SlimWiFi: Ultra-Low-Power IoT Radio Architecture Enabled by Asymmetric Communication

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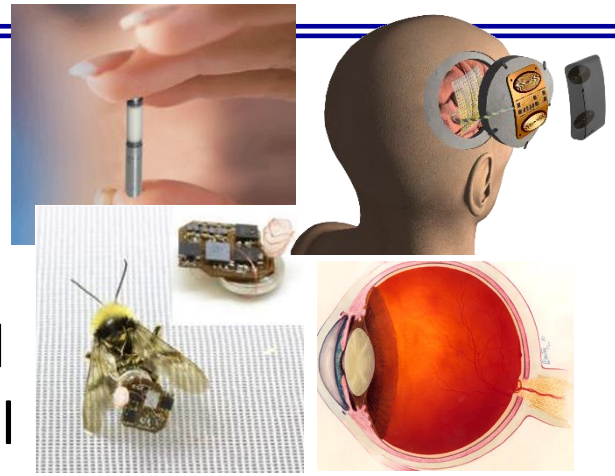
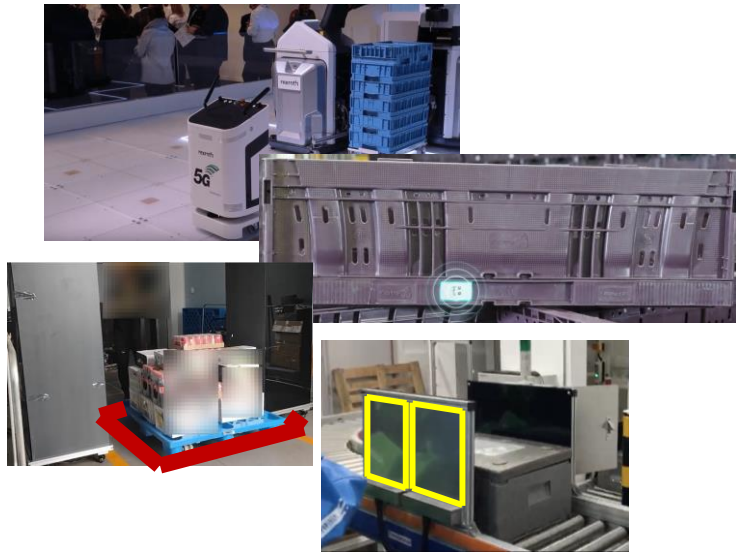
Ultra-low-power communication



