Enabling Practical Backscatter Communication for On-body Sensors

Pengyu Zhang, Mohammad Rostami, Pan Hu,
Deepak Ganesan

UMass Amherst

Ubiquitous deployment of on-body sensors

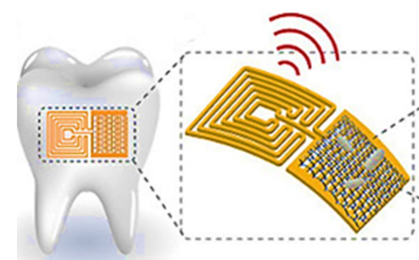
Fitness-band
WiFi Bluetooth

Smart Watch
WiFi Bluetooth

Smartphone
WiFi Bluetooth

Biometric clothing

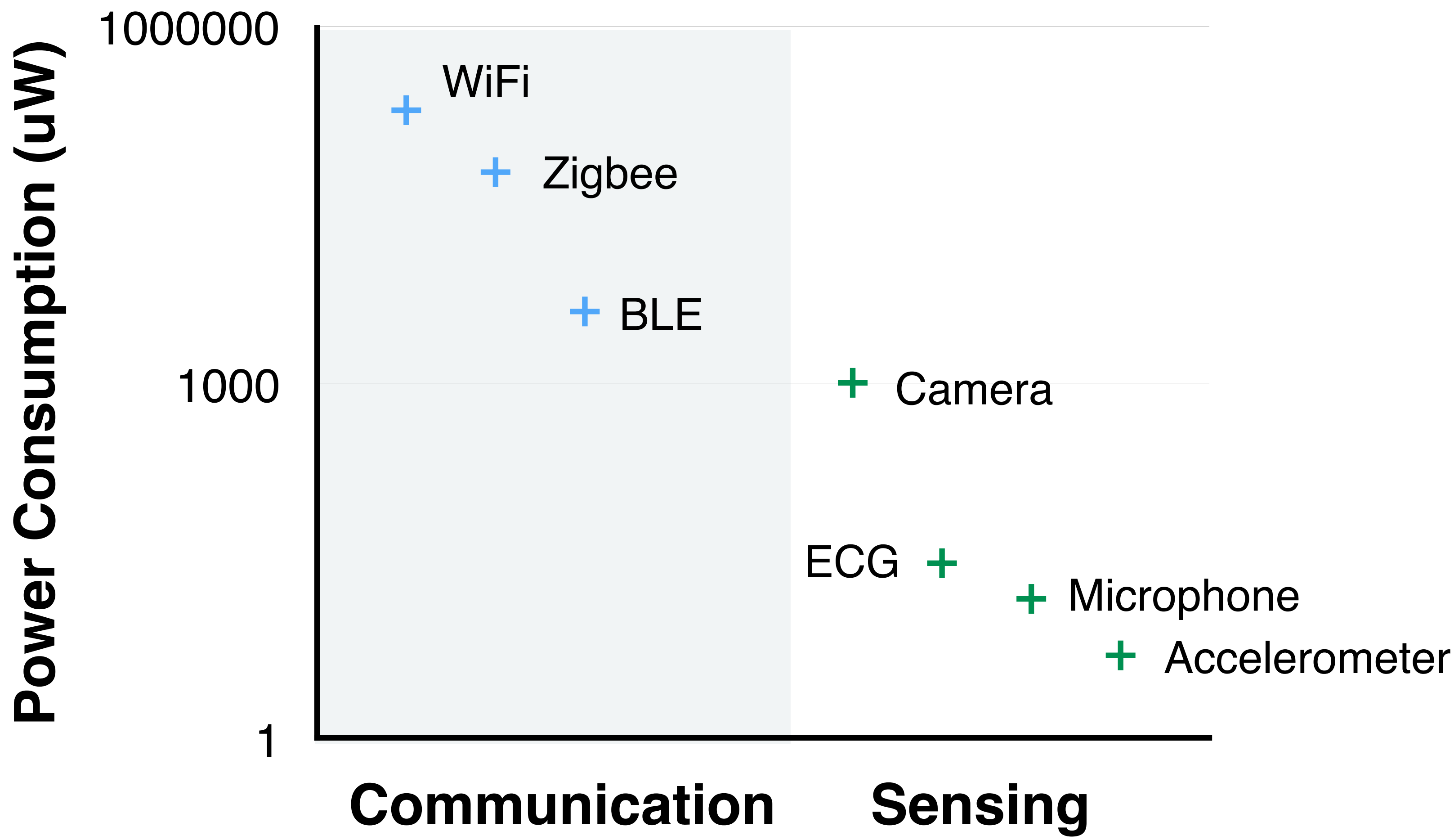
Sensor Tattoo



Teeth Sensor

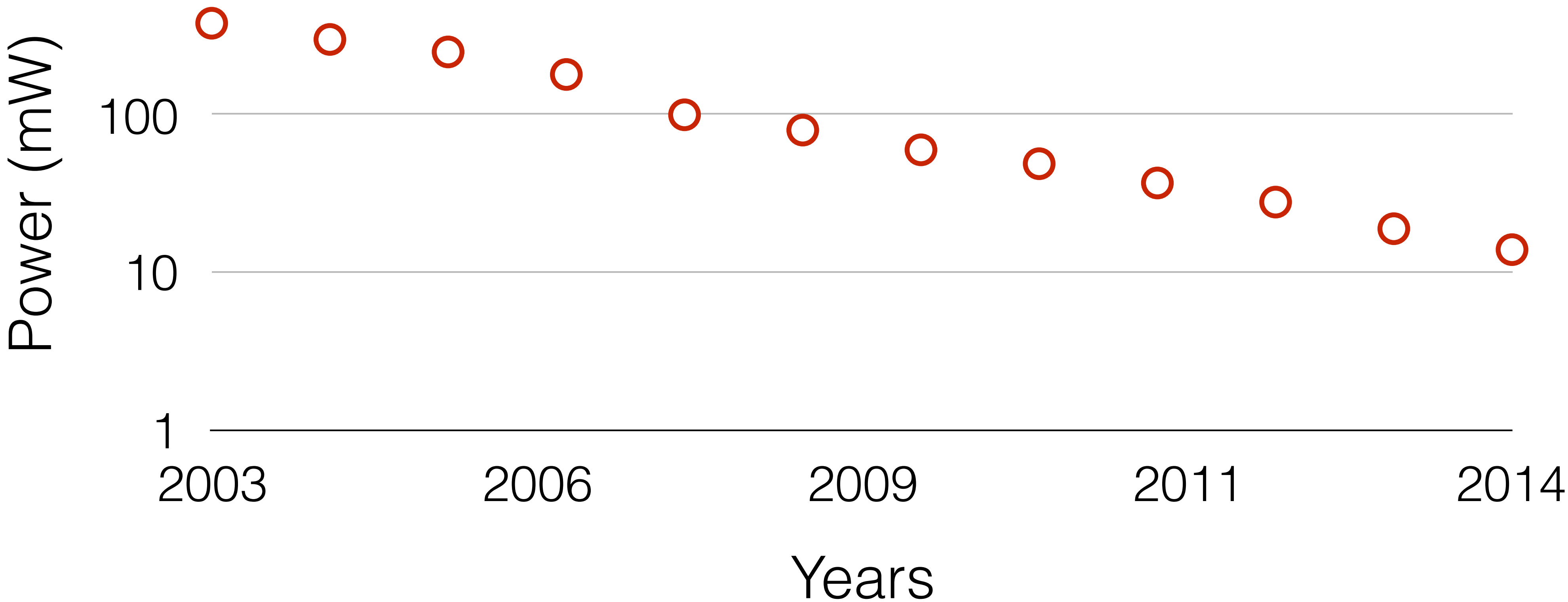
How should we communicate with on-body sensors which have a limited energy budget?

Current state of wireless radio power consumption



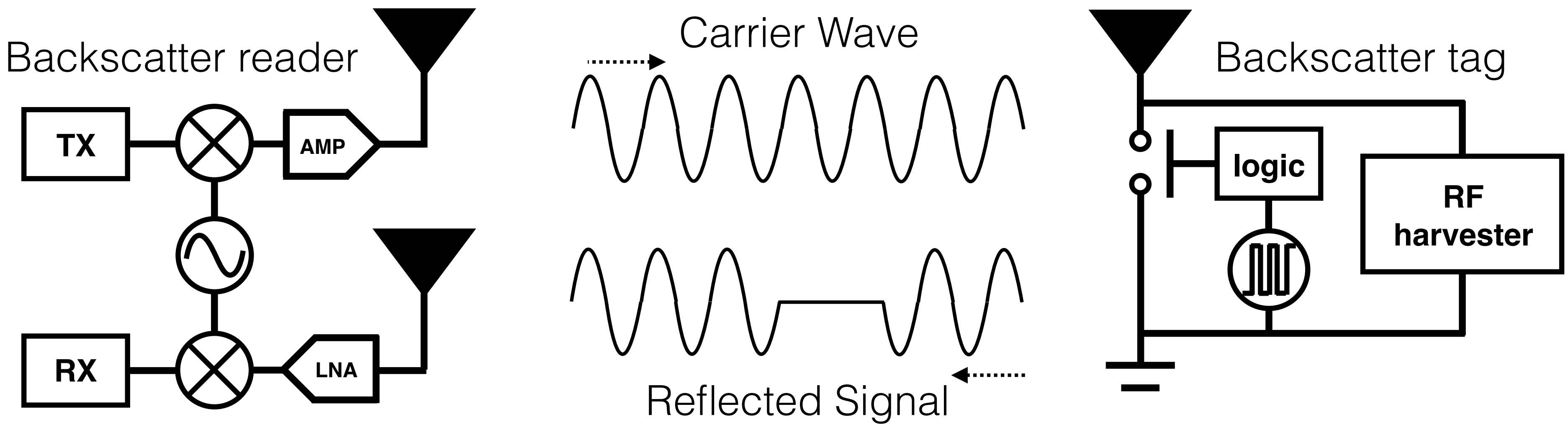
Wireless radios consume an order of magnitude higher power compared to low power sensors

