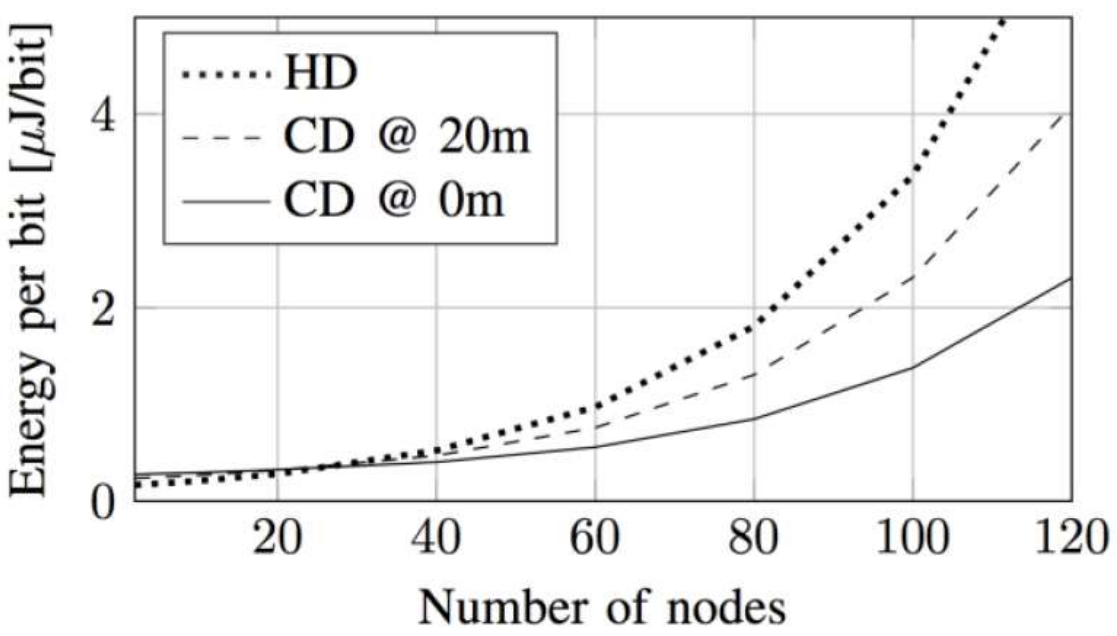


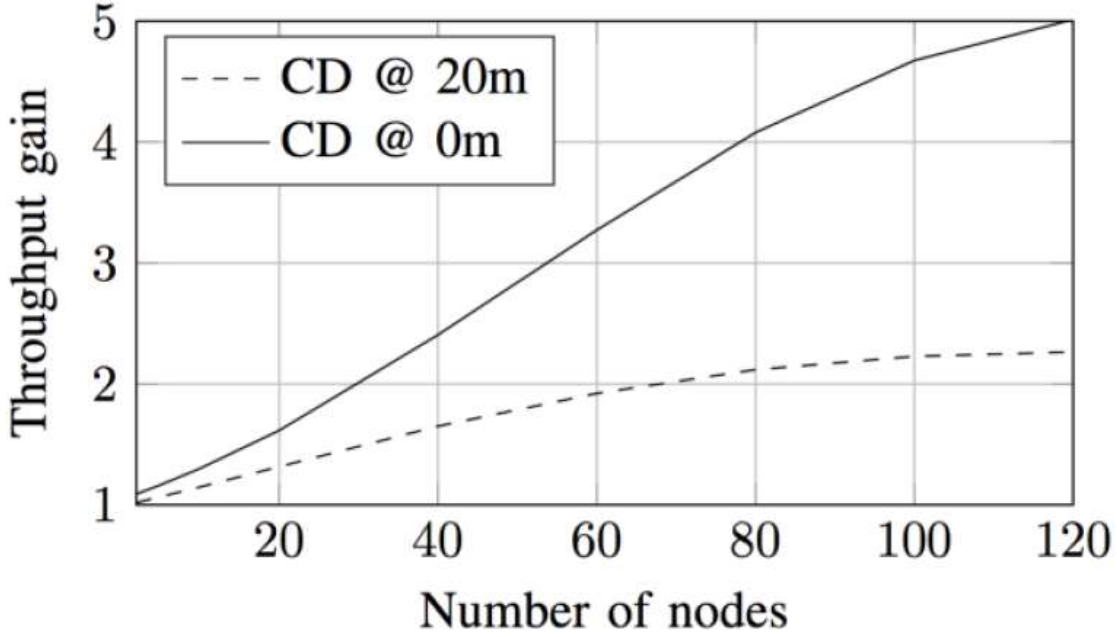
# Our Solution

# Collision detection at transmitter side

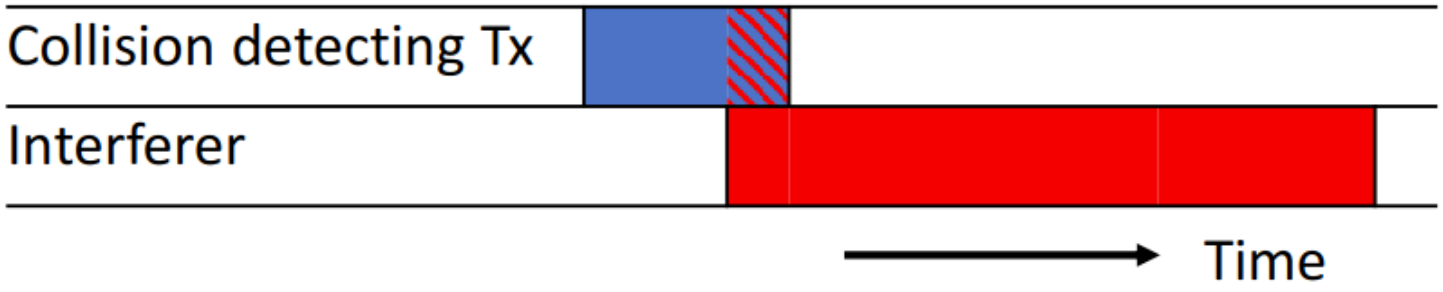