Biomedical & Biological

Industry 4.0

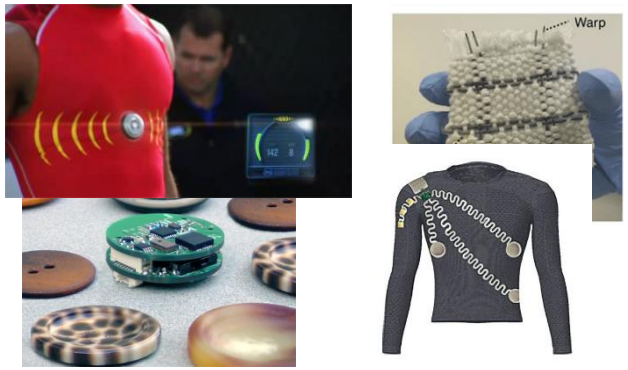


Logistic automation

Smart home

Consumer IoT

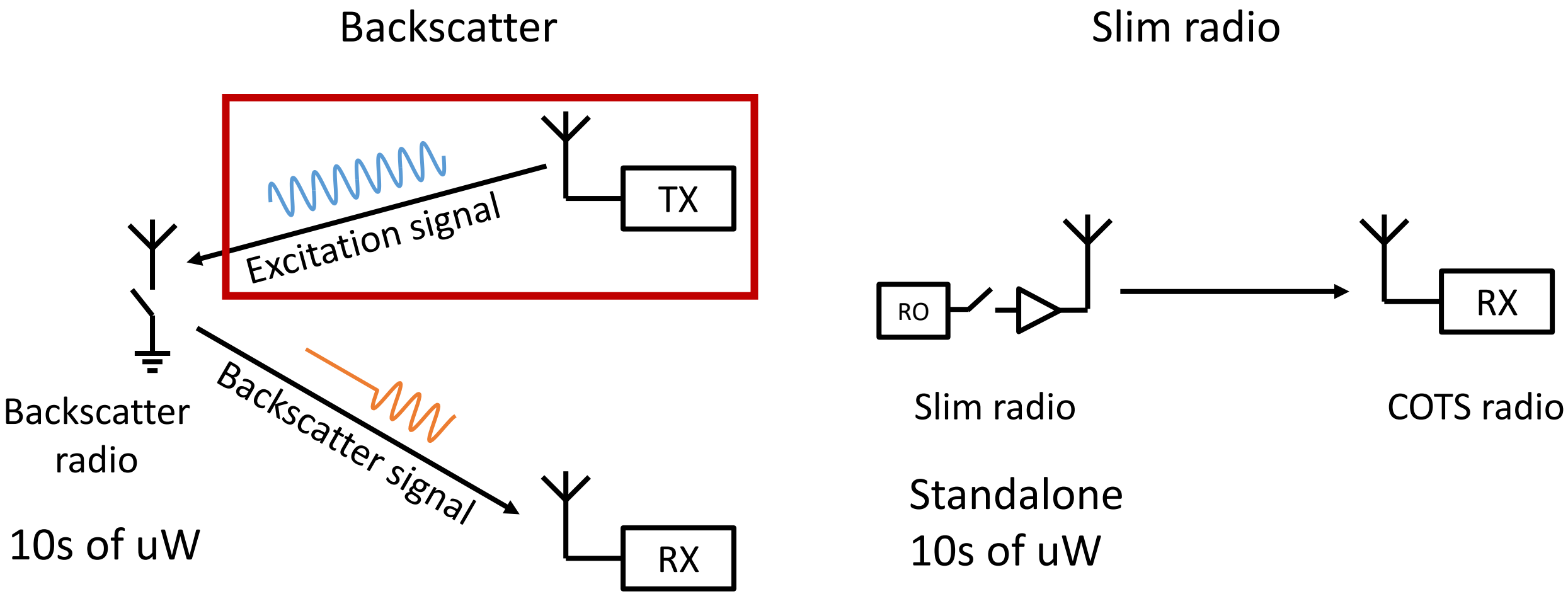
Industrial IoT



Wearable textiles

Infrastructure monitoring

New radio architecture for ULP communication



[1] Dehbashi, Farzan, et al. "Verification: can wifi backscatter replace RFID?." In proceedings of MobiCom. 2021.

