



# Passive Backscatter Sensors for IoT applications

Nuno Borges Carvalho

Ricardo Correia

Daniel Belo

Felisberto Pereira

# Motivation

## Present Io“Things”

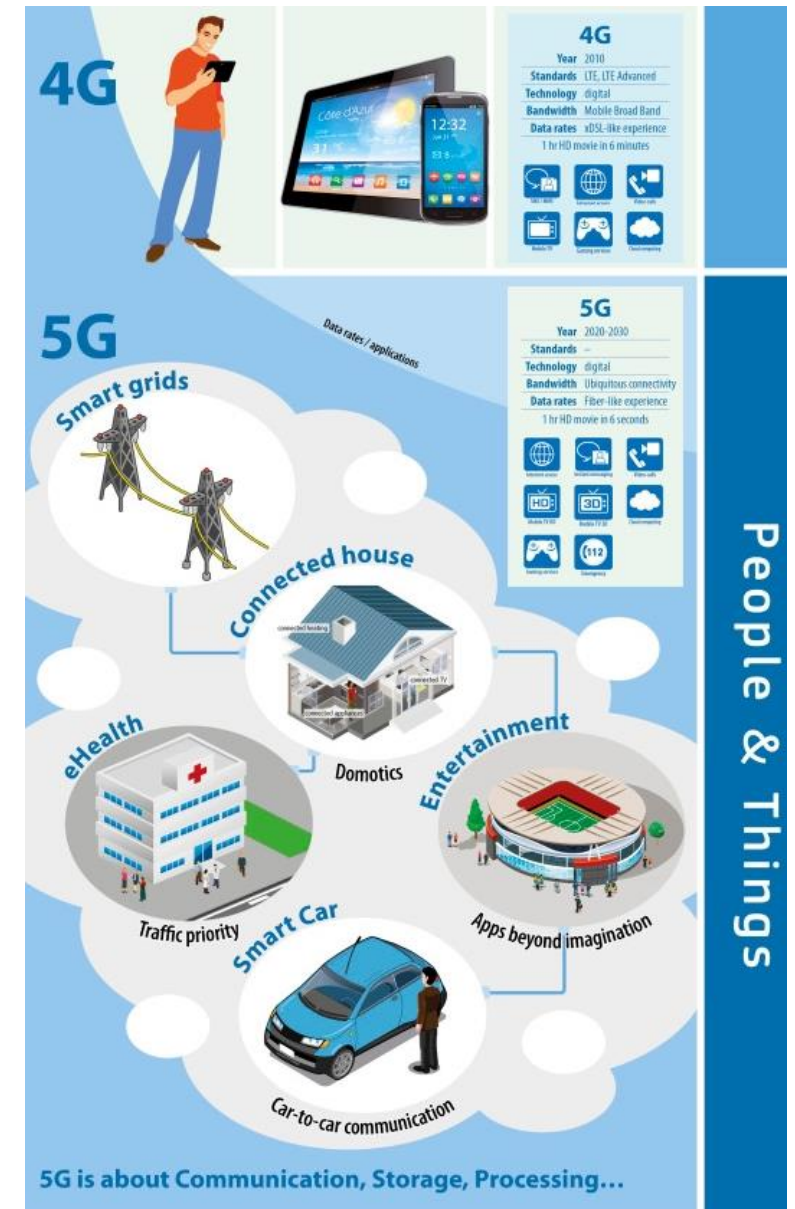
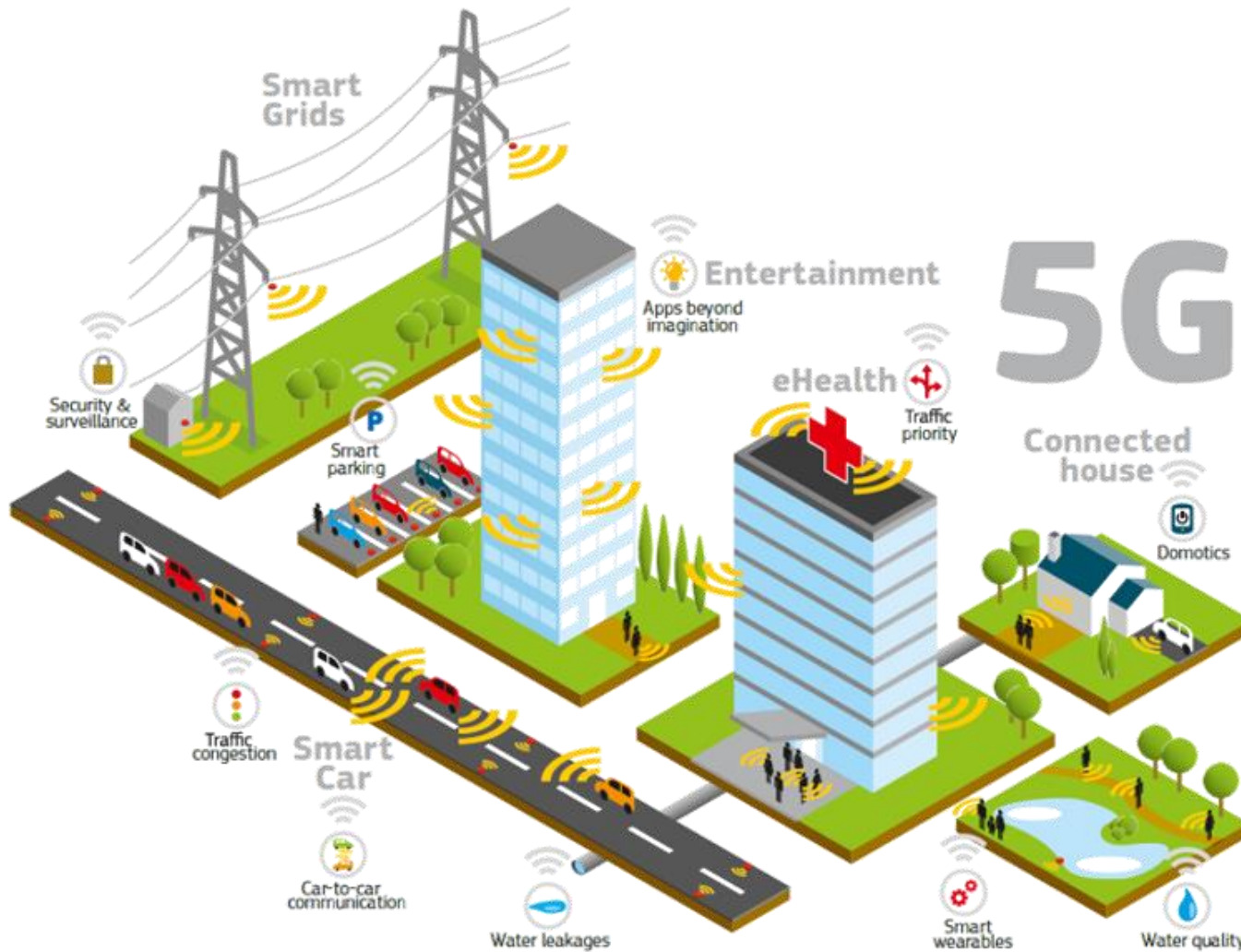