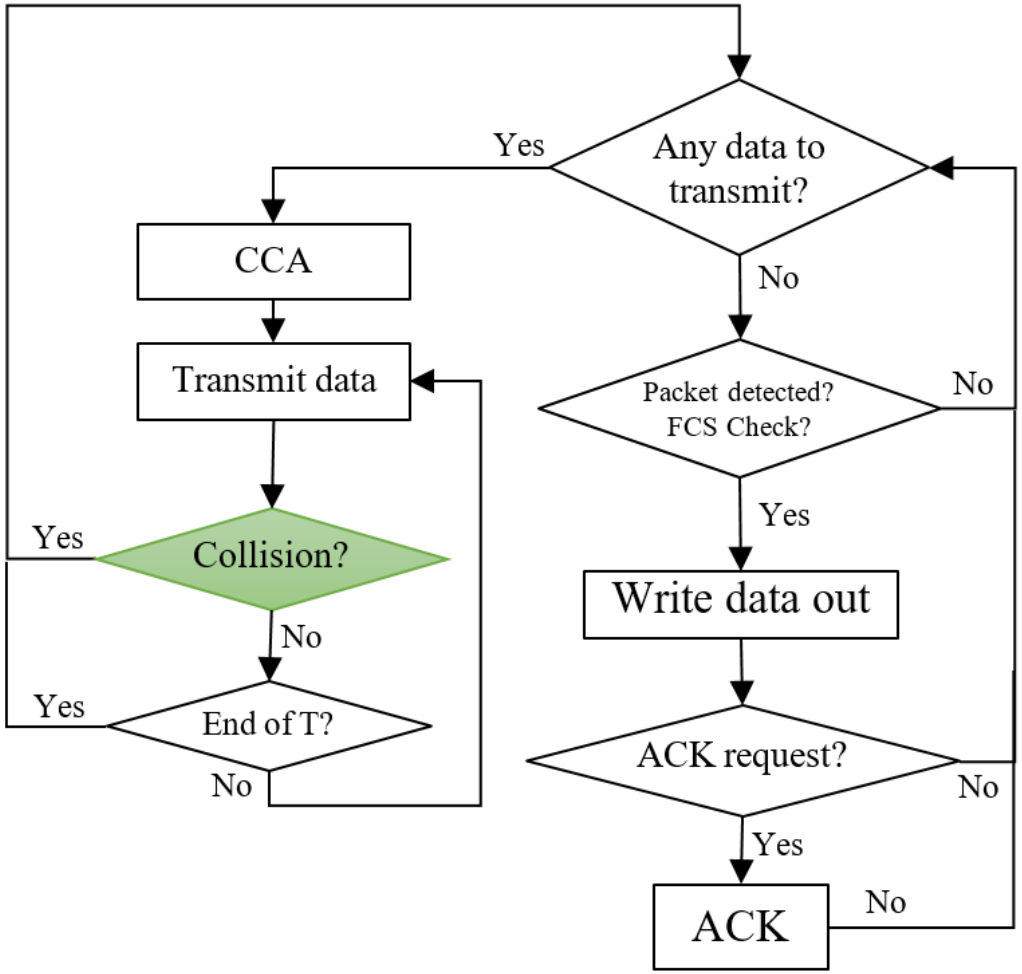



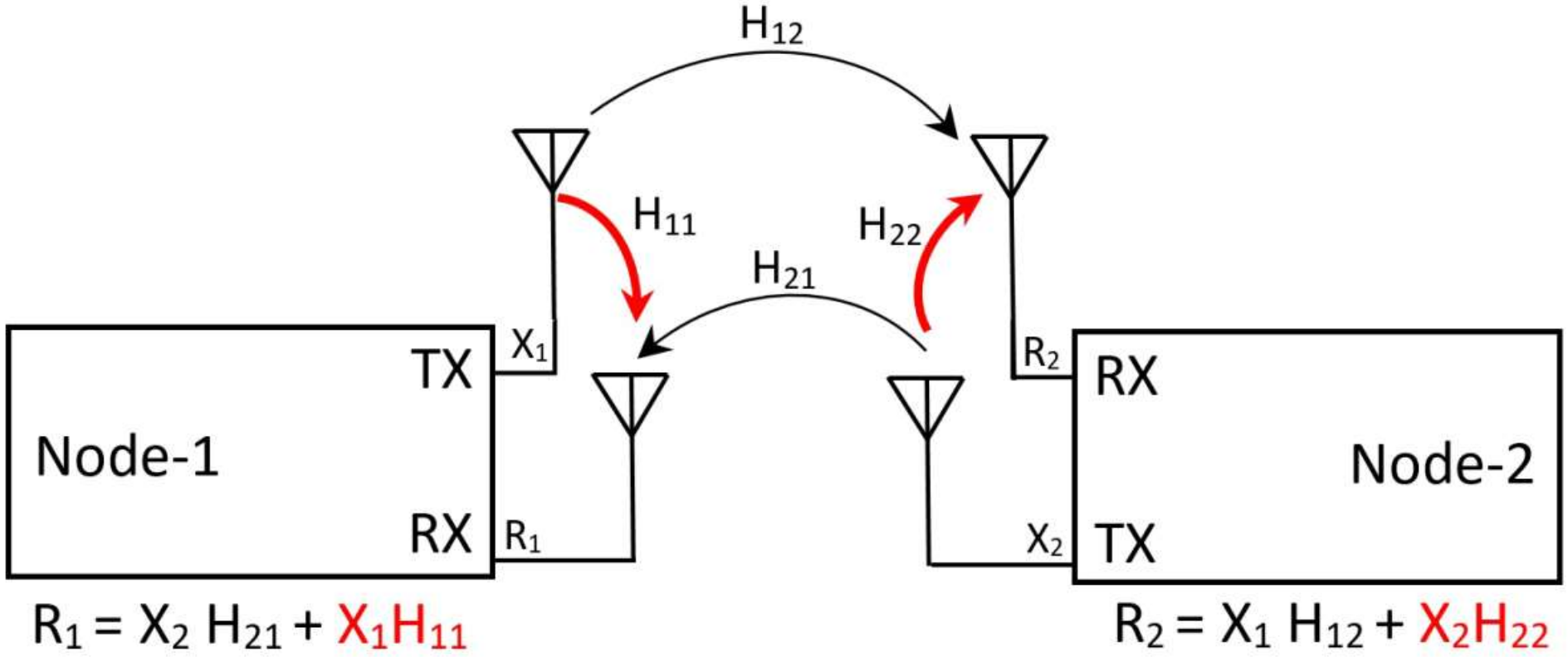
# Carrier Sense Multiple Access + Collision Detection CSMA/CD




Simultaneous send and receive!