COTS radio v.s. slim radio

- Modulation
  - OFDM → OOK
  - mW → sub-uW

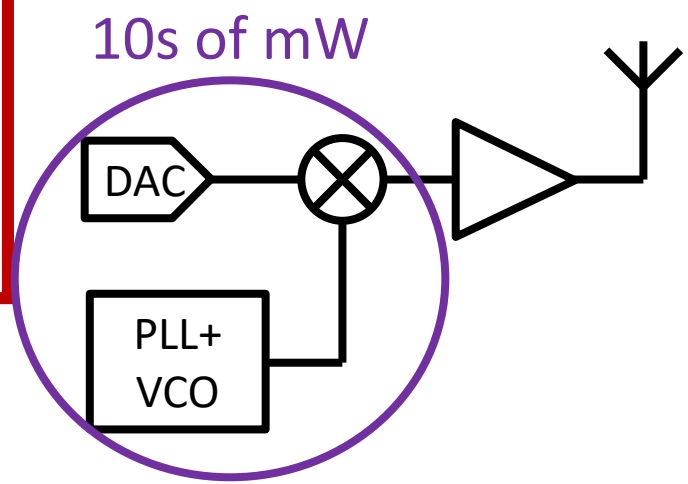
Incompatible modulation

- Carrier generation
  - Closed-loop → open-loop
  - mW → 10s uW

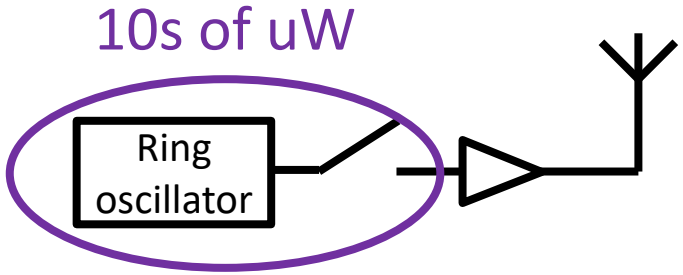
Large frequency offset

- TX power
  - 20 dBm → -20 dBm
  - 100s mW → 10s uW

Low signal strength

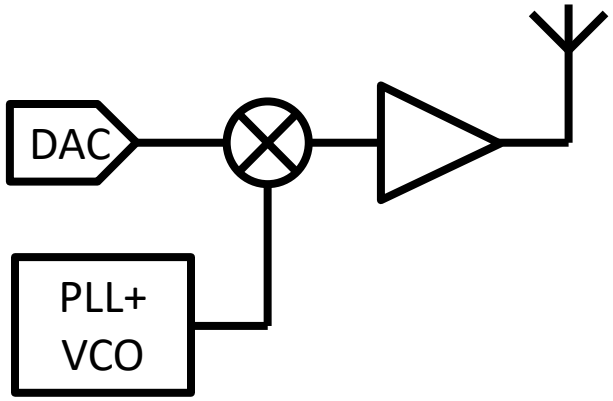


COTS radio

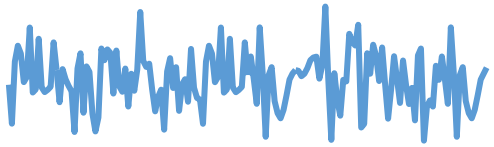


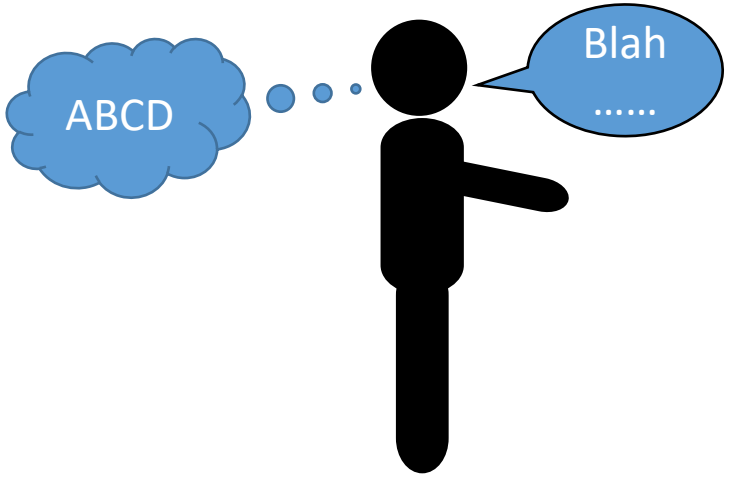
Slim radio

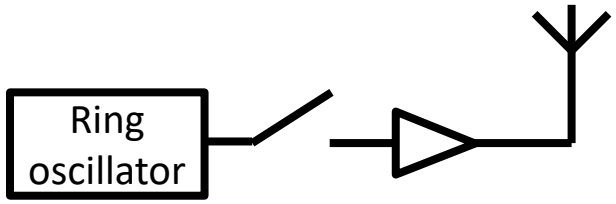
Challenge 1: incompatible modulation



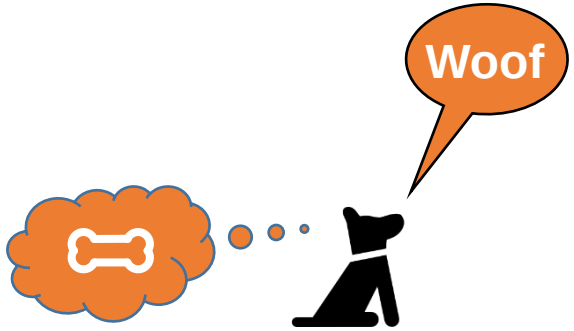
COTS radio



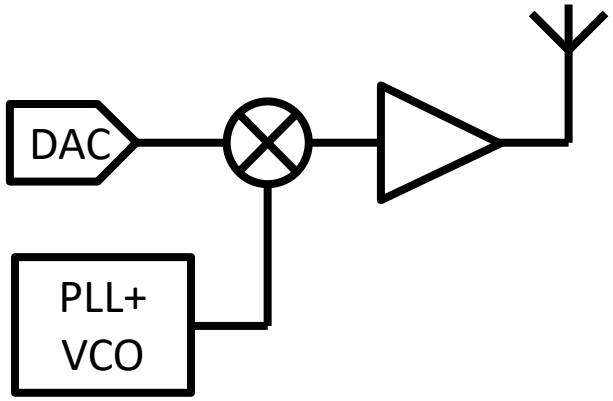




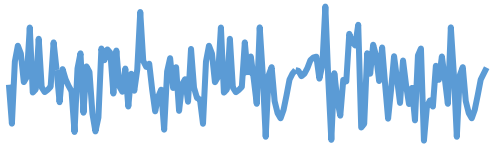
Slim radio

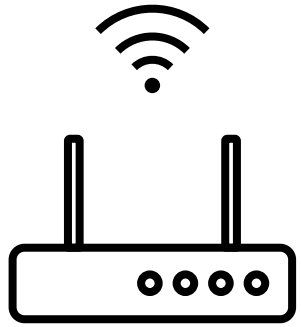


Customized gateway?



COTS radio





COTS radio

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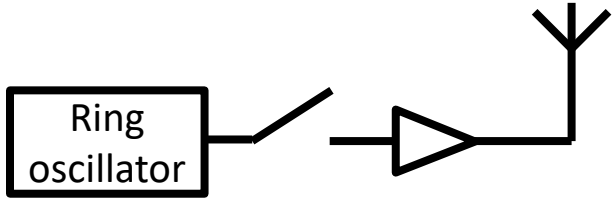


Slim radio

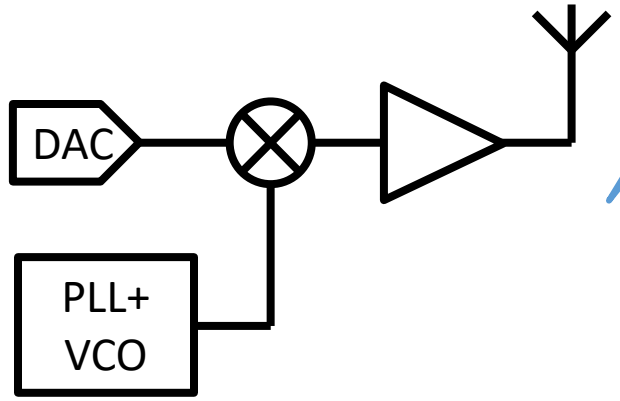
$billions

Customized radio?

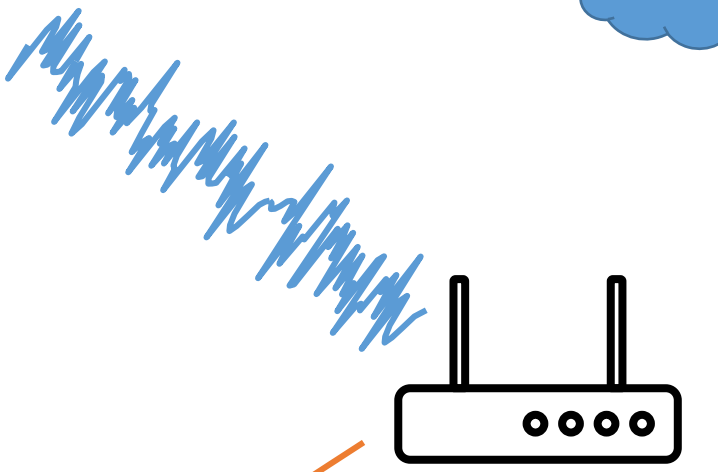
How can slim radio communicate with COTS devices without modifying the COTS hardware?