Technology trends in wireless radio power consumption



Wireless radio power reduction is slow…

Backscatter — an ultra low power communication primitive



Backscatter enables ultra low-power wireless communication

Problem: **NO** reader infrastructure in mobile environment

Fitness-band

Wi Fi Bluetooth®

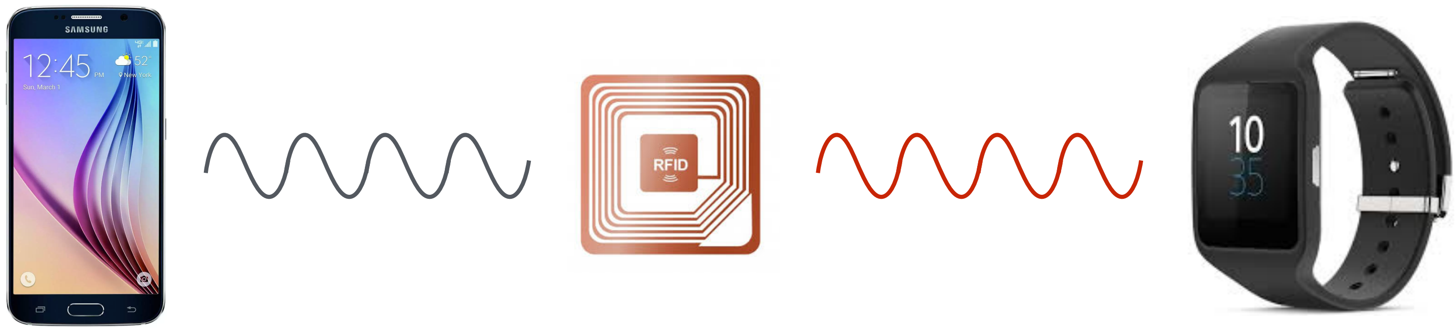
Smart Watch

Wi Fi Bluetooth®

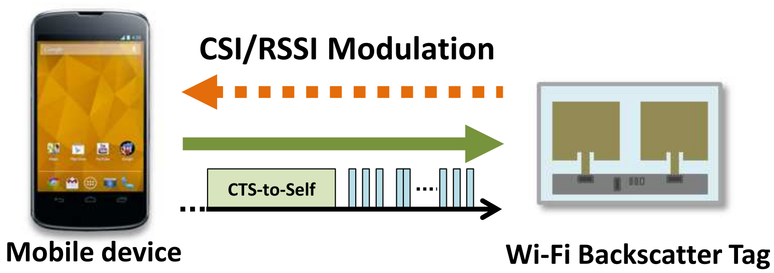
Smartphone

Wi Fi Bluetooth®

Related work: leveraging WiFi signals for backscatter

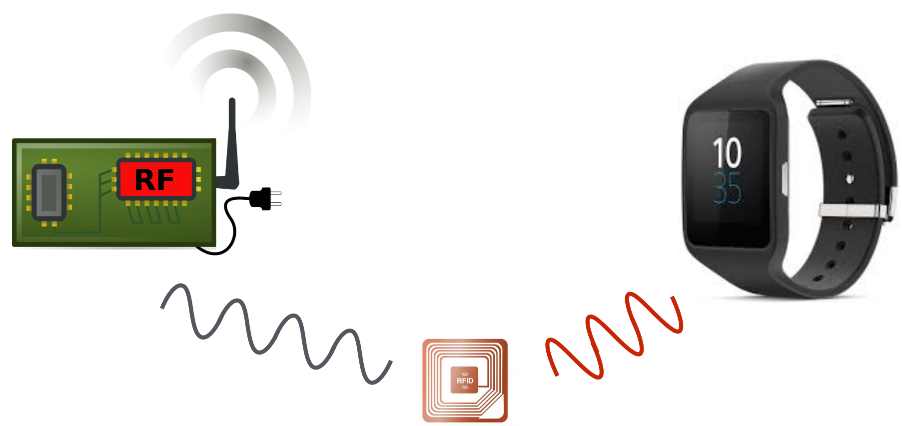


Infrastructure-less backscatter



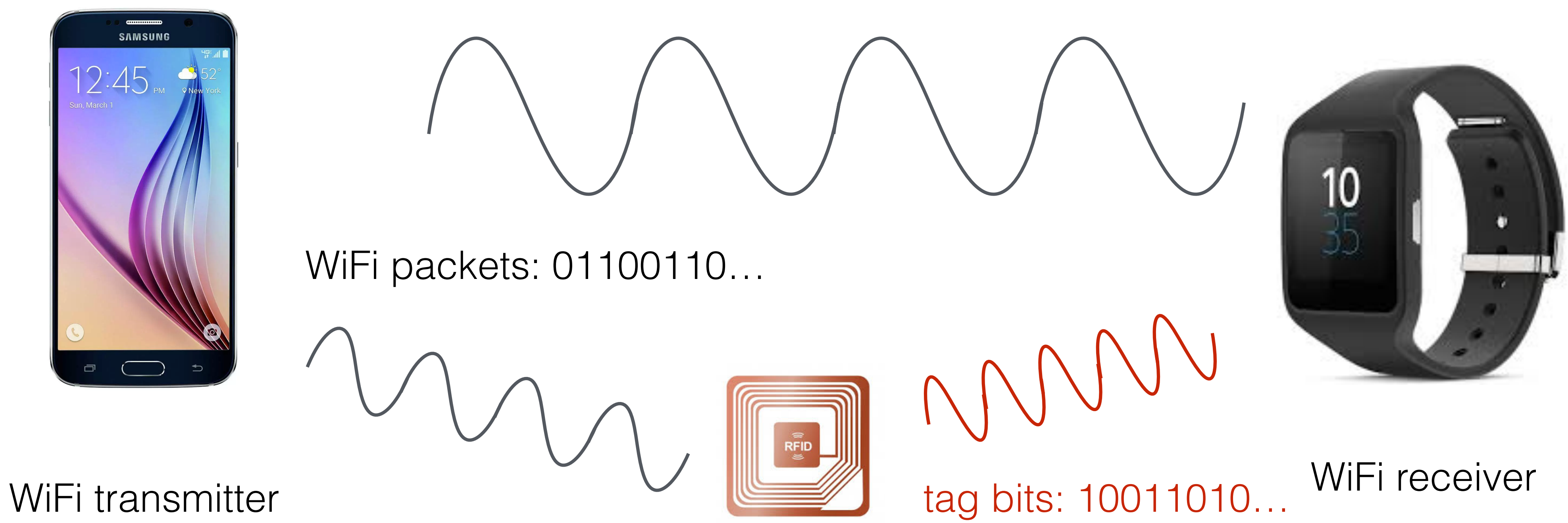
WiFi Backscatter (Sigcomm14)

Infrastructure-assisted backscatter



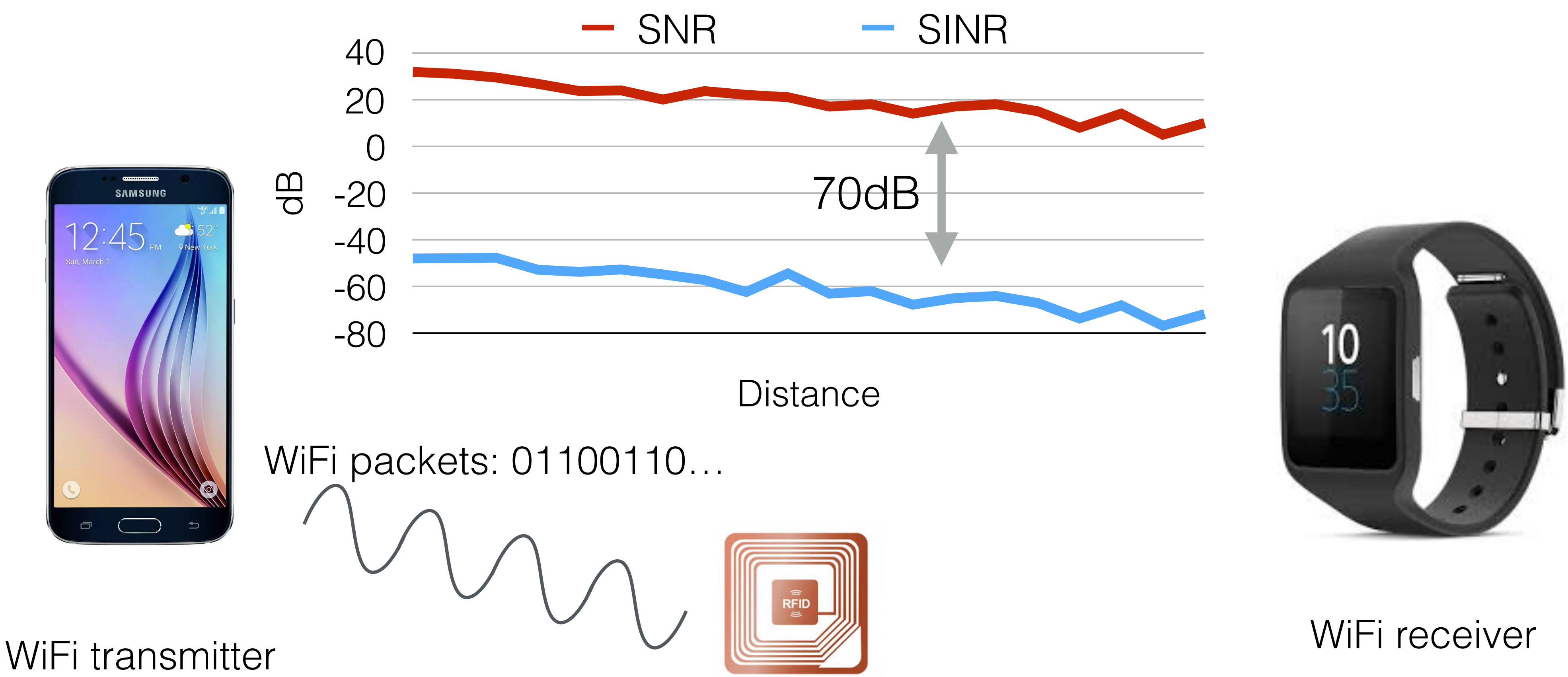
Passive WiFi (NSDI16)