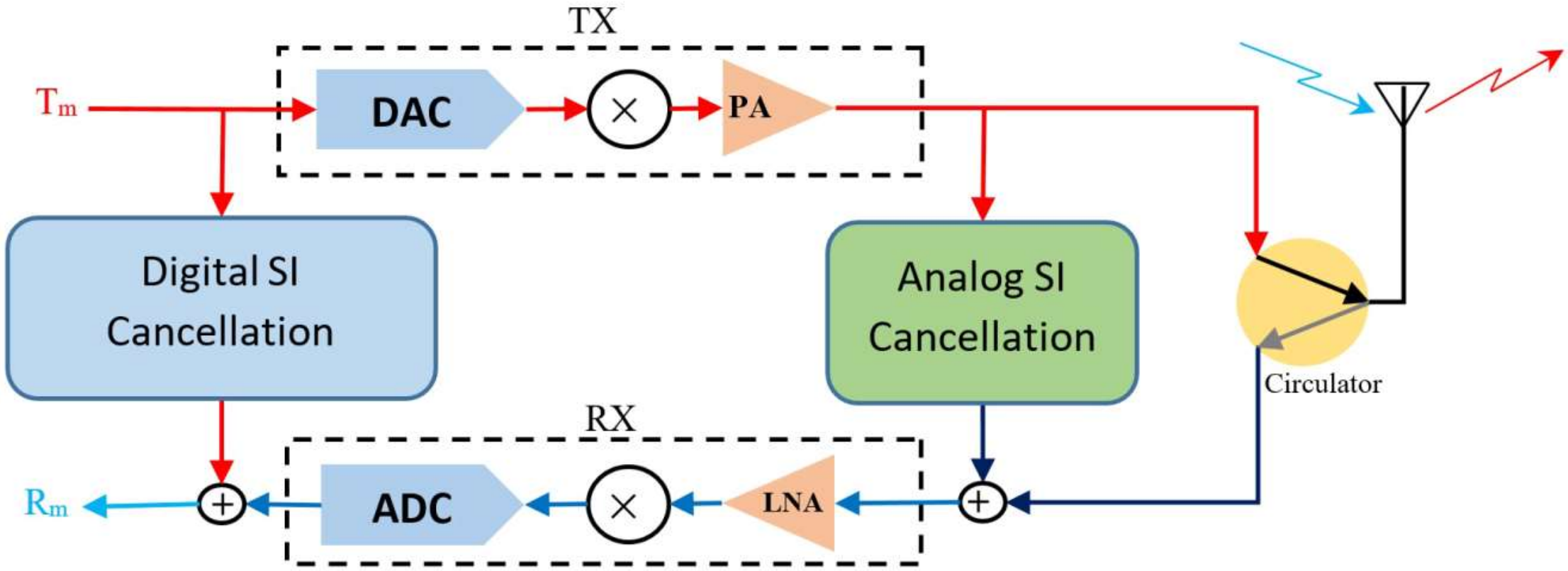
# In-Band Full-Duplex (IBFD)



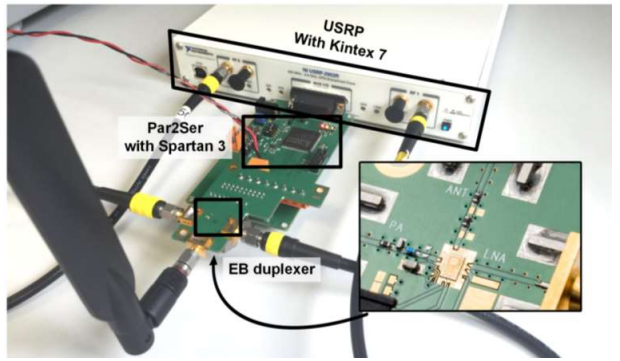

Self-interference problem!

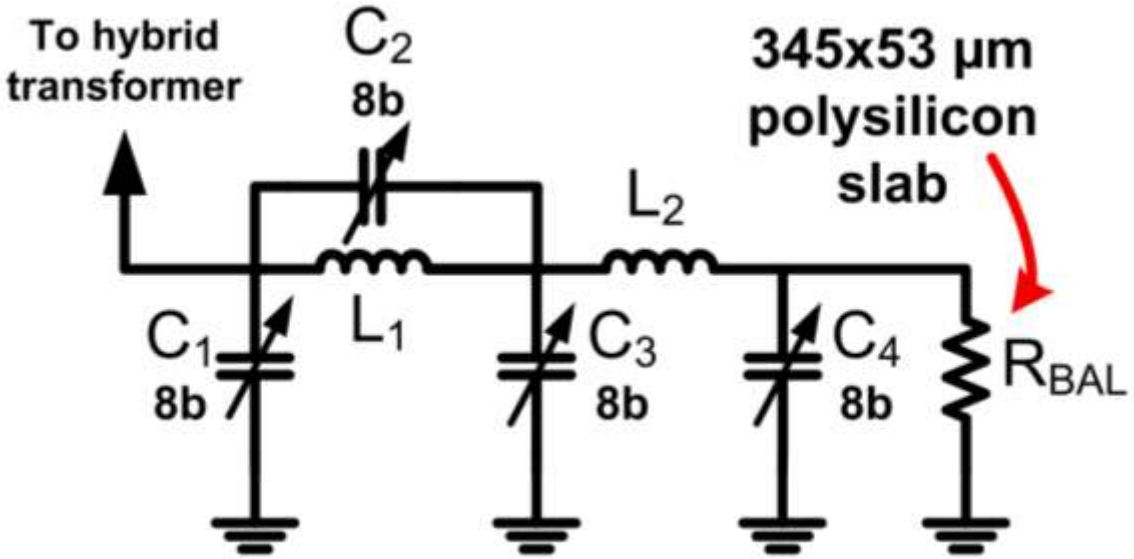
# In-Band Full-Duplex (IBFD)

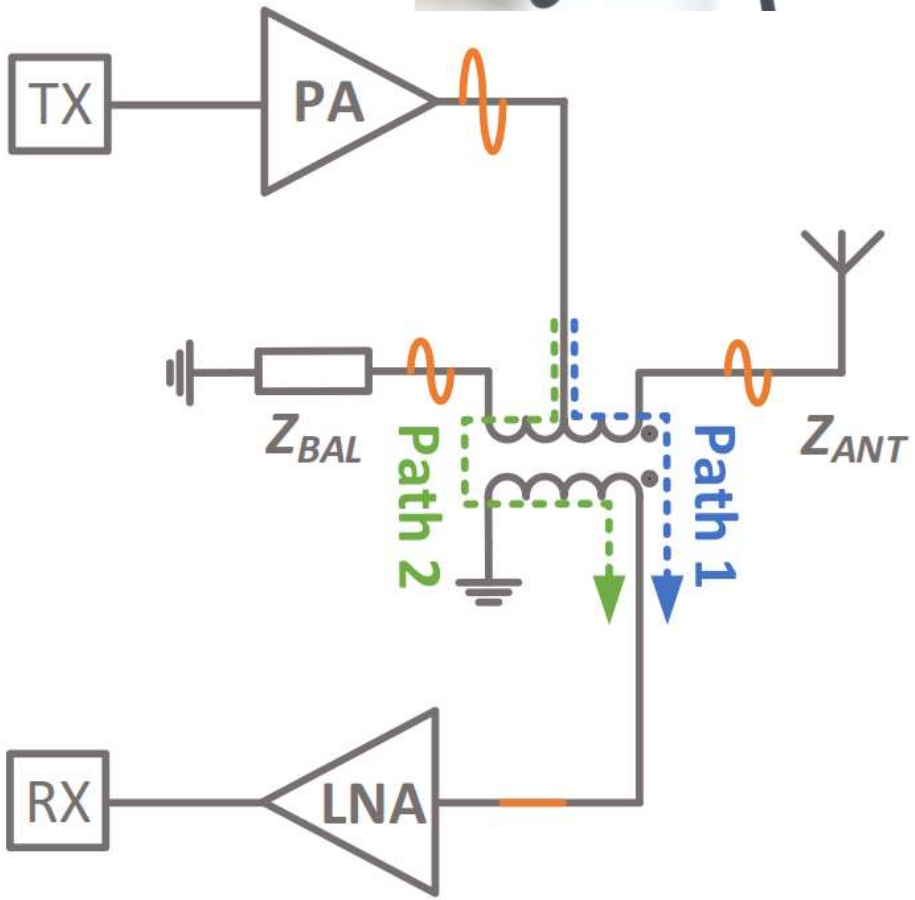
- Analog cancellation achieves 50 to 70 dB
- Digital cancellation up to 30dB further