Answer: asymmetric communication

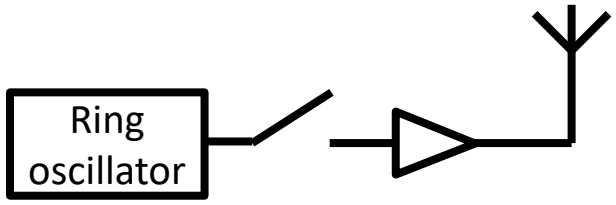
Symmetric v.s. asymmetric



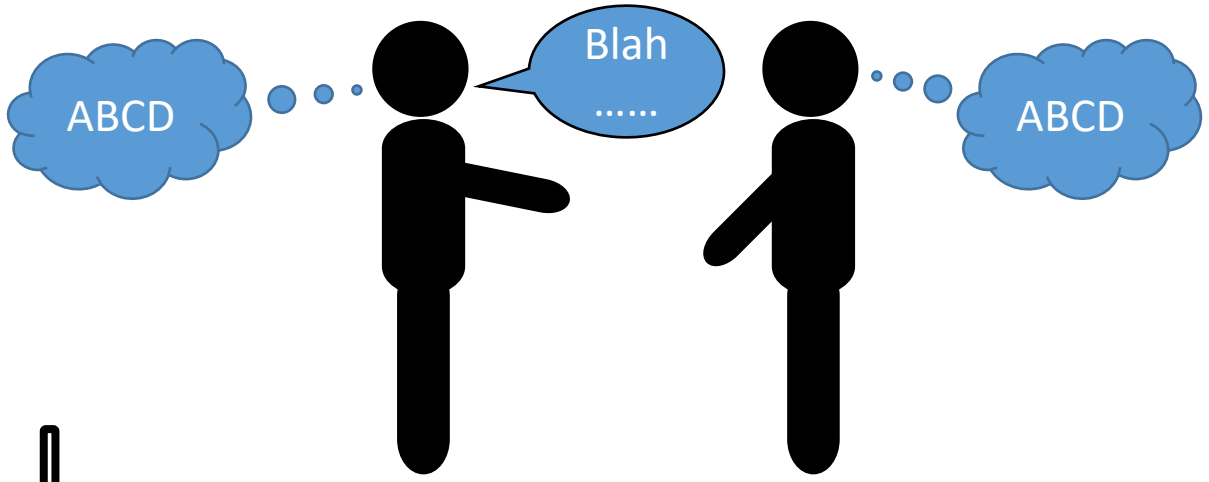
COTS radio



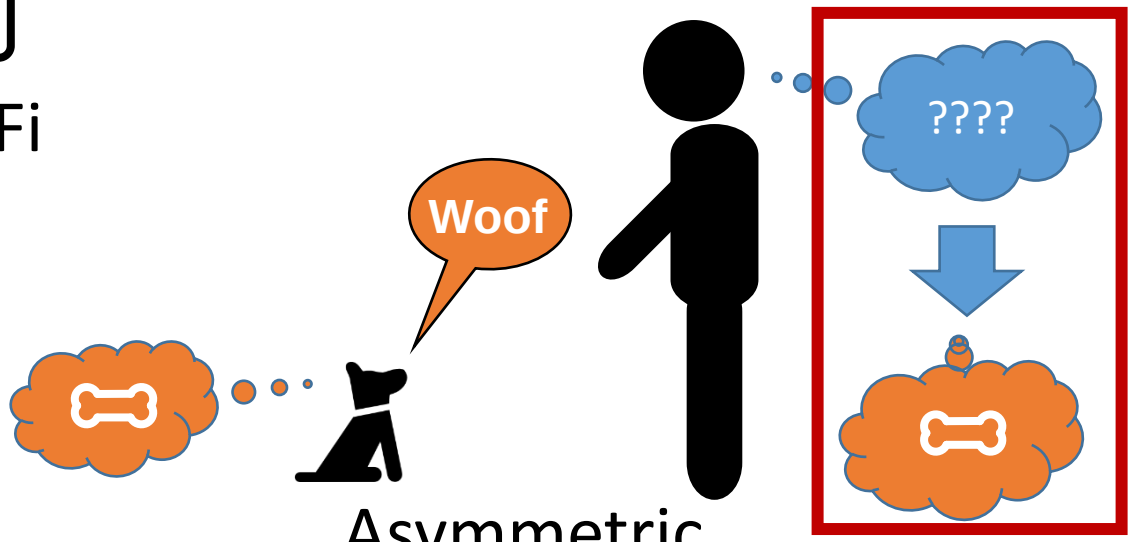
COTS Wi-Fi



Slim radio

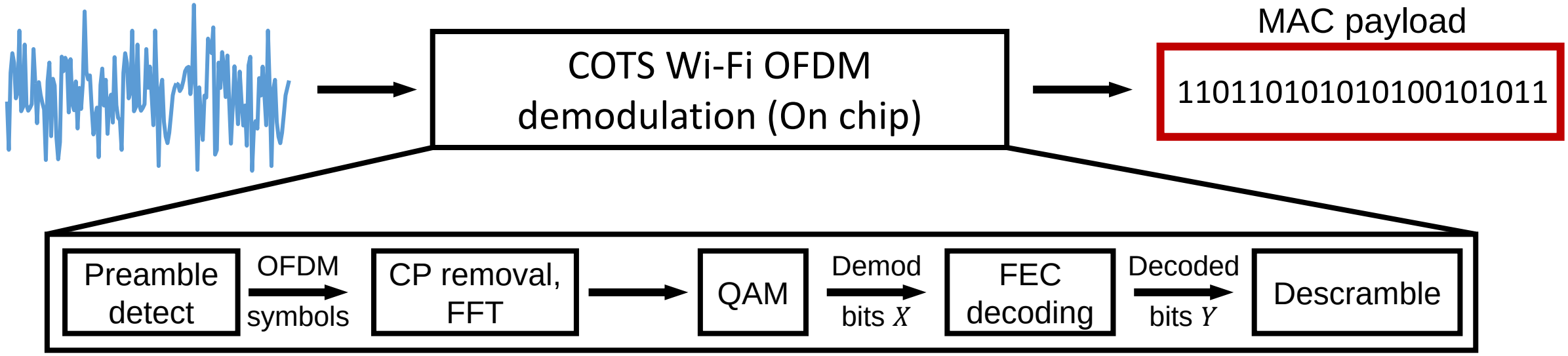