WiFi Backscatter (Sigcomm 14) — backscatter WiFi signals



Limitation: WiFi signal is much louder than the backscatter signal

WiFi Backscatter (Sigcomm 14) — backscatter WiFi signals



Limitation: WiFi signal is much louder than the backscatter signal

Passive WiFi (NSDI 16) — independent carrier transmitter

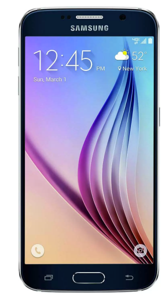
Limitation: needs a new device to be carried

Fitness-band

WiFi Bluetooth

Smart Watch

WiFi Bluetooth

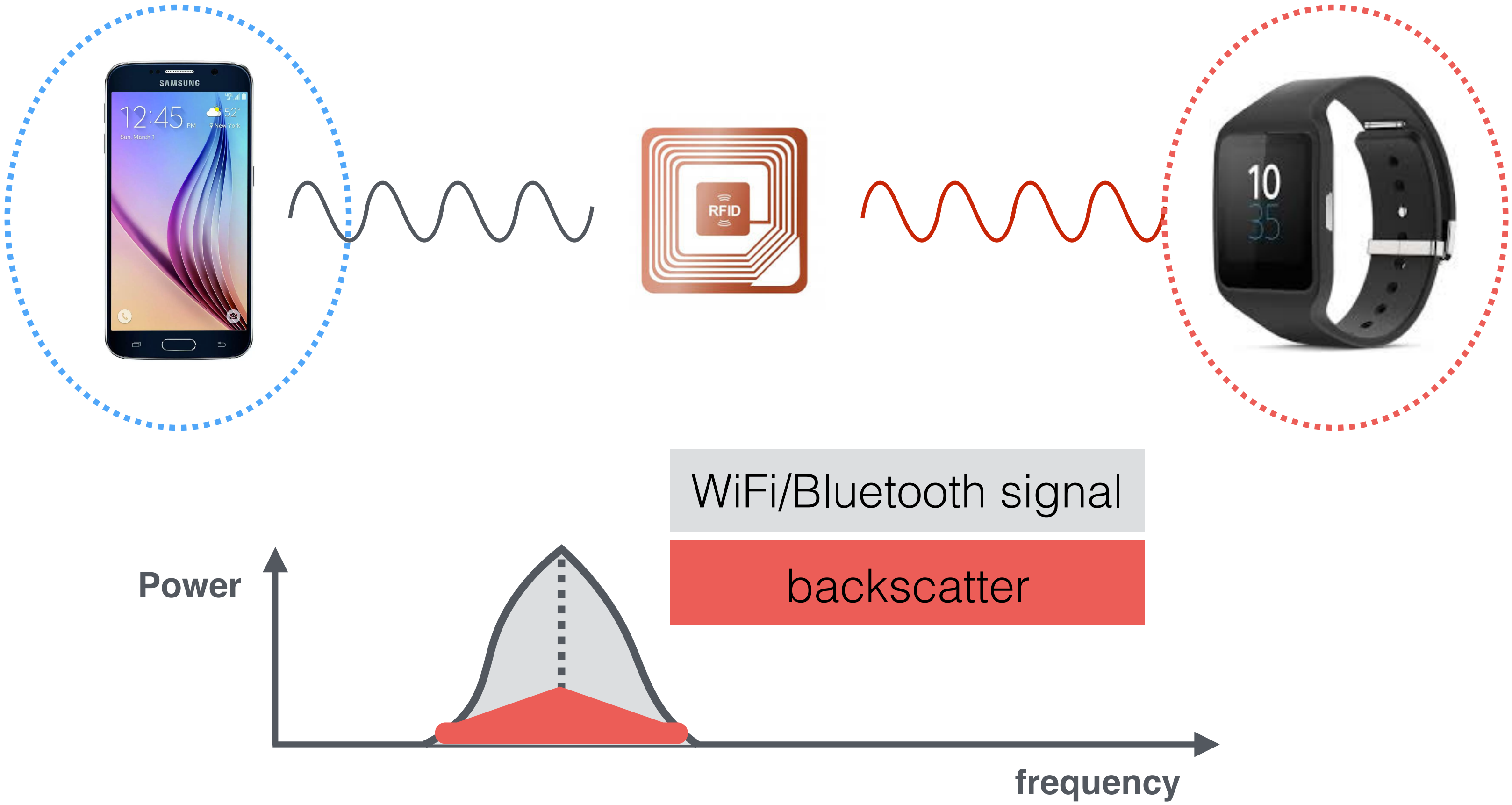


Smartphone

WiFi Bluetooth

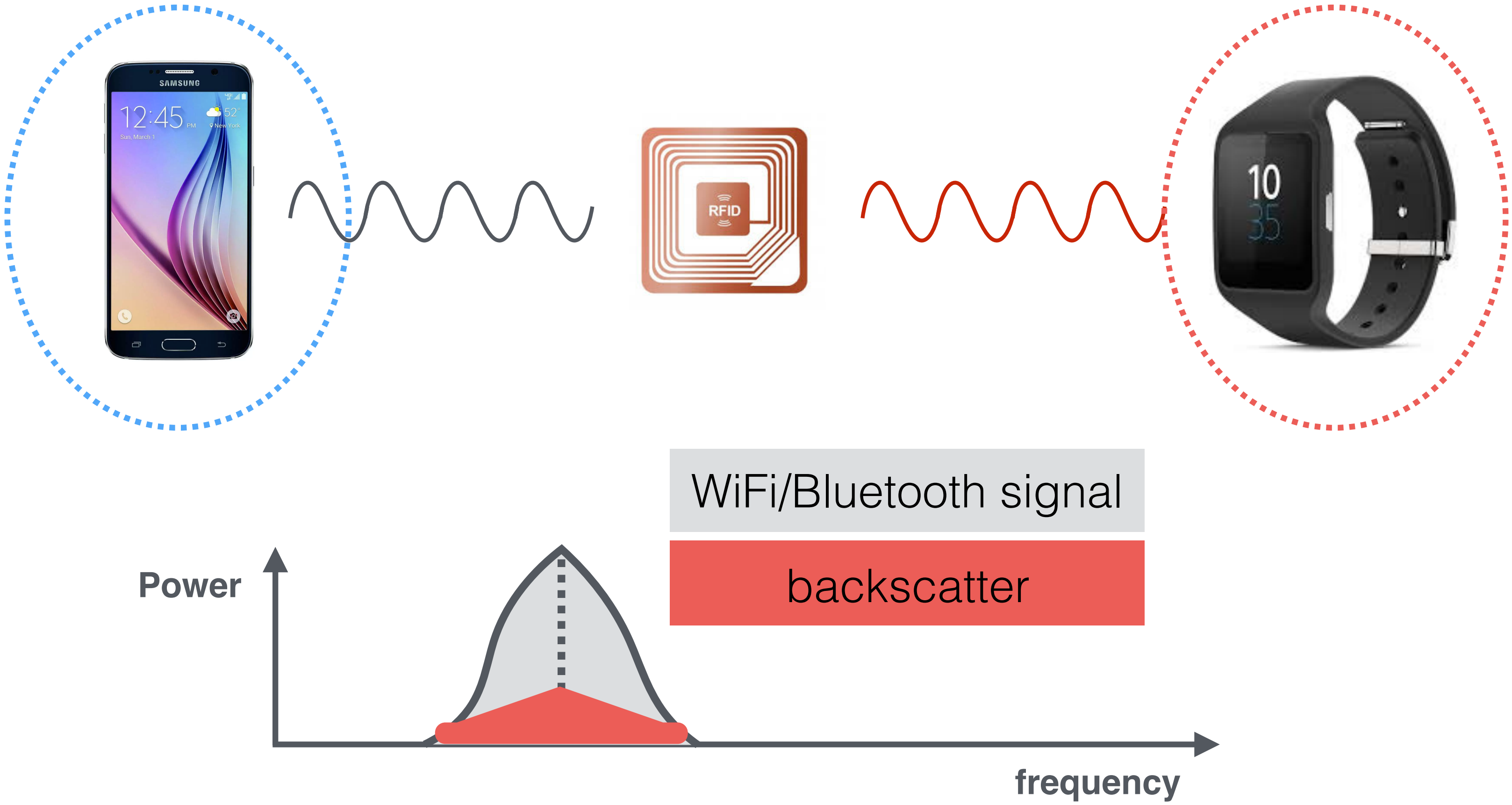
Can we leverage multiple WiFi/Bluetooth radios on mobile devices to enable backscatter?

How do we deal with interference?