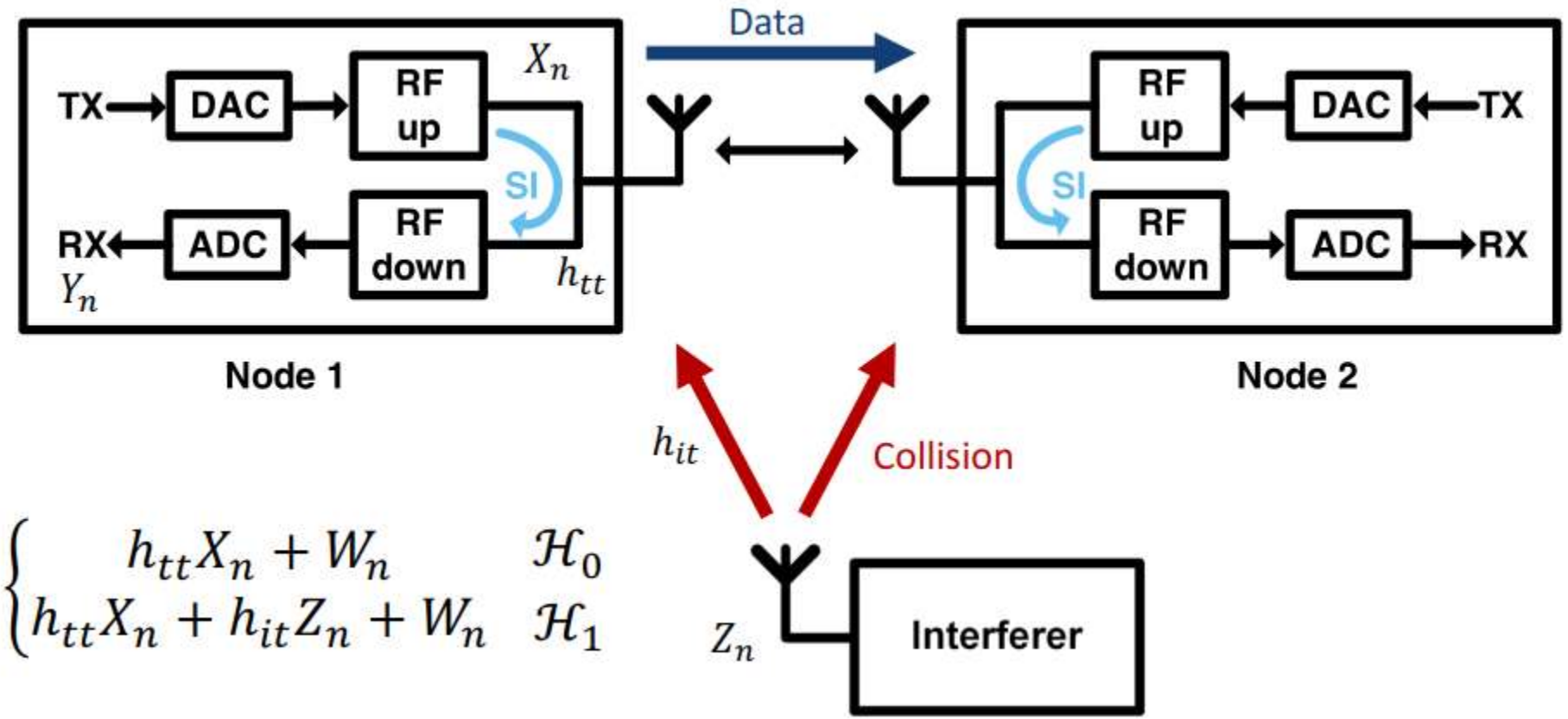
# Analog Self-Interference Cancellation Electrical Balance Duplexer (EBD)



# Collision detection by full-duplex




$$Y_n = \begin{cases} h_{tt}X_n + W_n & \mathcal{H}_0 \\ h_{tt}X_n + h_{it}Z_n + W_n & \mathcal{H}_1 \end{cases}$$