Symmetric



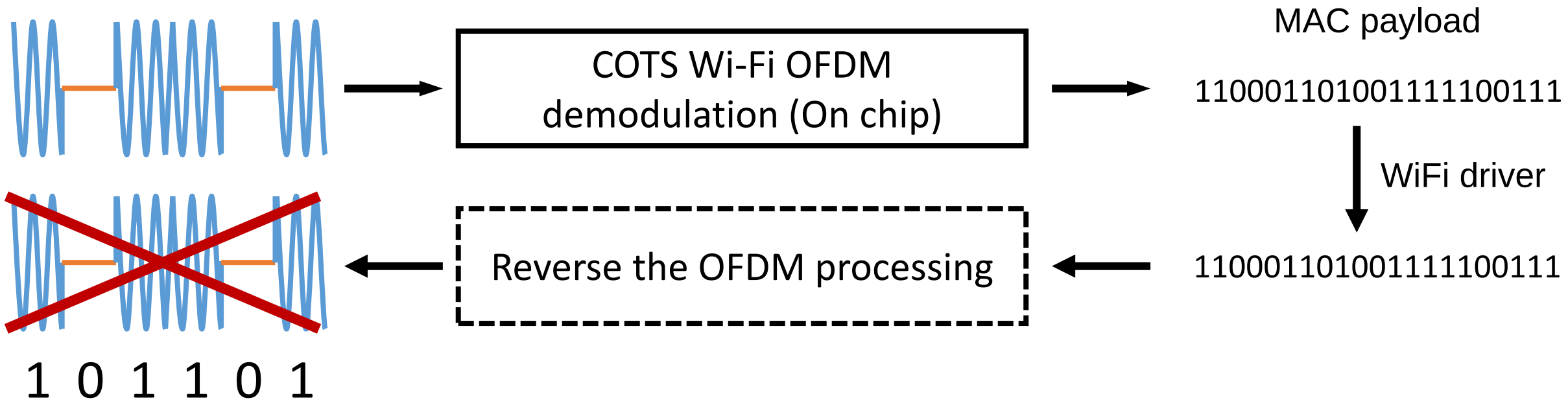
Asymmetric

COTS Wi-Fi receiver



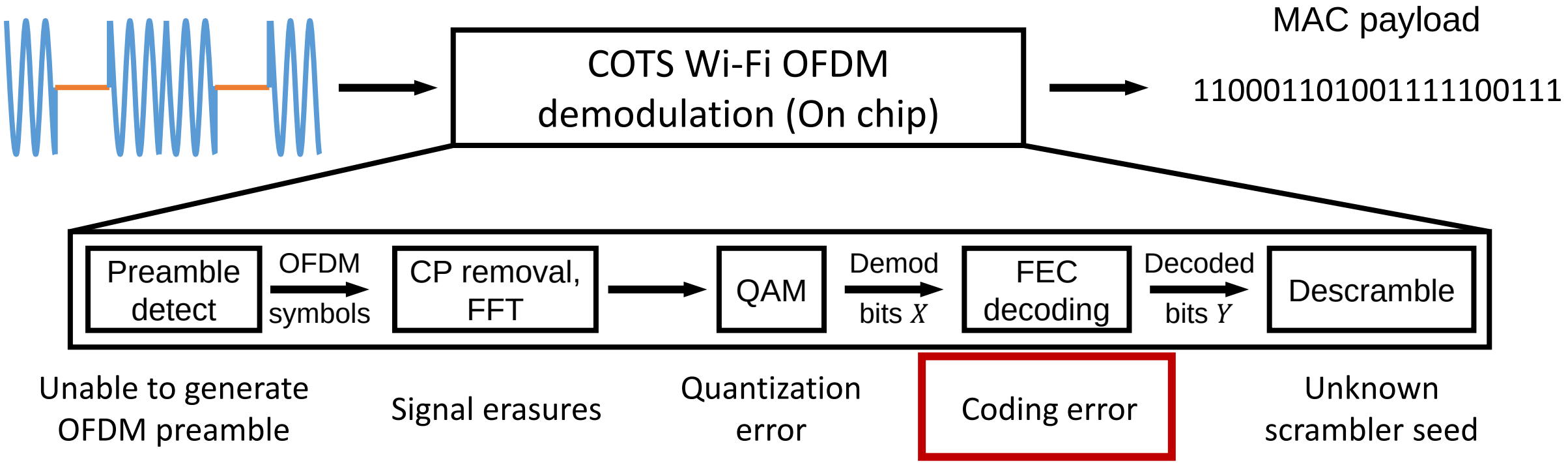
- Implemented on chip, cannot be bypassed or modified
- COTS Wi-Fi only can collect the bit sequence