## Near future Io“Things”

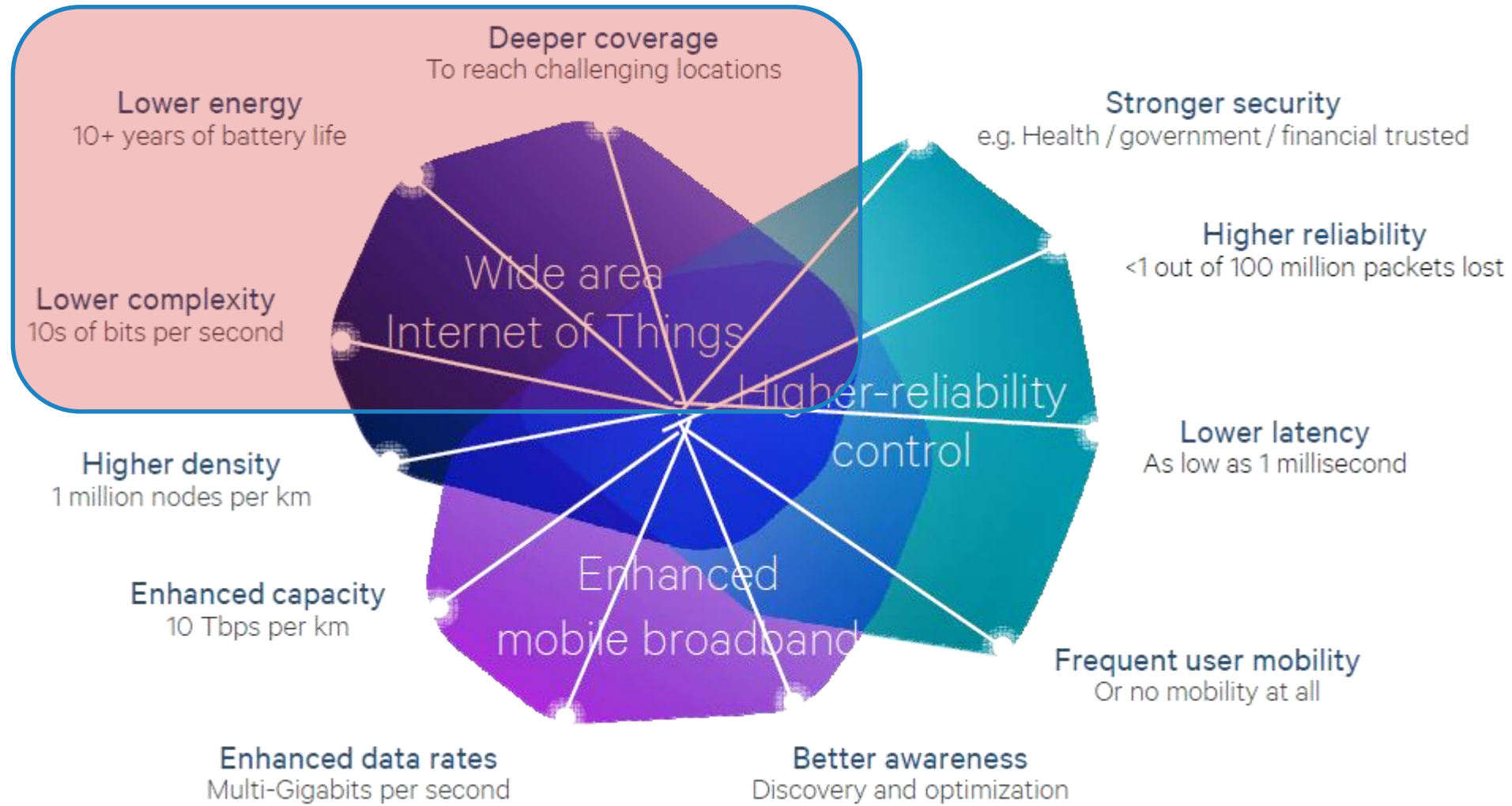




# Motivation

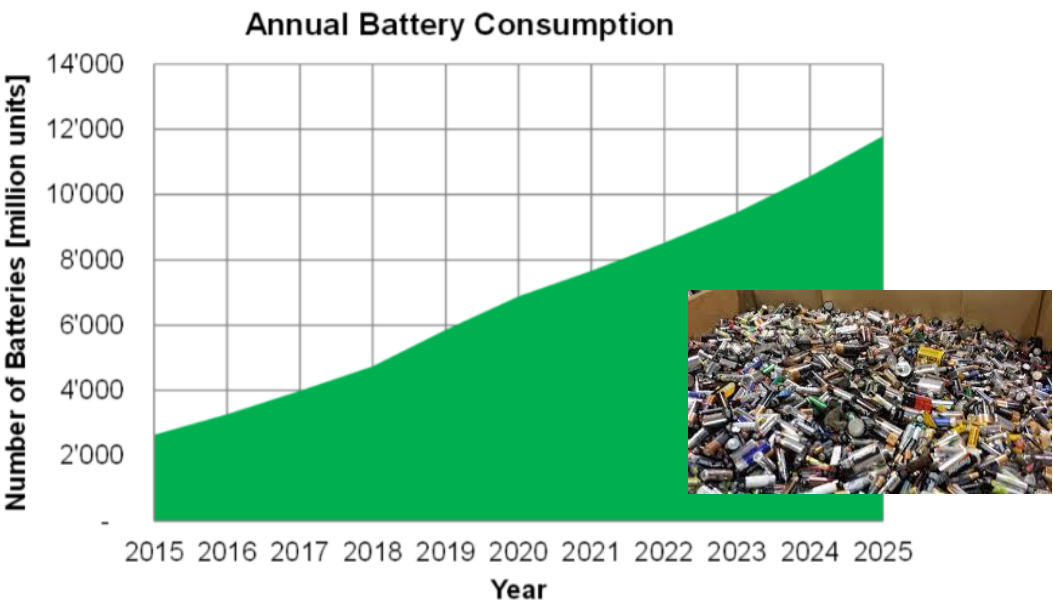