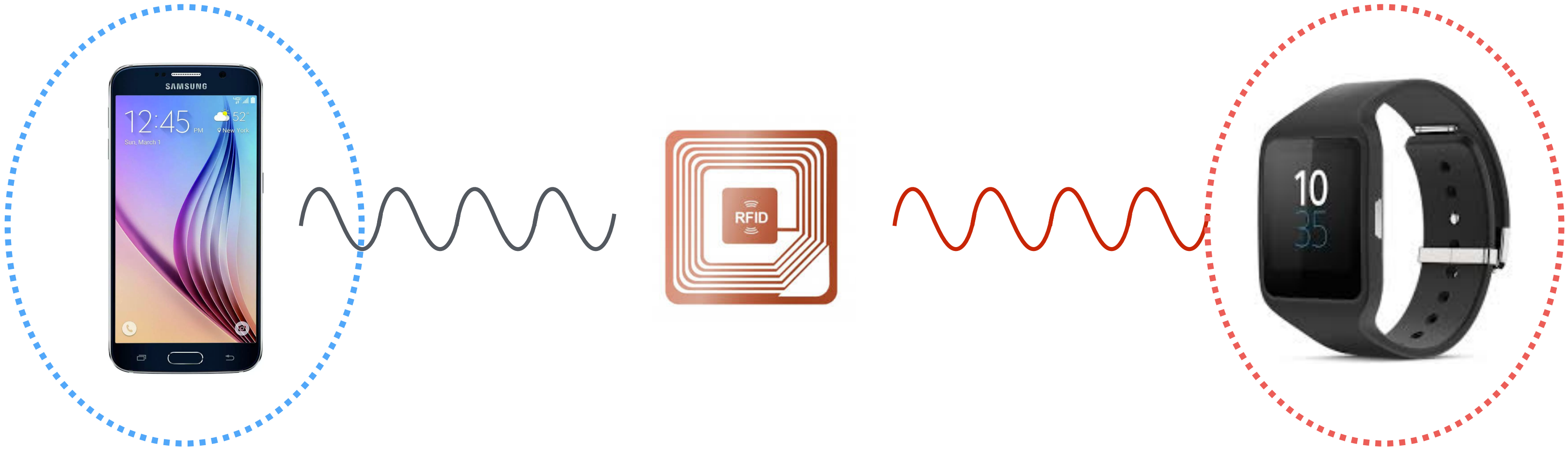
Strong interference because backscatter channel and WiFi/ Bluetooth channel are same.

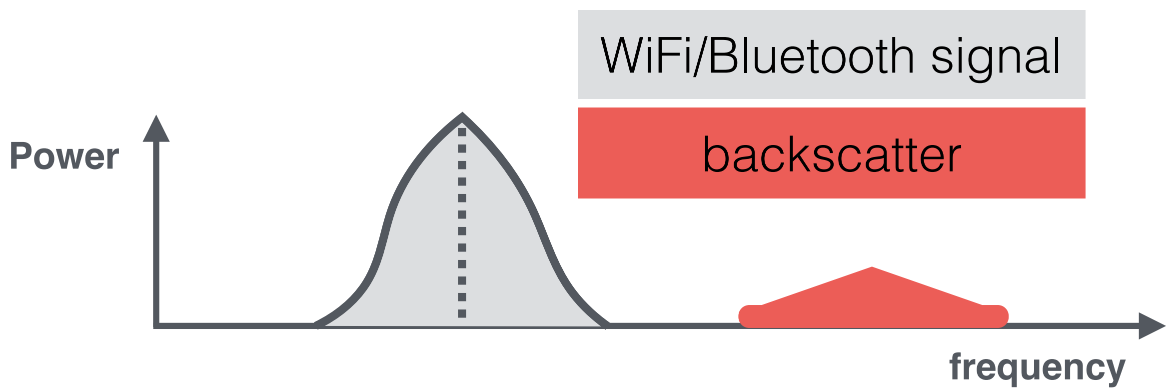
How do we deal with interference?



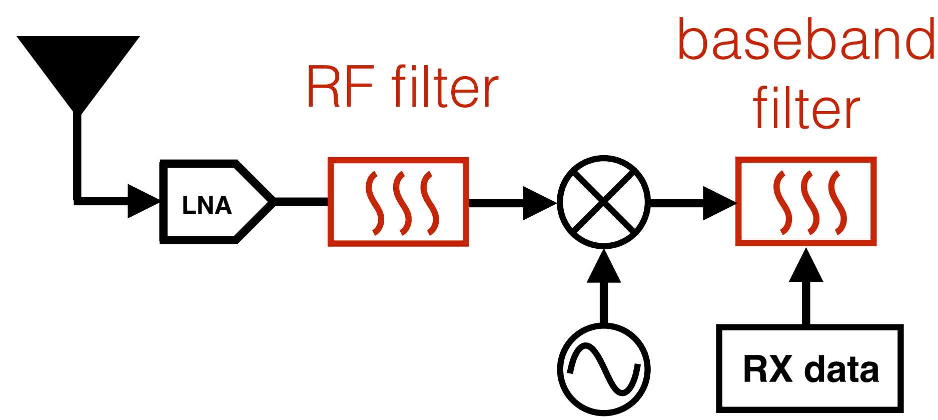
Interference reduces if backscatter channel is shifted away from WiFi/Bluetooth channel

Why does interference reduce?

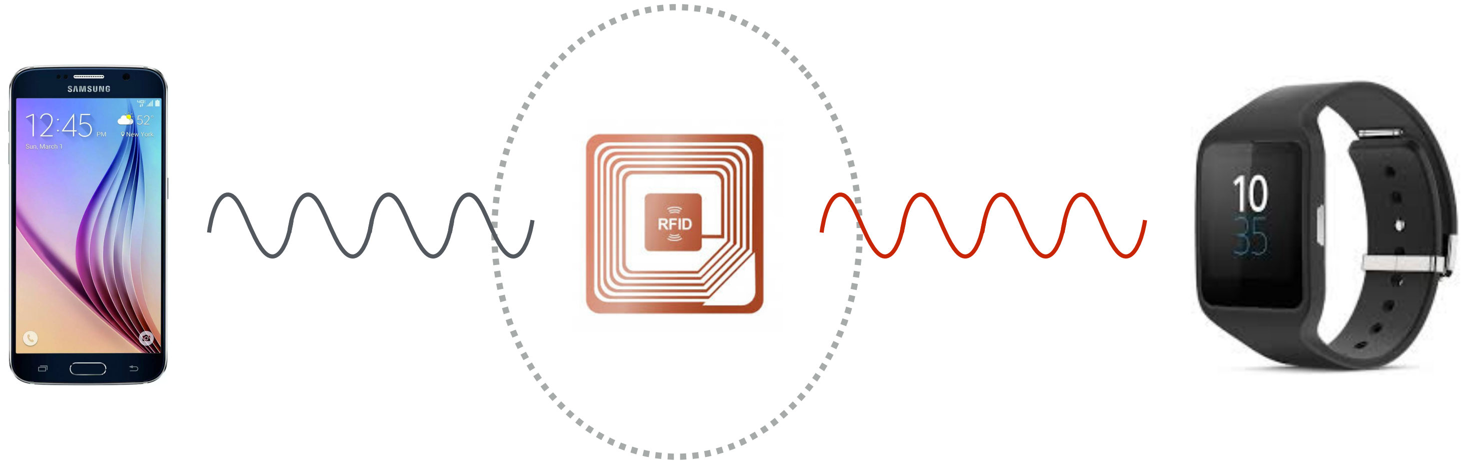




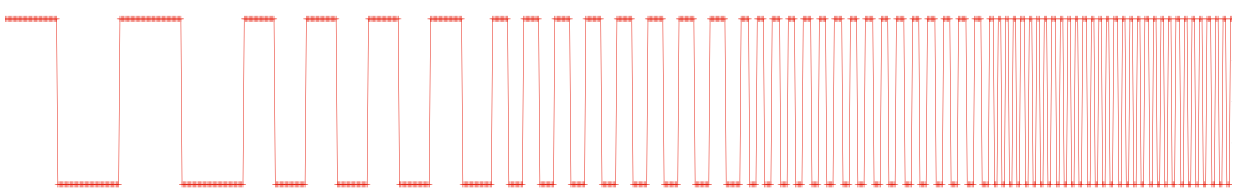
Filters on commodity radios help interference reduction

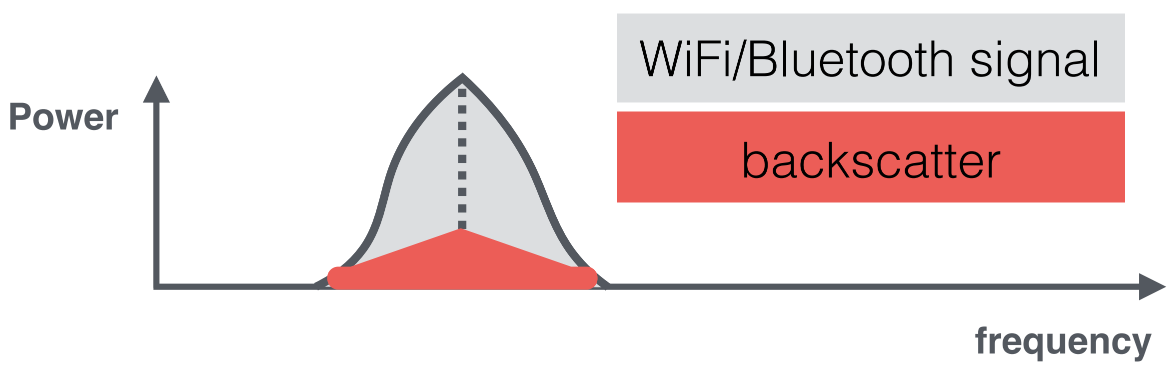


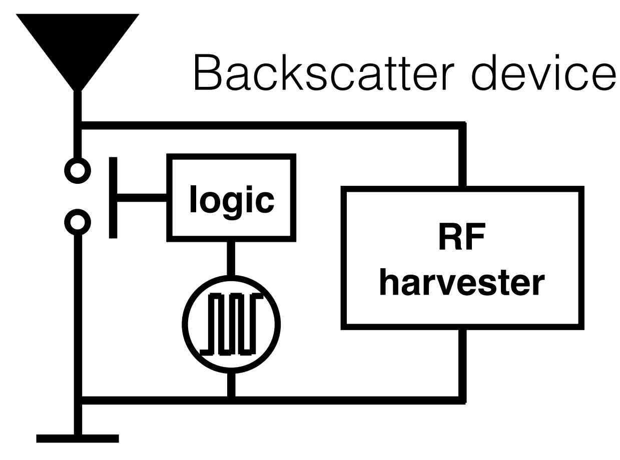
How to frequency-shift backscattered signals?