Asymmetric demodulation



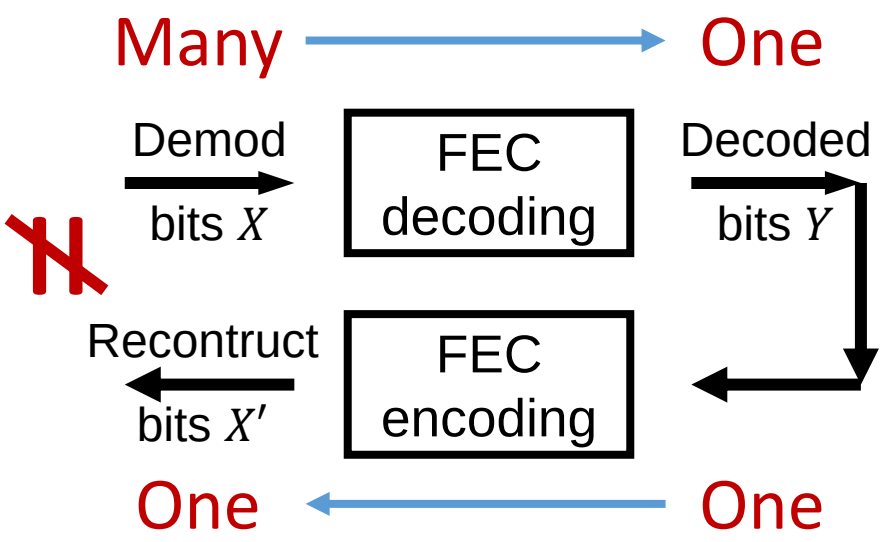
- Mapping between waveform and bits
  - Reconstruct and extract the information by reverse the processing

Errors introduced by OFDM processing

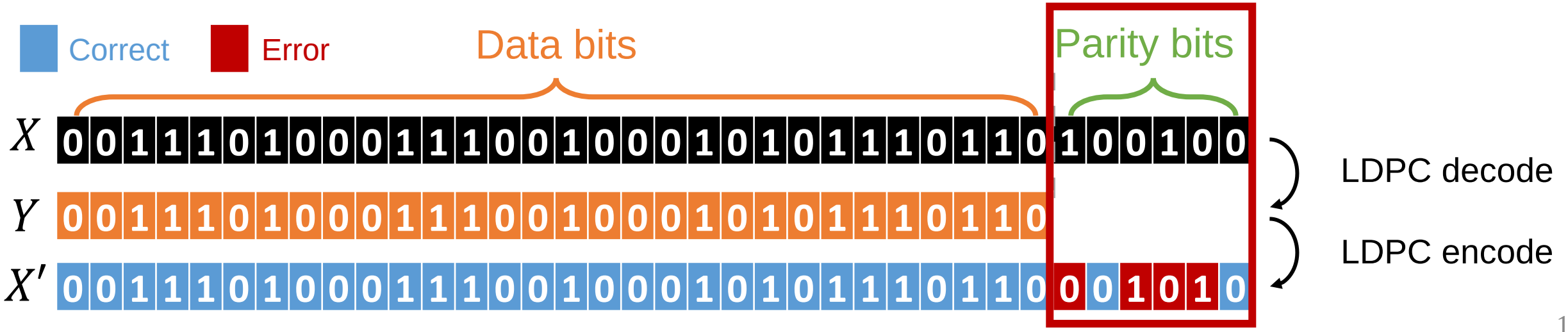


- A co-design of TX waveform and demodulation
- Careful configuration of the receiver