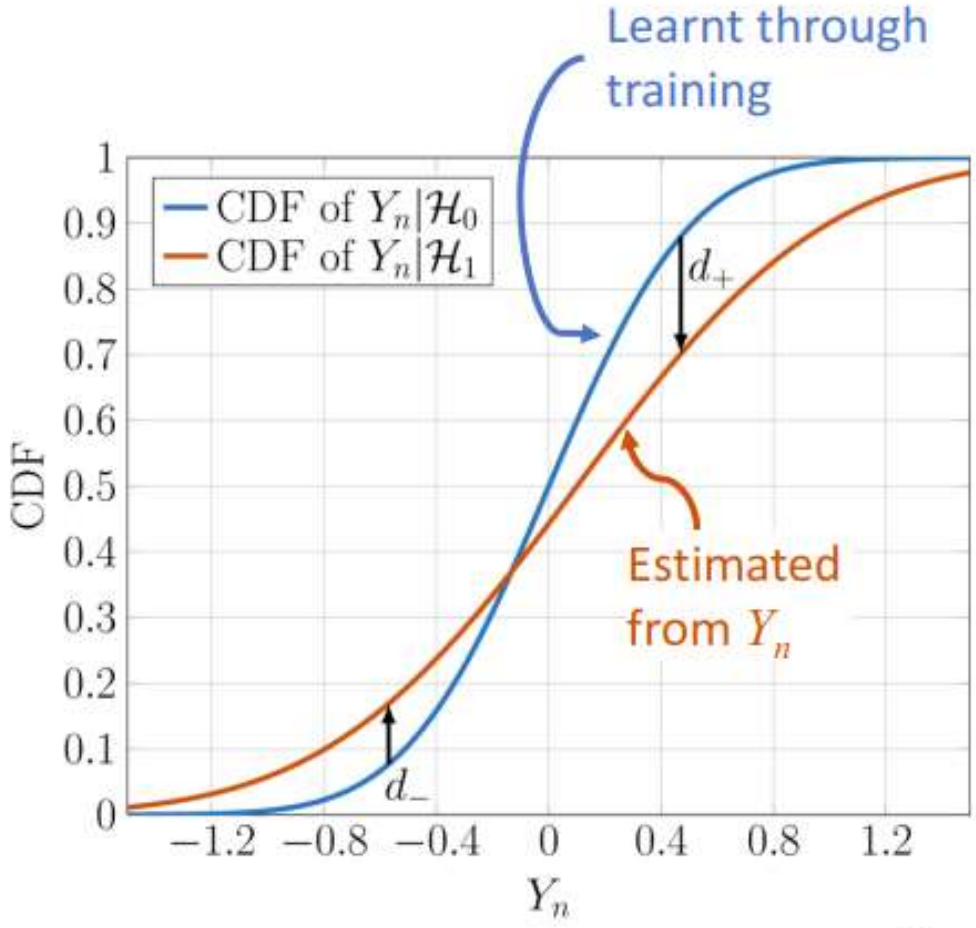
# Energy detection VS Goodness of fit

- **Energy Detection test**

$$T_{ED} = \sum_{n=0}^{\infty} |Y_n|^2$$

- **Kuiper Test**

$$D_{KP} = d_+ + d_-$$



# Recap

More Nodes

↓

More transmission

↓

Higher chance of collision

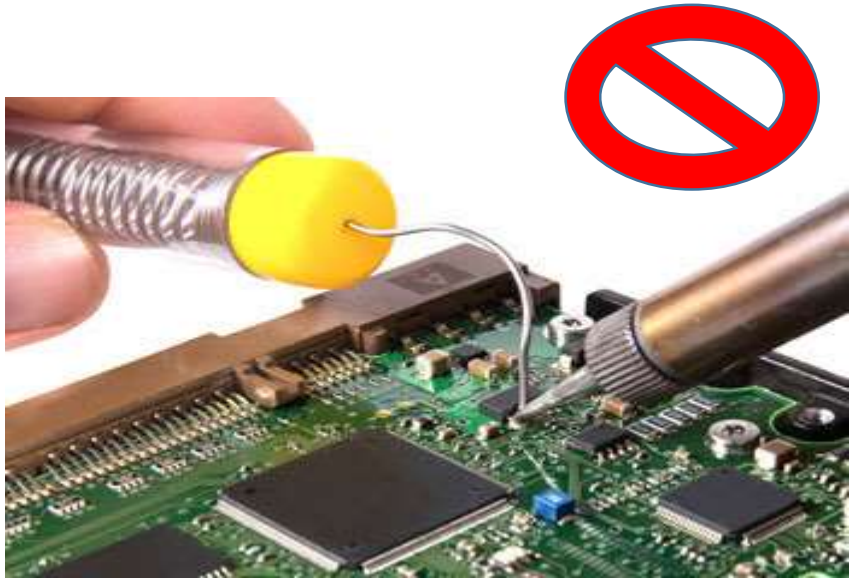
↓

**Full-Duplex + Collision detection**

How to make a prototype and prove the concept!?

# Software Defined Radio (SDR) for wireless networking

- No need to modify hardware (mixer, filter, …) any more!
- Flexible and programmable platform
- Design solution for rapidly prototyping wireless communication systems
- Real-time SDR for high-throughput communication