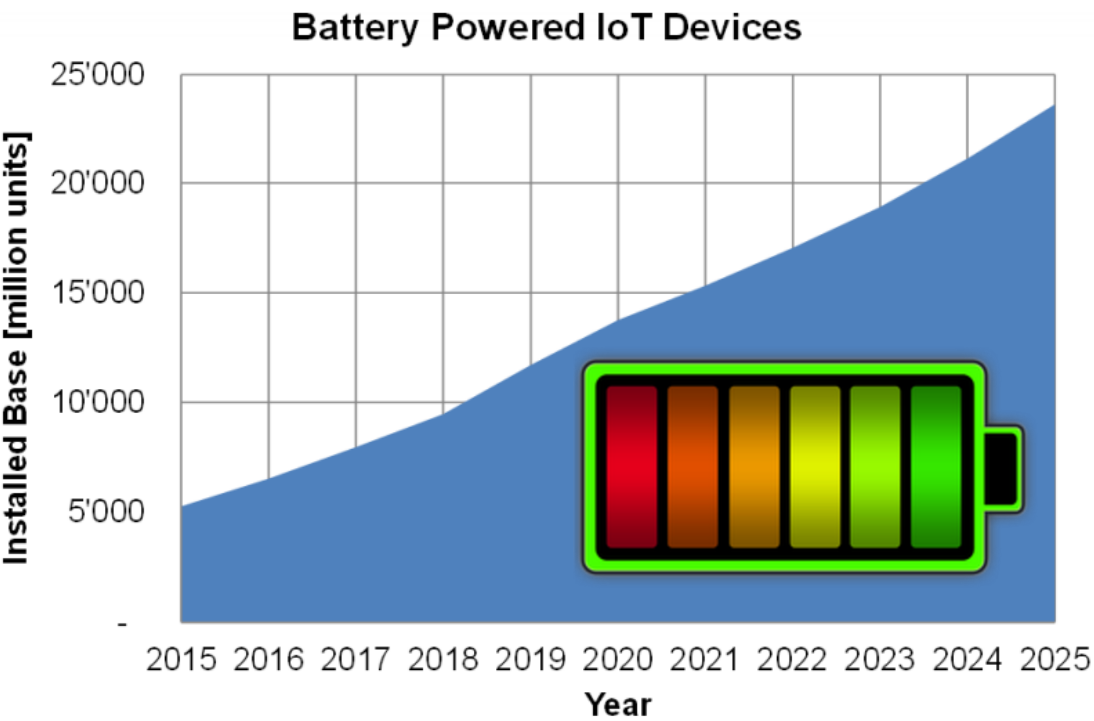


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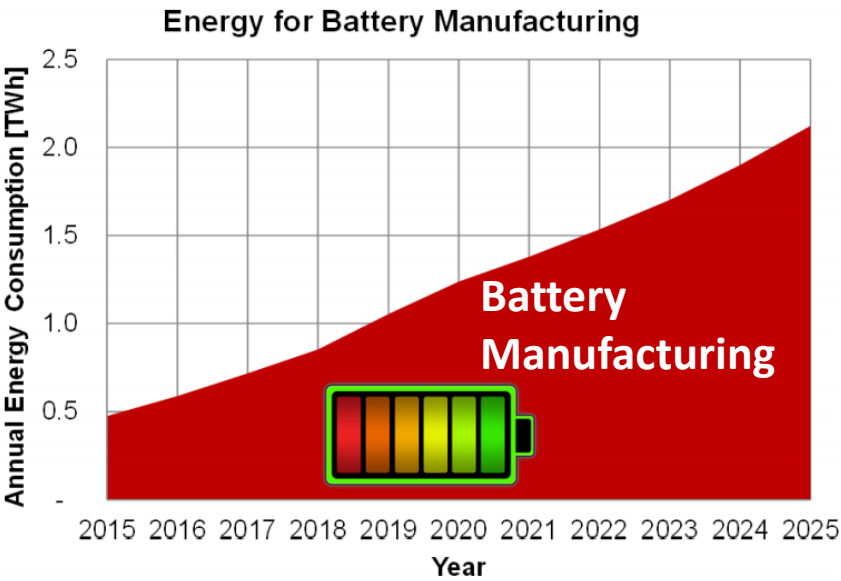