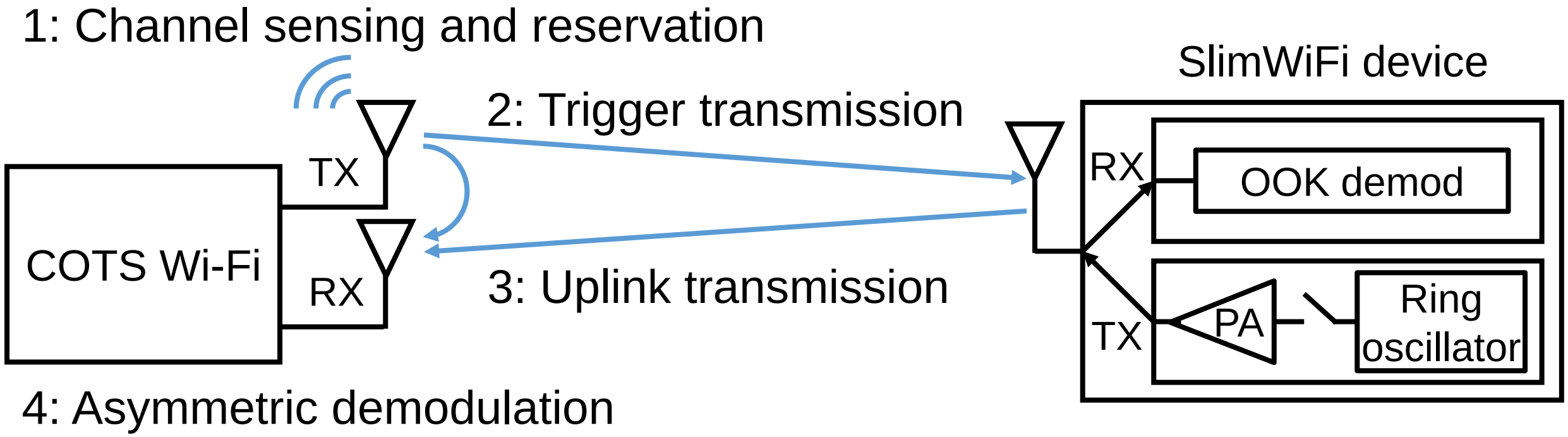
Coding error



- Inevitable errors between X and X'
- Fewer coding errors at a higher coding rate
  - Configure RX to highest coding rate
    - 5/6 coding rate → less than 1/6 error
- Error locations are known a priori
  - Apply convolutional coding to X