# LabVIEW, an effective tool for fast prototyping

**LabVIEW FPGA**



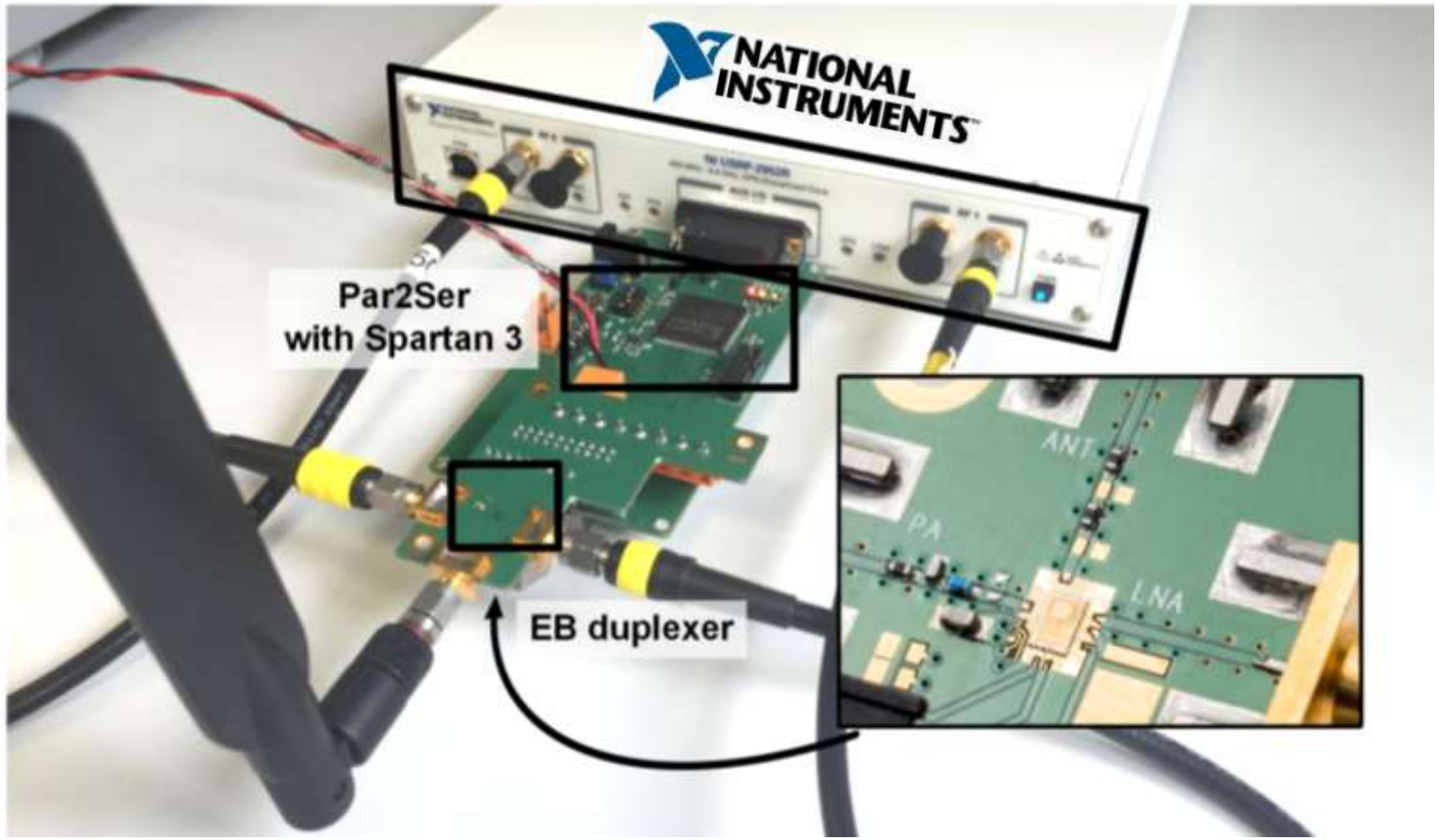
**PHY**

**heavy in data flow**
**dominated by processing latency**

**MAC**

**complex control**
**little on data processing**

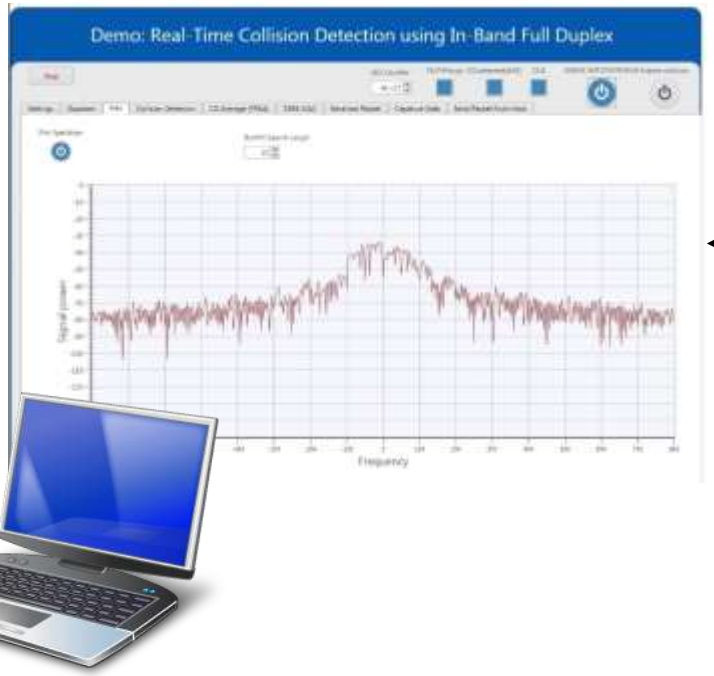
# Our prototype



# Our prototype



Host Interface




PCI EXPRESS

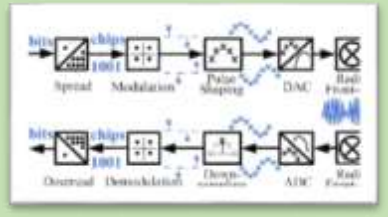
USRP FPGA

Transceiver

MicroBlaze

MAC
CSMA/CD

IEEE 802.15.4 PHY



Collision Detector

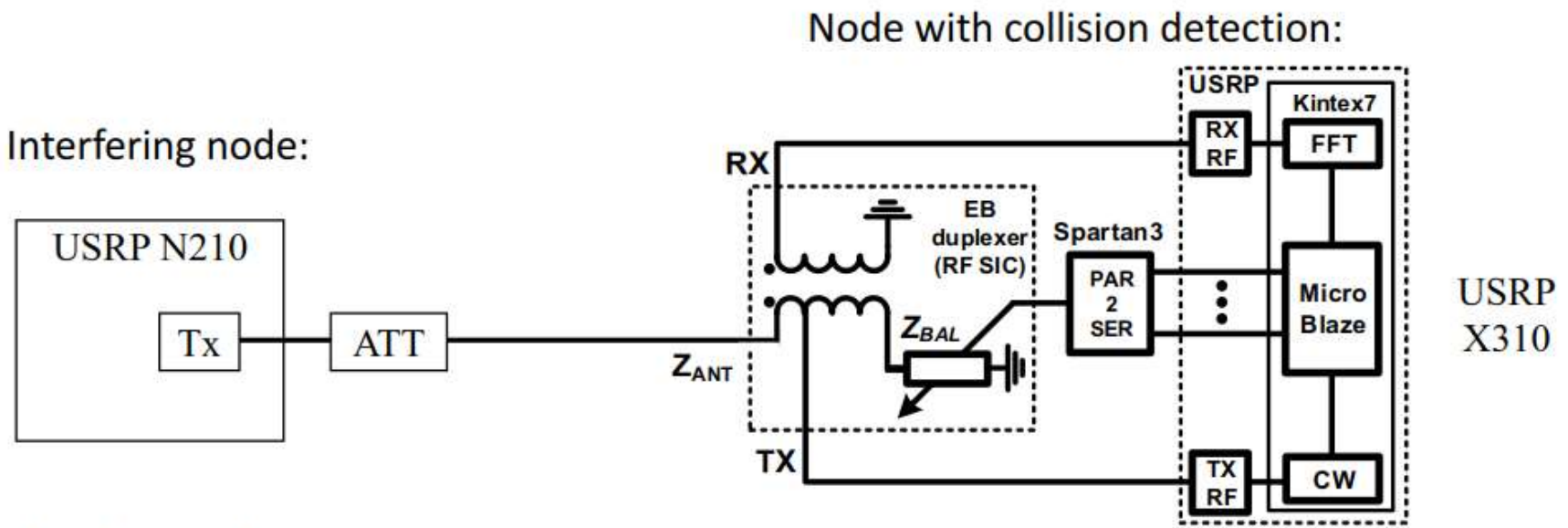
MicroBlaze

EBD Tuner