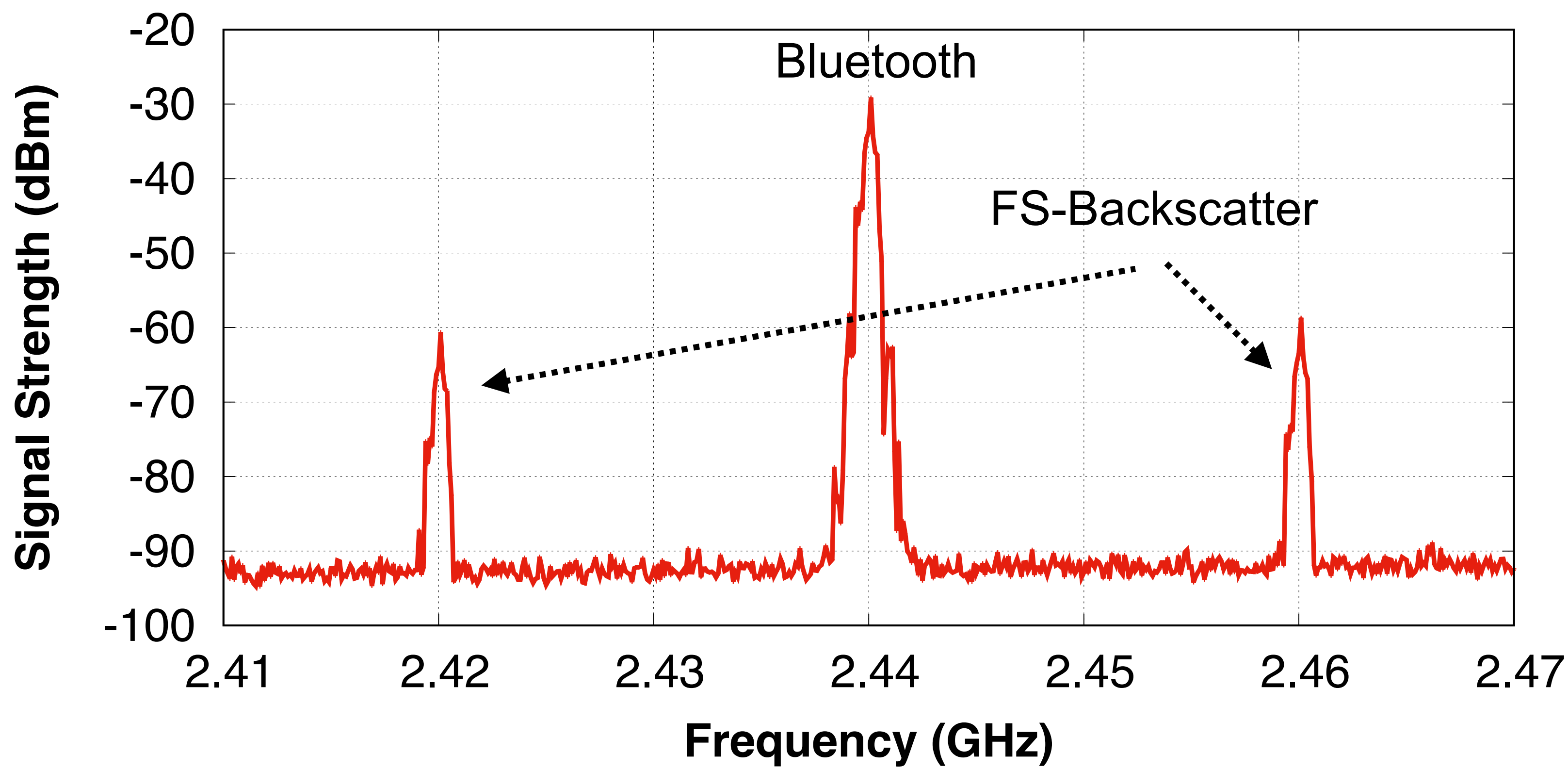
backscatter(t) = wifi(t) * tag(t)



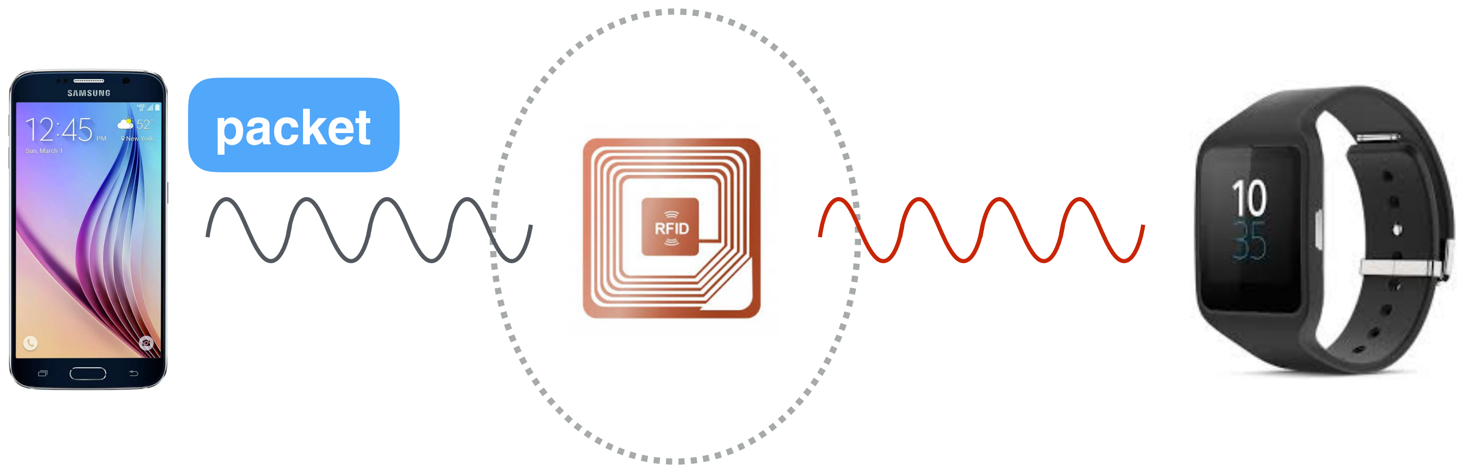




Spectrum when tag backscatters Bluetooth signals



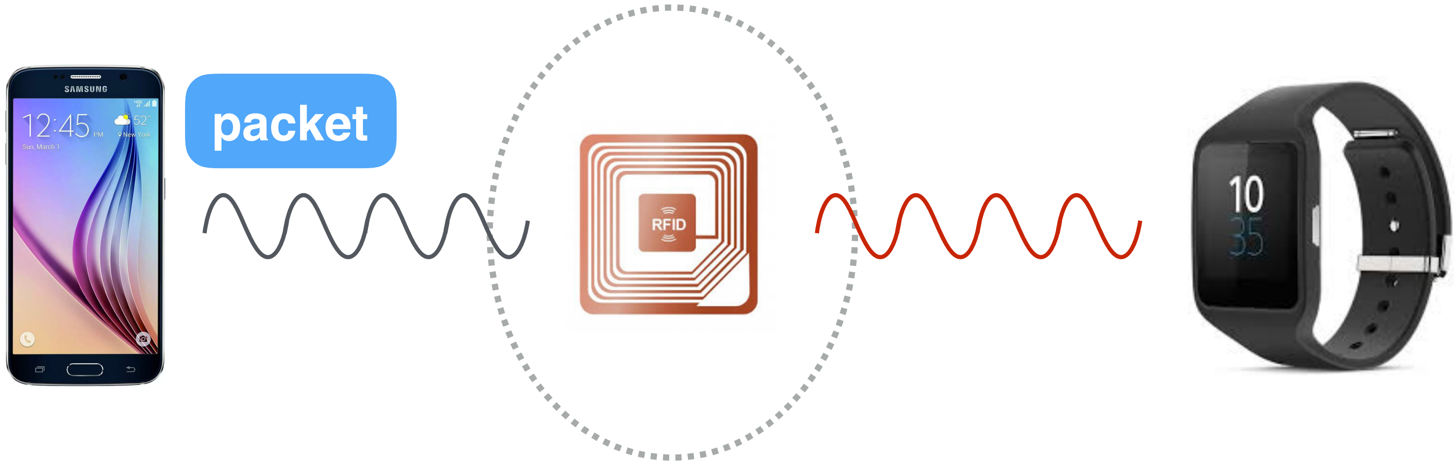
How to embed bits? — packet-level encoding