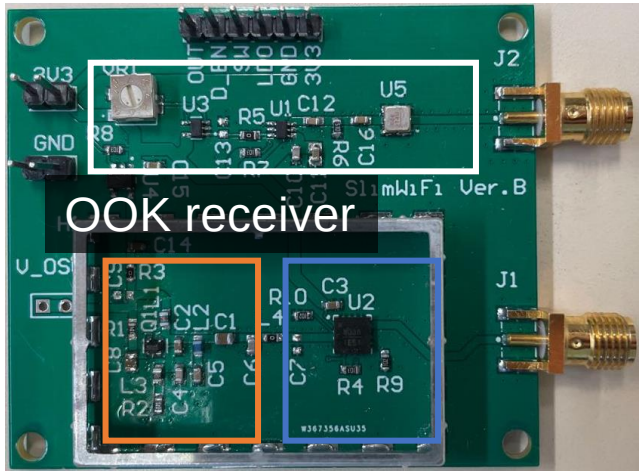


Putting everything together



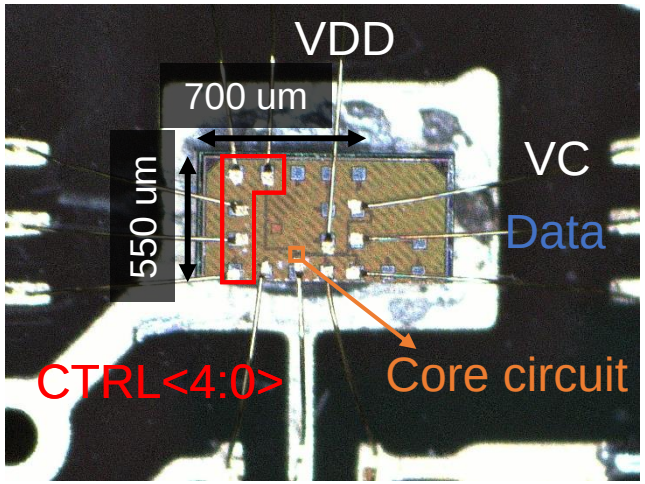
Implementation

COTS Wi-Fi access point
No hardware modification
No firmware modification



LC oscillator RF switch

Prototype
End-to-end test



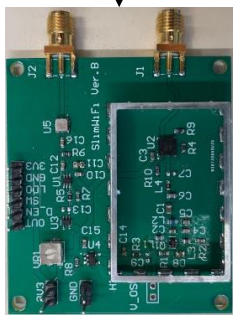
GND RF output

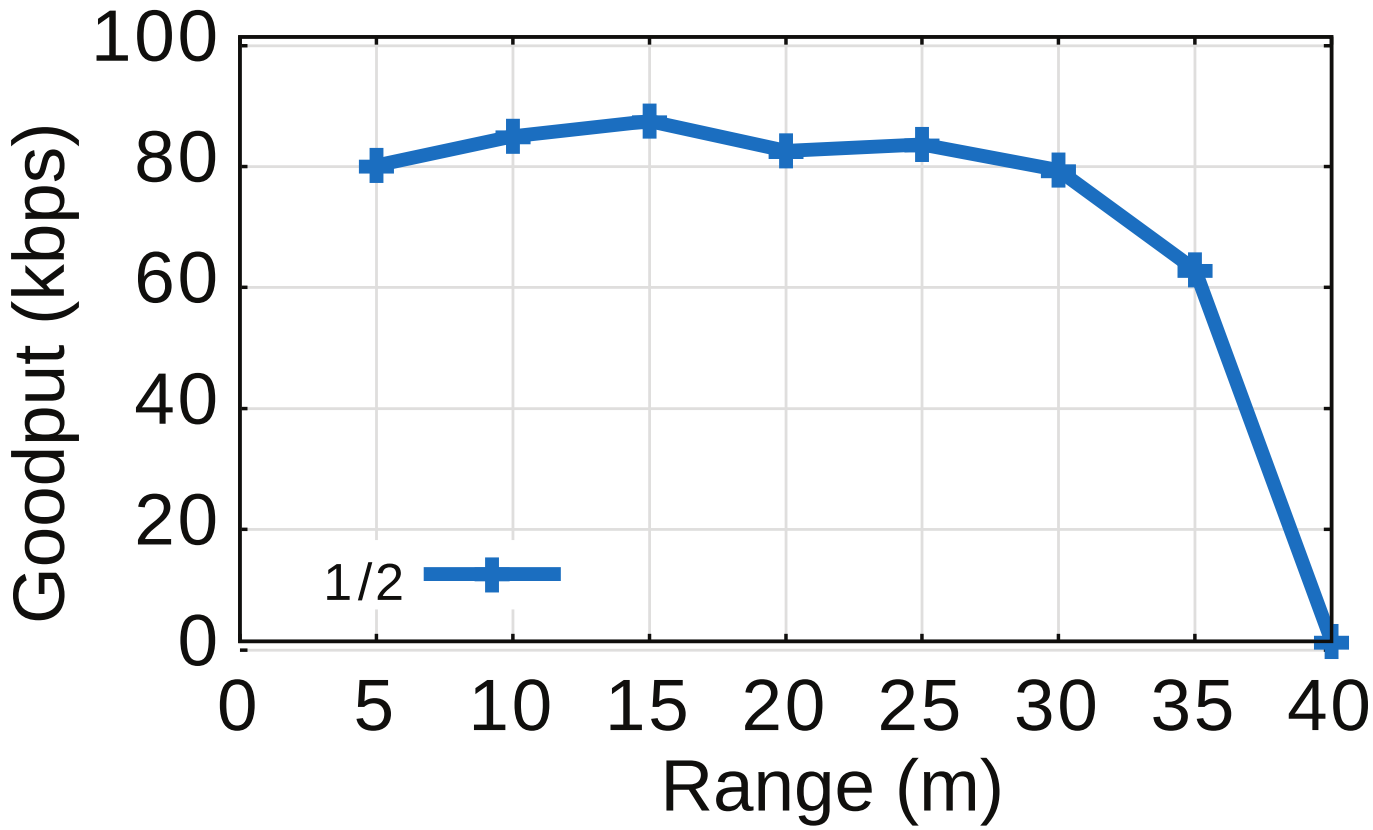
IC tape-out
Slim radio verification

	Frequency (Drift)	Power Consumption @TX Power
Prototype	2460 (± 5) MHz	1 mW @ -20 dBm
Simulated IC	2438 (± 10) MHz	73 µW @ -21 dBm
Fabricated IC	2465 (± 10) MHz	90 µW @ -24 dBm

End to end test

Range

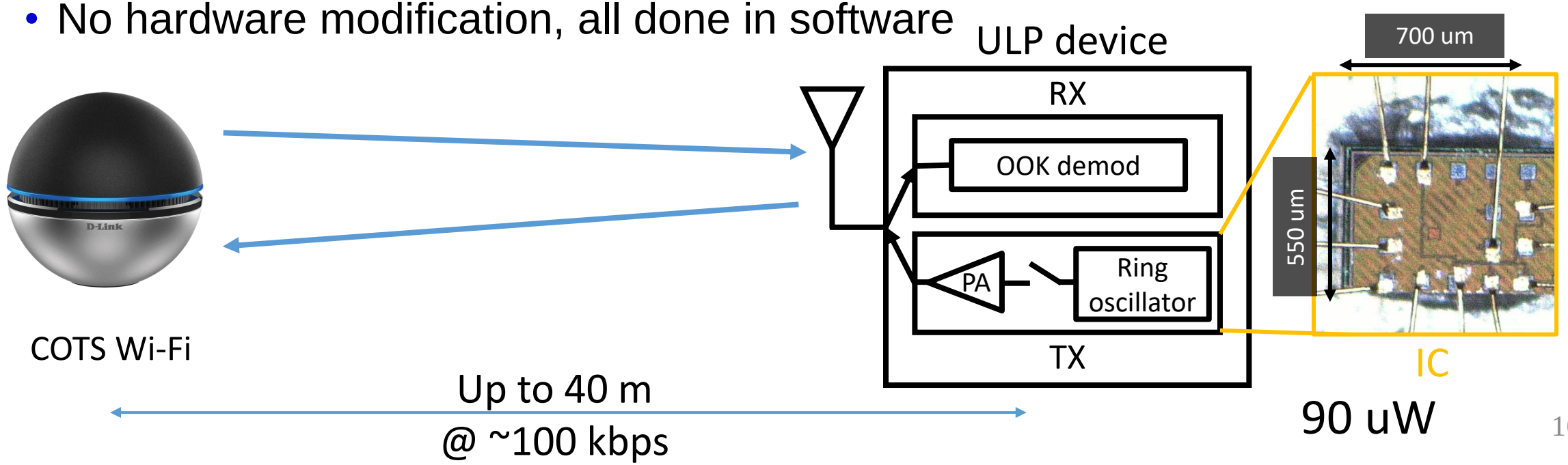




Bit rate:10s of kbps
Range:10s of m

Conclusion

- Slim radio architecture:
  - Throw away power hungry analog components
  - 1000x lower power than Wi-Fi
- Asymmetric communication:
  - Enable slim radio communication with COTS radio infrastructure
  - No hardware modification, all done in software



Thanks!