AUX

EBD, Analog SIC

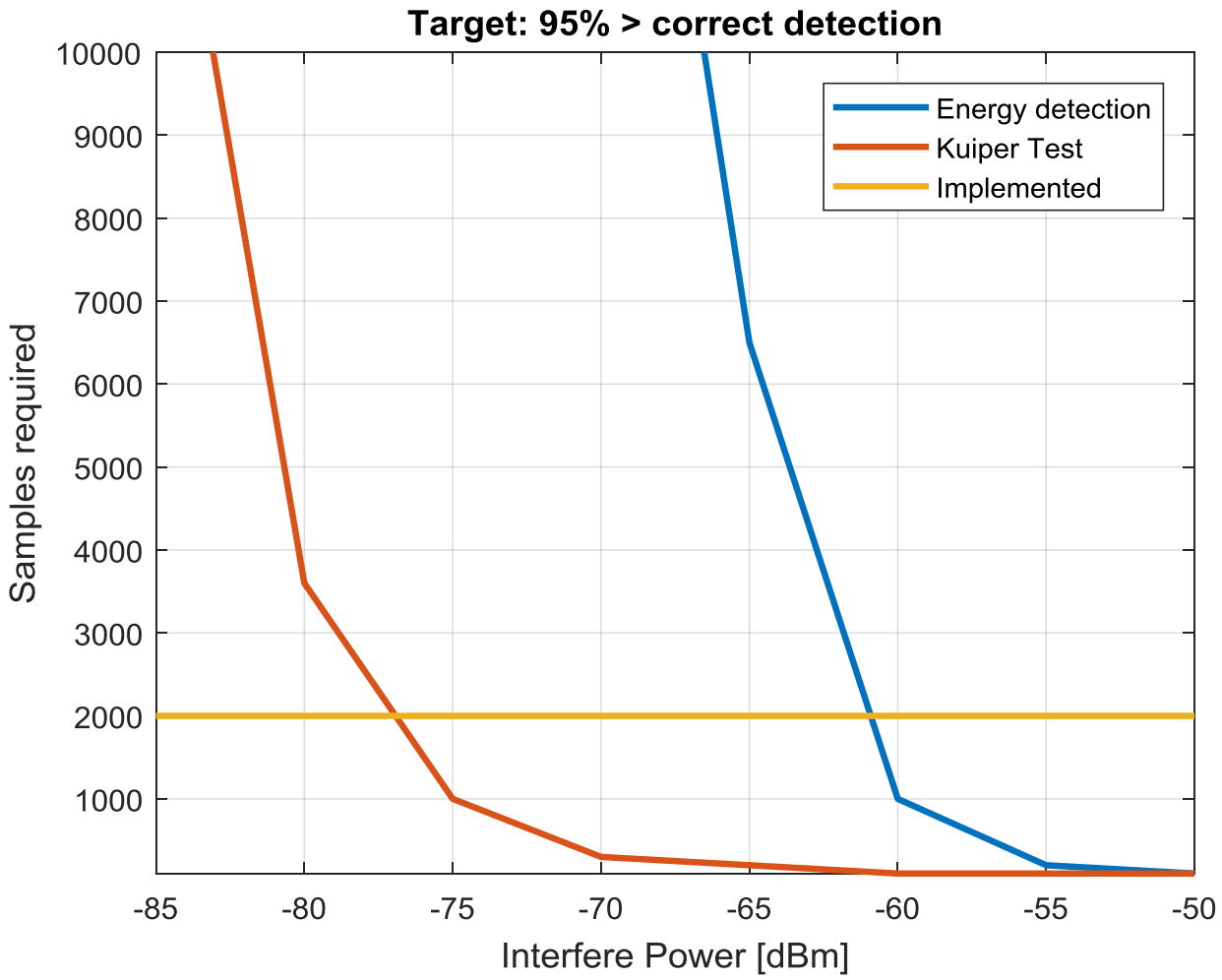
# Experimental setup




- IEEE 802.15.4 signals
- TX power: 0dBm
- Noise floor: -90dBm
- EBD cancellation: 50-70dB

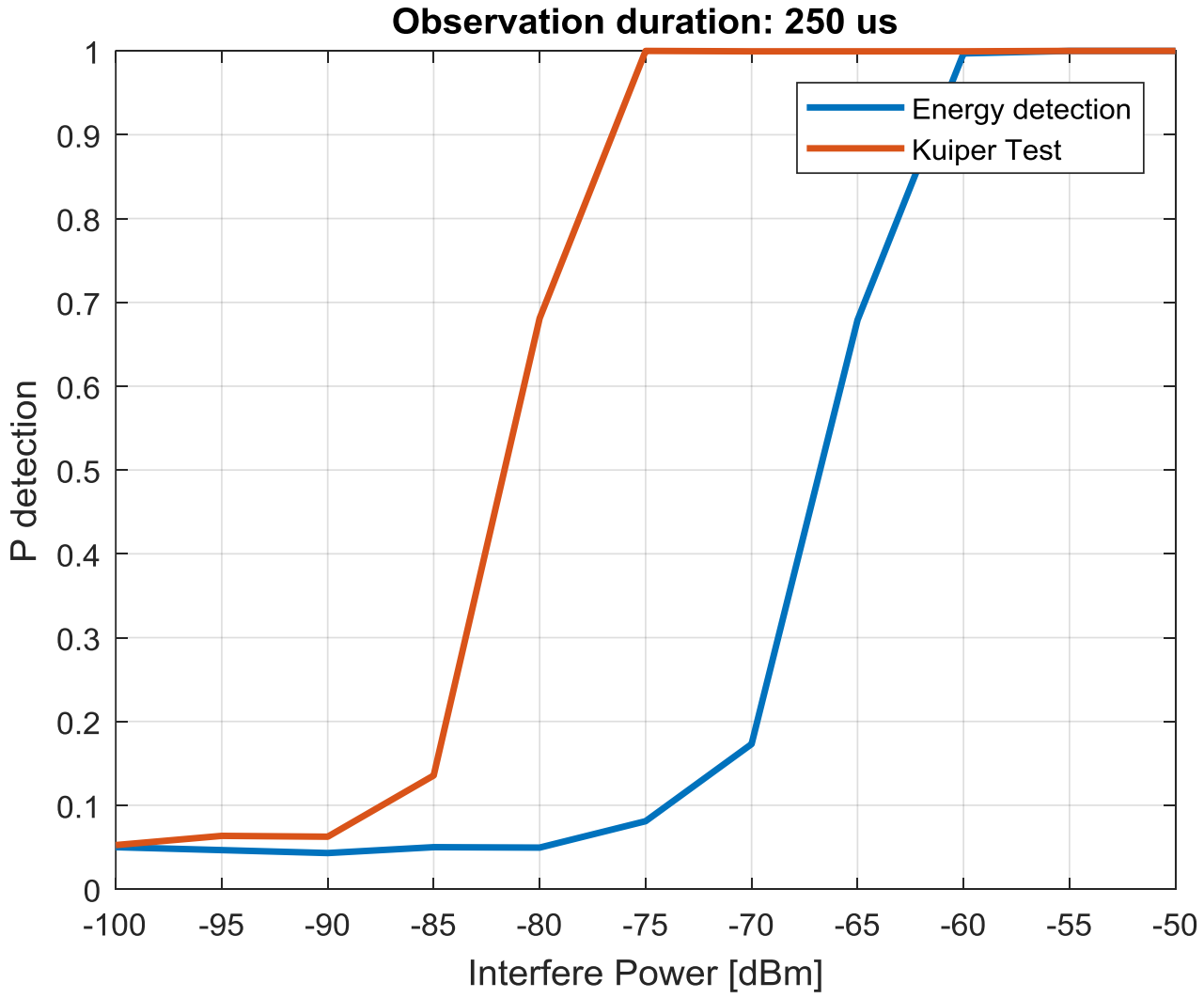
- Receiver oversamples by 8
- Results averaged over 2000 measurements per interfering power
- Threshold trained for each test statistic such that $P_{\mathrm{FA}} = 5\%$

# Experimental results



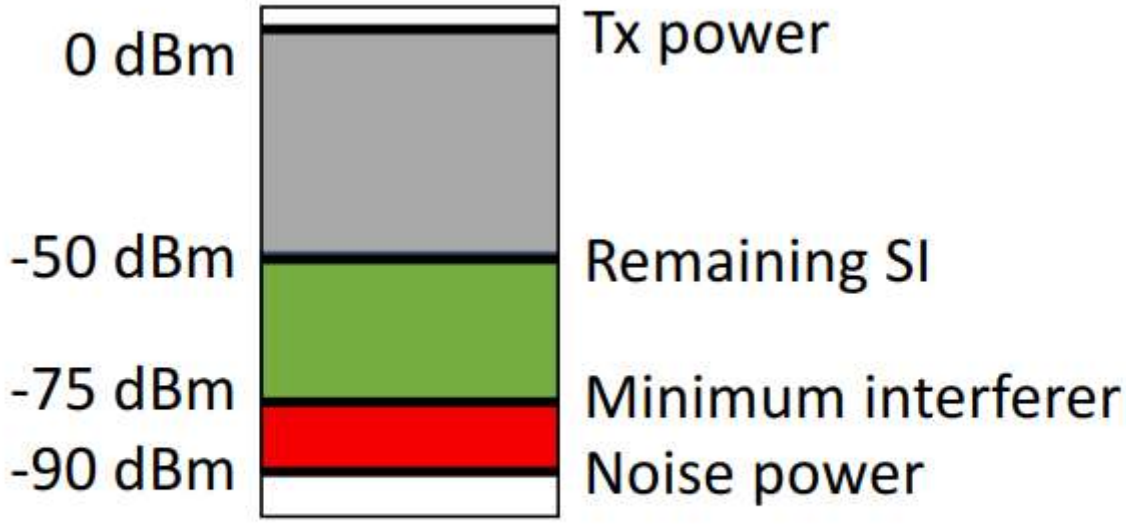

2000 samples = 250 us, i.e., 4 bytes in an 8 times oversampling 802.15.4 receiver