Packet-level Encoding

Bit-level Encoding

How to embed bits? — packet-level encoding



Packet-level Encoding

Bit-level Encoding

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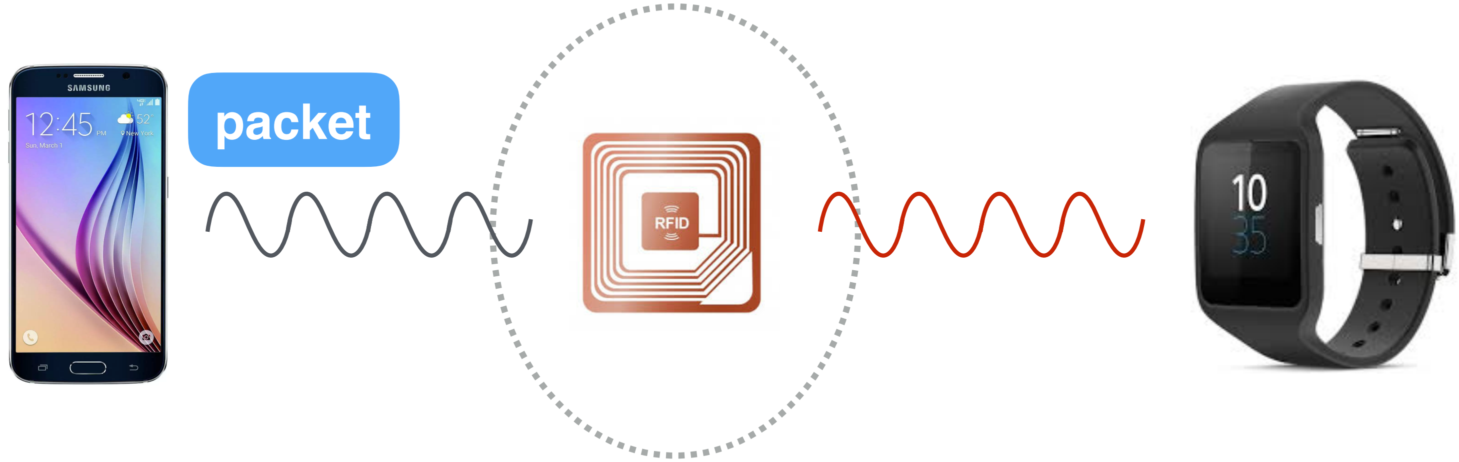
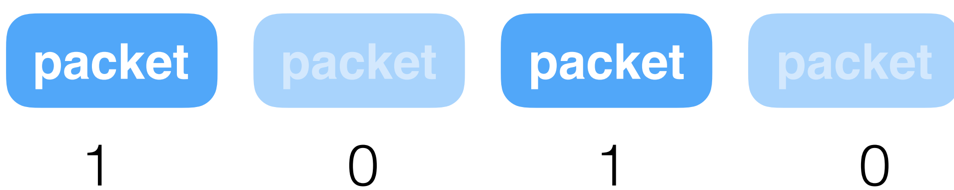
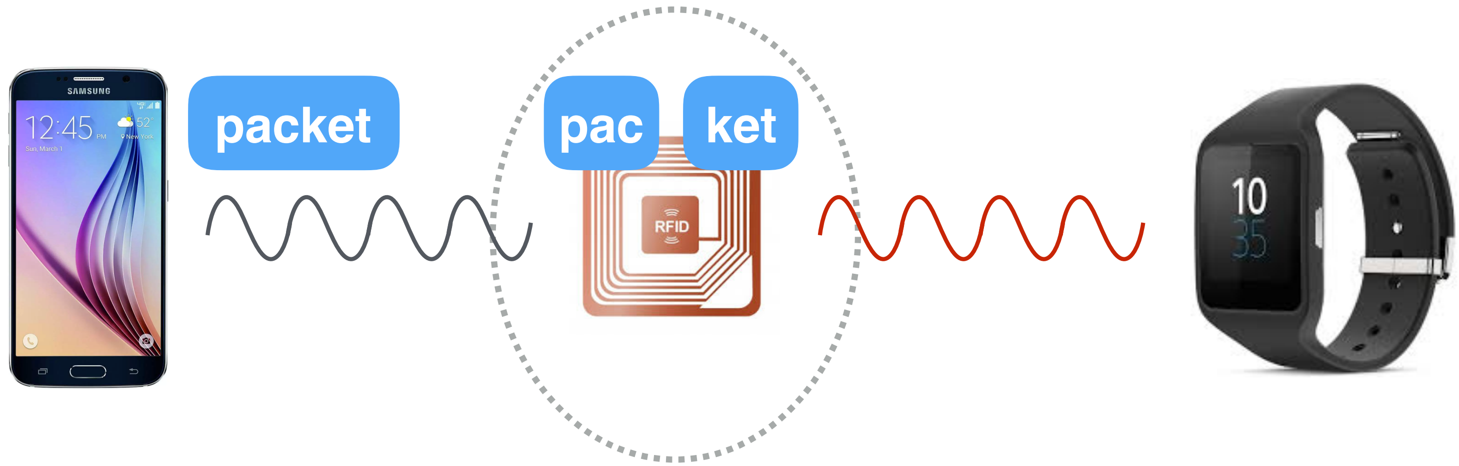