from QUALCOMM

# Motivation Energy waste in IoT



One battery per IoT device and replaced every 2<sup>nd</sup> year



Source: 2016 data <http://edna.iea-4e.org>

# Motivation

## Energy waste in IoT



Batteries take **hundreds of years to decompose**, posing a serious threat to the public health and to the environment.

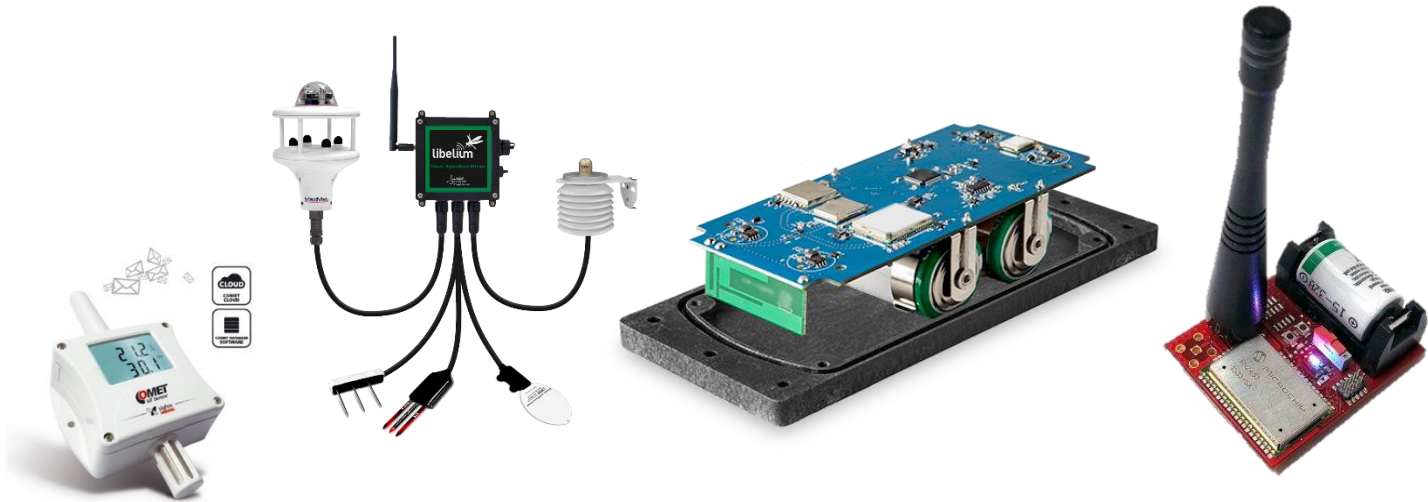
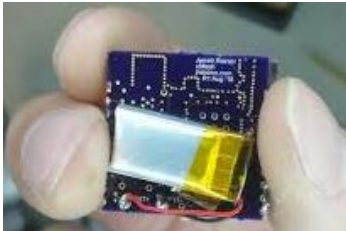