# Experimental results



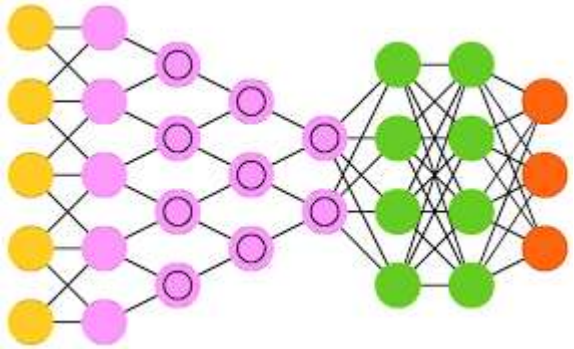
# Conclusion

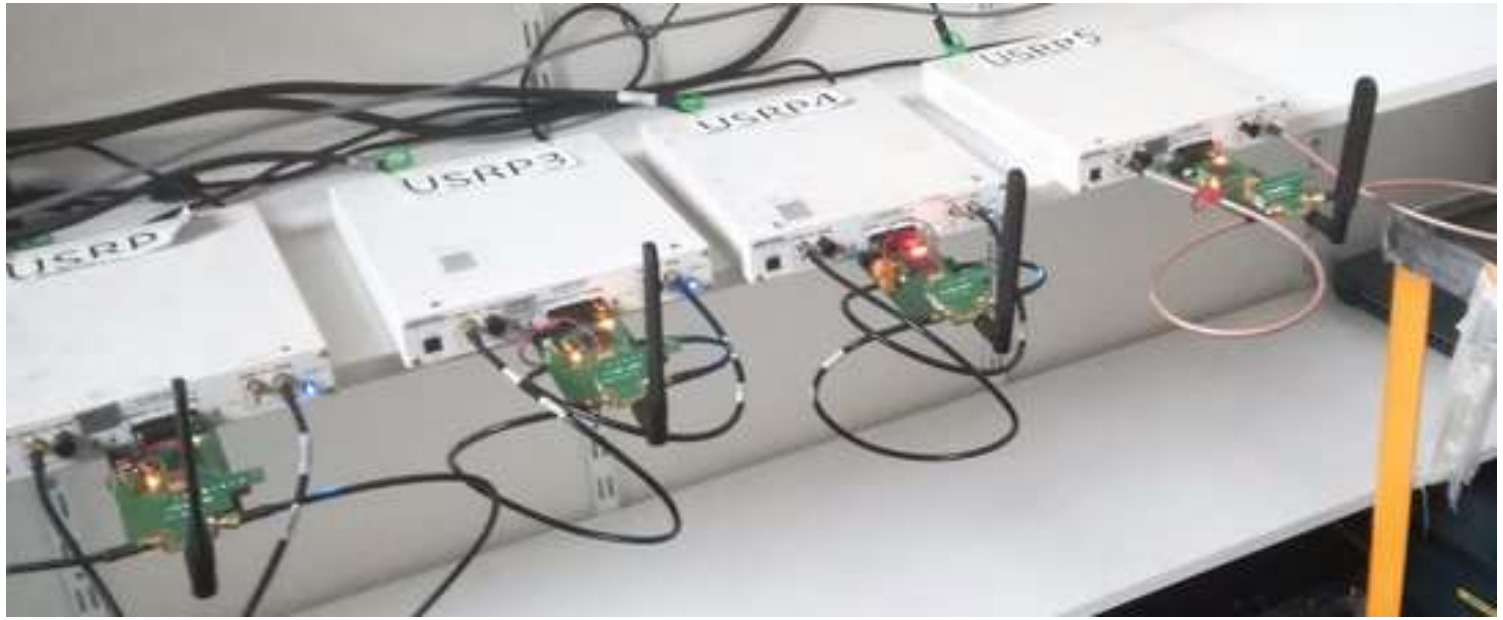
- Collision detection at TX is practical for indoor environments
- Kuiper test + analog SI cancellation can detect interferers up to -70 dBm
- Almost instantaneous: 250 µs
- Throughput and energy gain + reliability

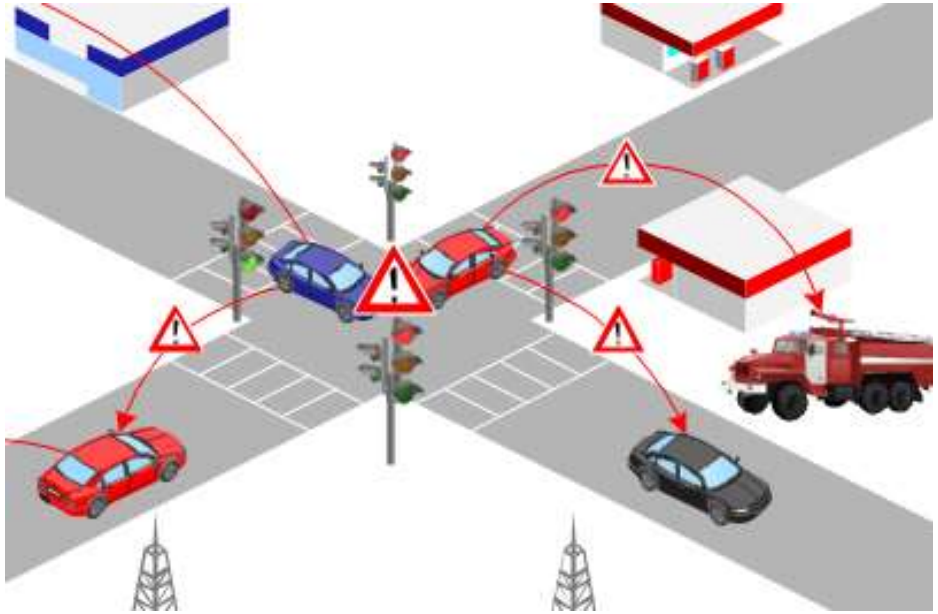


# Future works

- Faster and more accurate Collision detection
- Collision VS high-priority message
- IEEE 802.11p and Car to X communication
- Full-duplex network with collision detection





# Thank you!

# Q&A