Packet-level Encoding

Bit-level Encoding



How to embed bits? — bit-level encoding

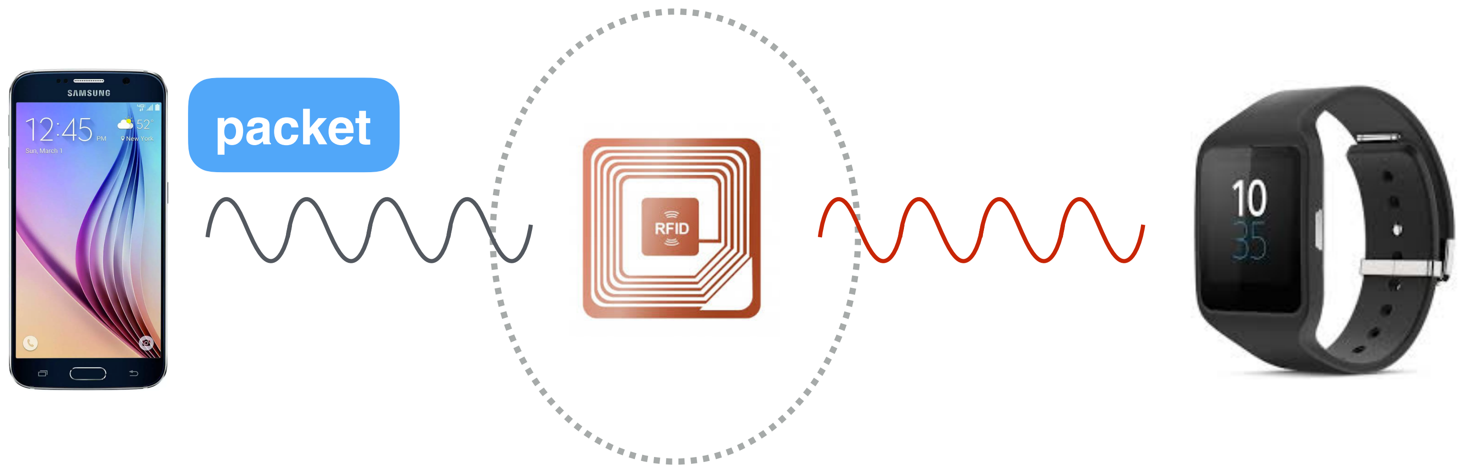


Packet-level Encoding

packet	packet	packet	packet
1	0	1	0

Bit-level Encoding

How to embed bits? — bit-level encoding



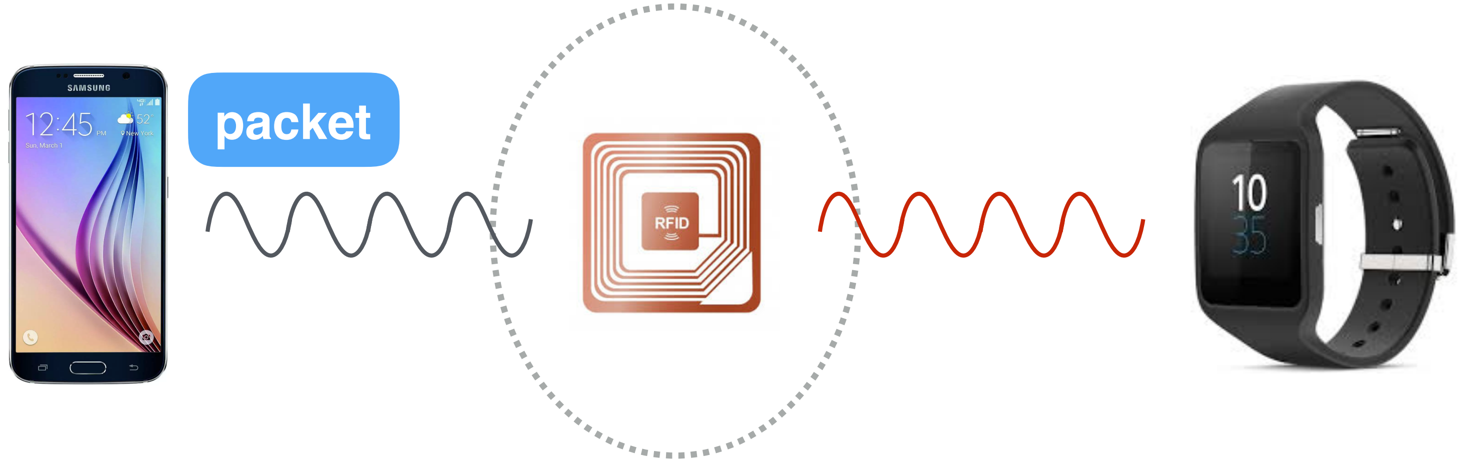
Packet-level Encoding

1 0 1 0

Bit-level Encoding

0 1 0 1 1 0 1

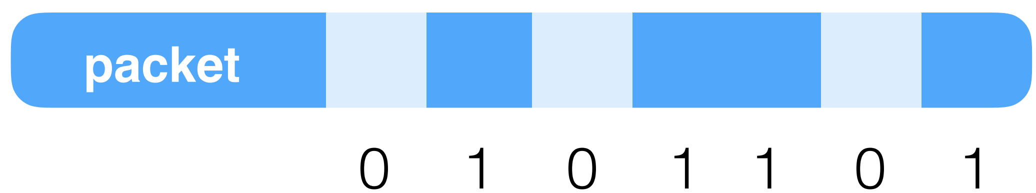
How to embed bits? — bit-level encoding



Packet-level Encoding

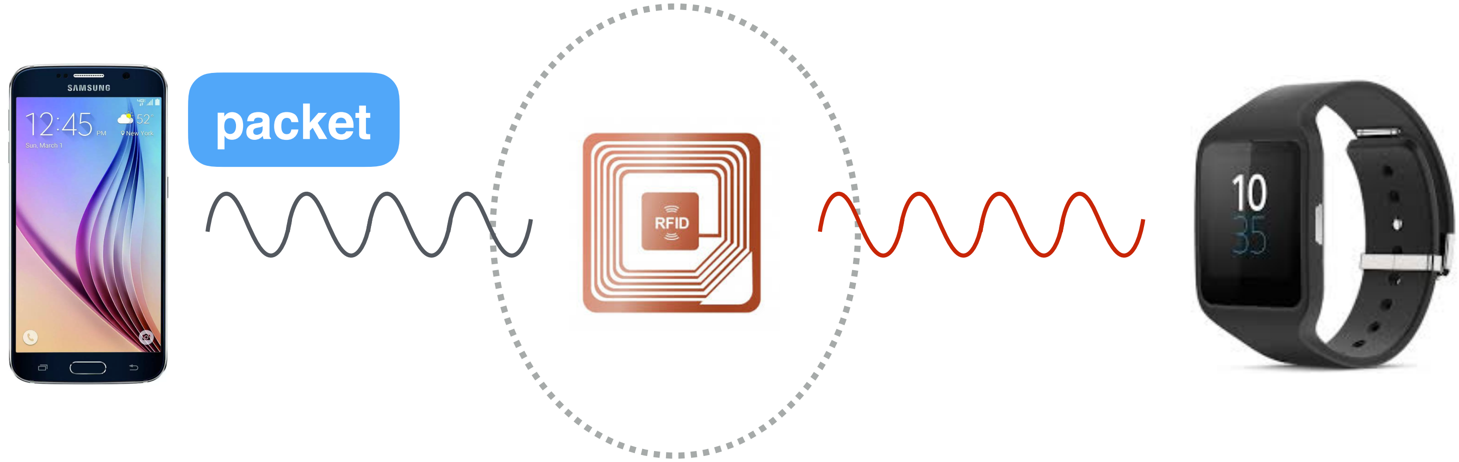
Longer communication range but lower bitrate

Bit-level Encoding

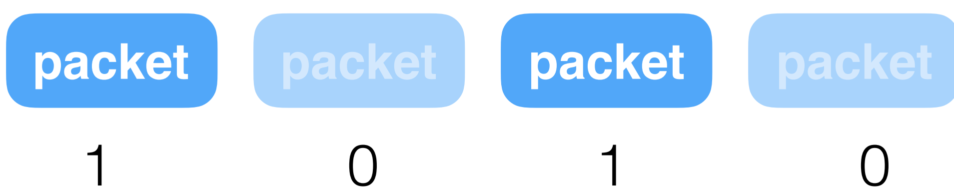


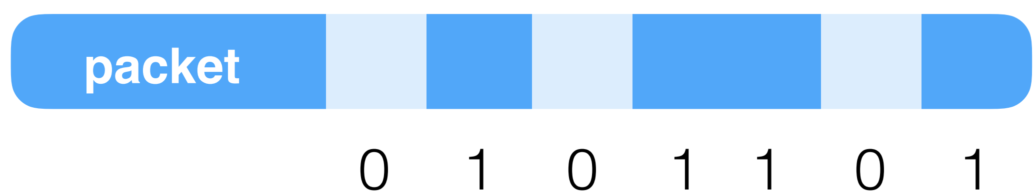
Higher data rate but shorter communication range

How to embed bits? — bit-level encoding



Packet-level Encoding	Bit-level Encoding





Packet-level Encoding:

- 400 bps throughput
- 5m communication range

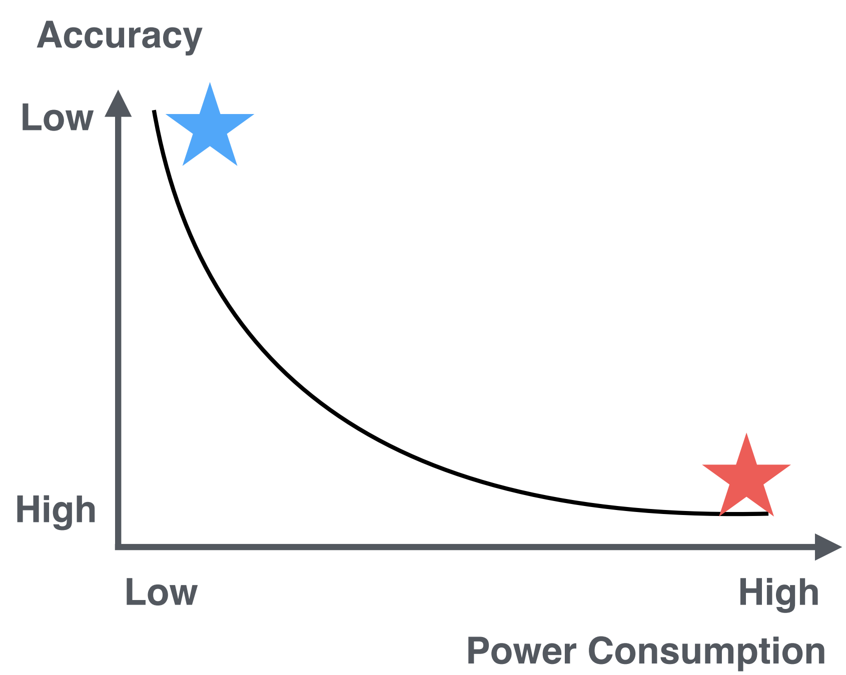
Bit-level Encoding:

- 48kbps throughput
- 3.6m communication range

What about the tag power consumption?

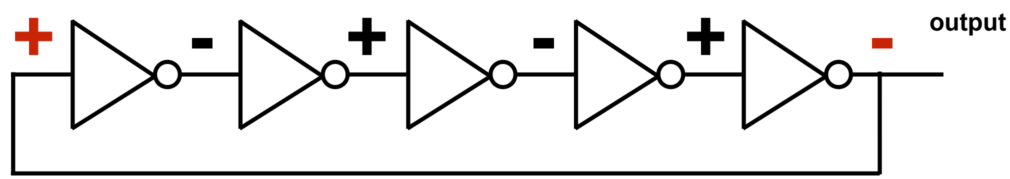
Can we perform 20MHz frequency shifting at a few uWs?

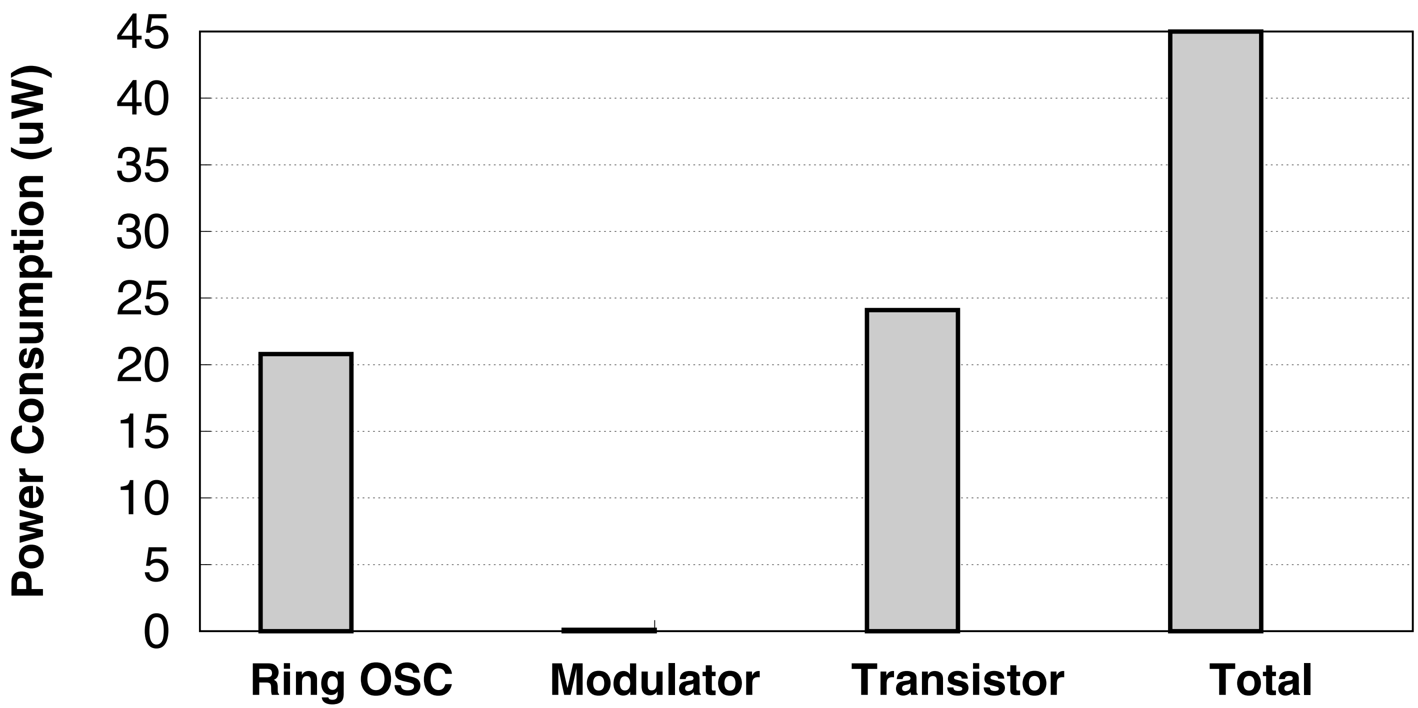
Oscillator Frequency	Power Consumption
32kHz	1.48μW
1MHz	326μW
10MHz	**2.04mW**



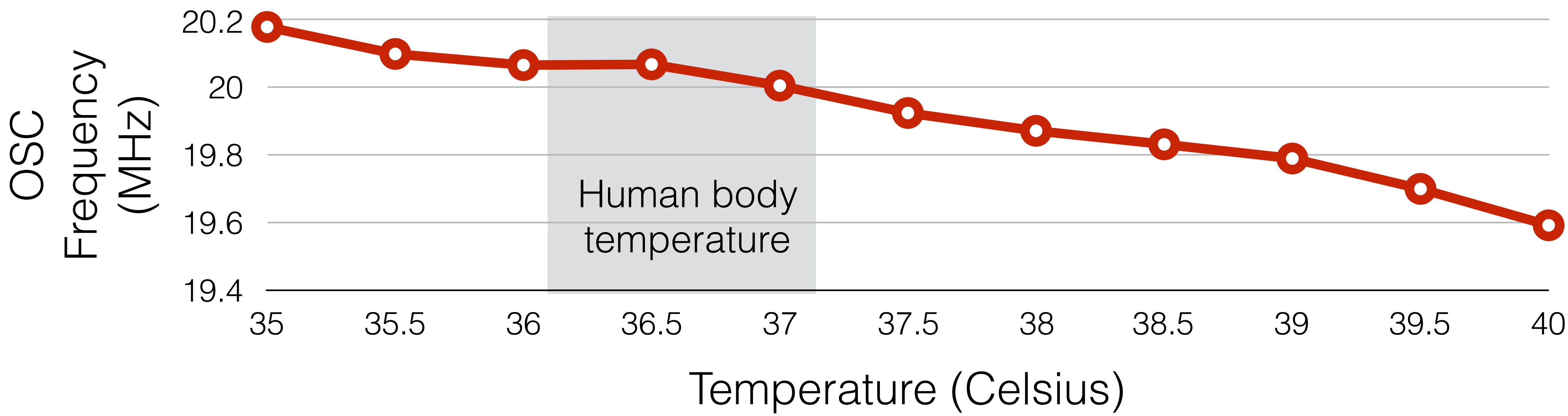
Leverage low power ring oscillator

Use the smallest number of gates to produce the desired frequency shift.

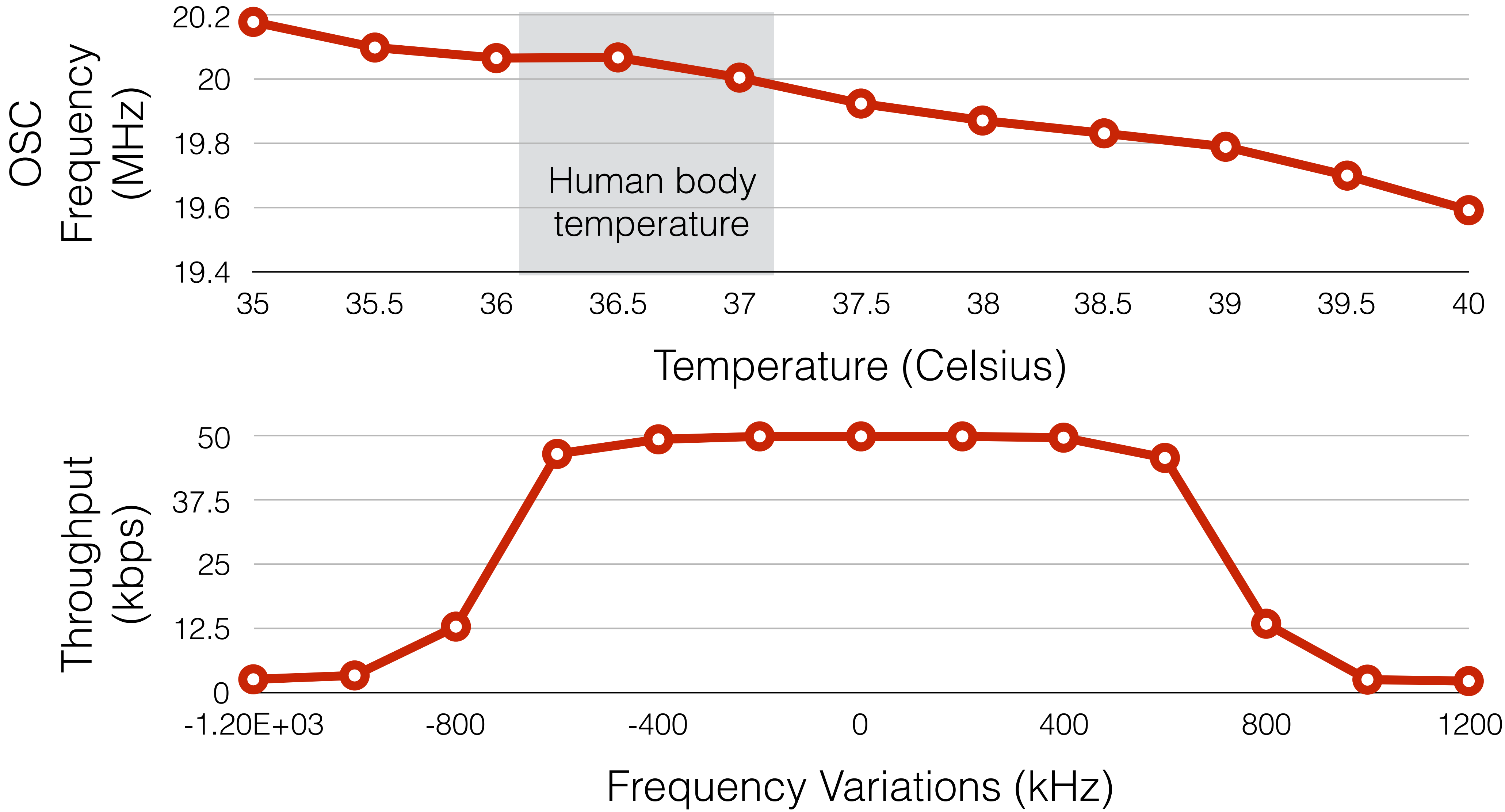




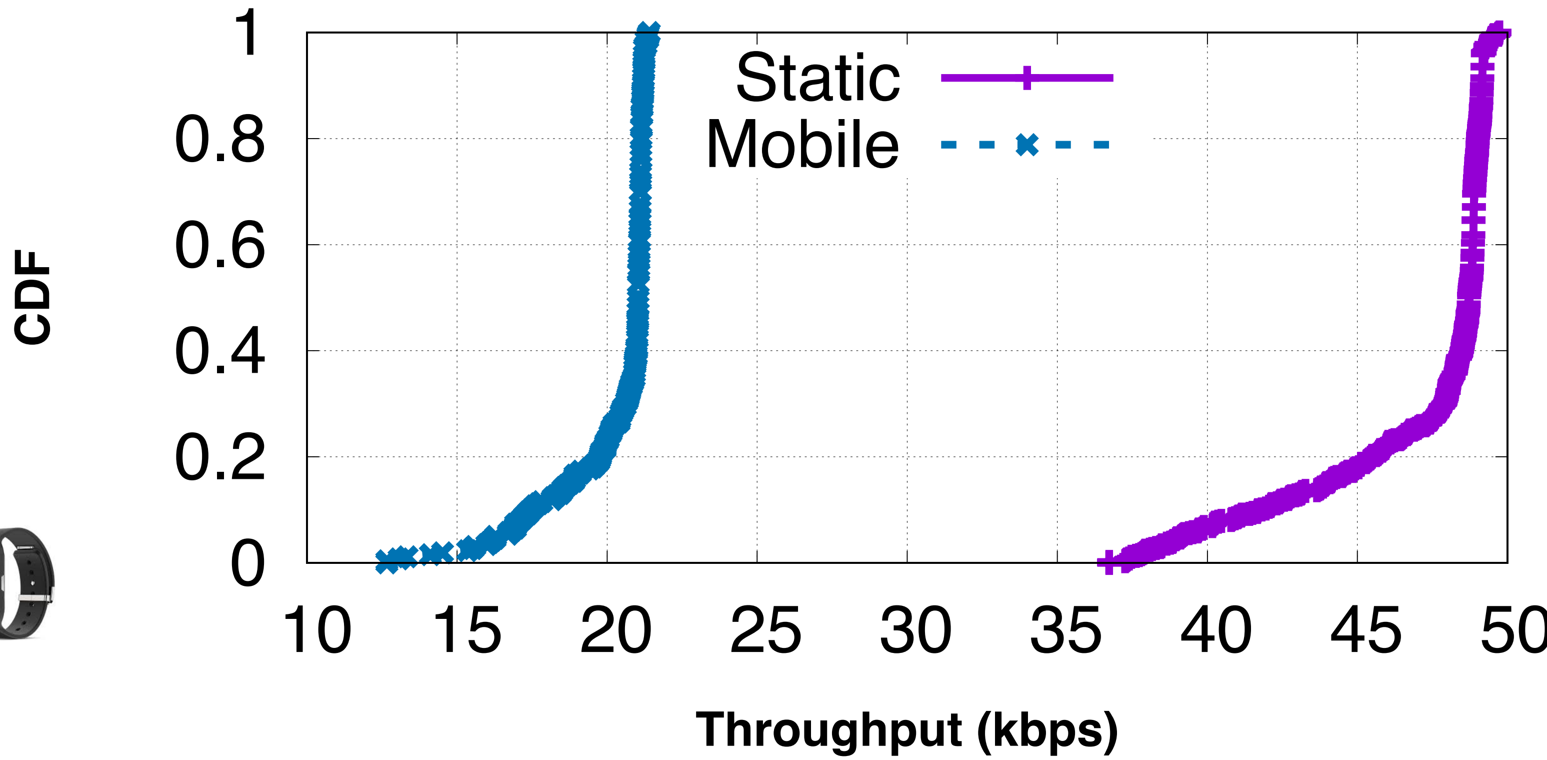
Disadvantages — sensitive to temperature variations



Disadvantages — sensitive to temperature variations



FS-Backscatter performance in mobile deployment



FS-Backscatter achieves around 22kbps in mobile deployment

Conclusion

Enable backscatter for wearables by leveraging multiple Bluetooth and WiFi radios on mobile devices.