# Market Solutions Power Consumption

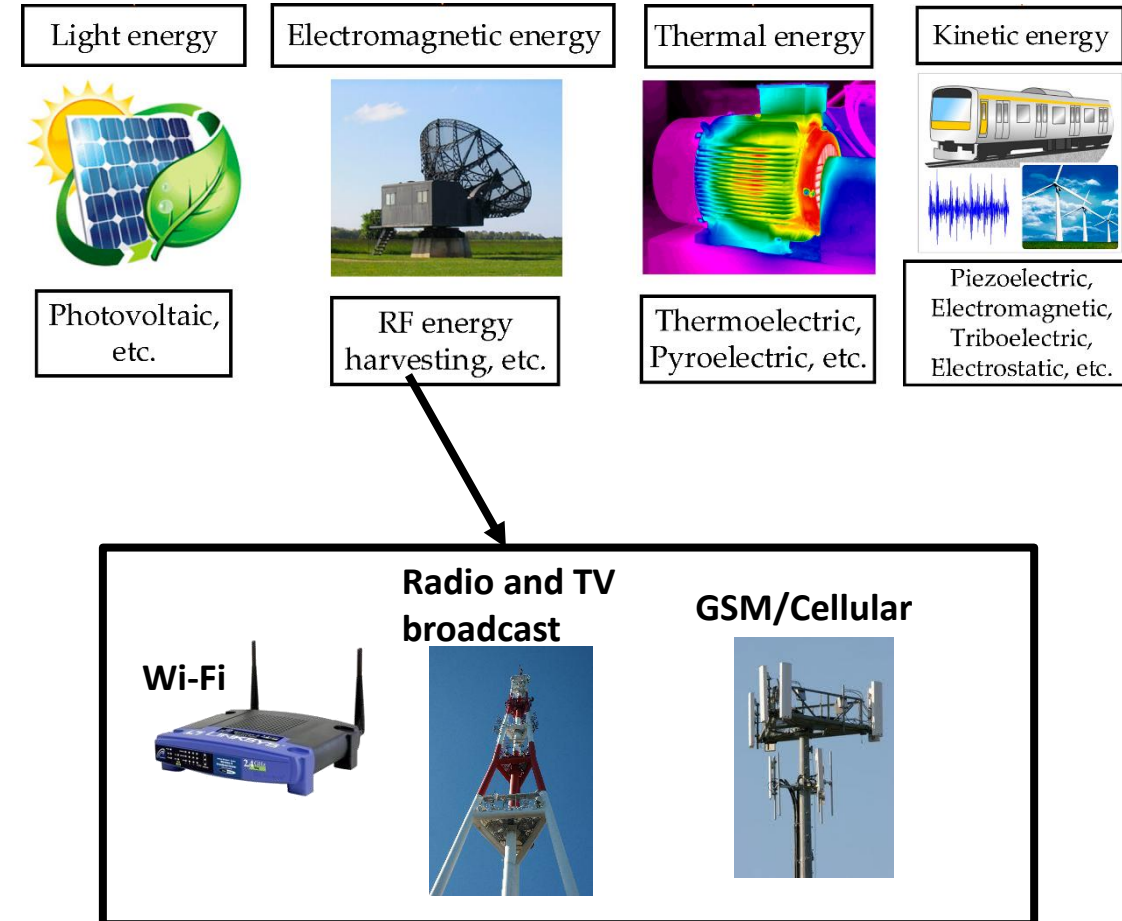


Type	AAA	CR2032	CR123A	CR2
Material	Alkaline	LiMnO2*	Lithium	Lithium
Voltage	3V	3V	3V	3V
Capacity	500 mAh	225 mAh	1500 mAh	800 mAh



# Energy harvesting sources

Comparison of Power Density of Energy Harvesting Methods		
Energy Source	Power Density & Performance	Source of Information
Acoustic Noise	0.003 $\mu\text{W}/\text{cm}^3$ @ 75Db 0.96 $\mu\text{W}/\text{cm}^3$ @ 100Db	(Rabaey, Ammer, Da Silva Jr, Patel, & Roundy, 2000)
Temperature Variation	10 $\mu\text{W}/\text{cm}^3$	(Roundy, Steingart, Fr�chette, Wright, Rabaey, 2004)
Ambient RF	1 $\mu\text{W}/\text{cm}^2$	(Yeatman, 2004)
Ambient Light	100 $\text{mW}/\text{cm}^2$ (direct sun) 100 $\text{W}/\text{cm}^2$ (illuminated office)	Not Cited
Thermoelectric	60 $\text{W}/\text{cm}^2$	(Stevens, 1999)
Vibration (micro generator)	4 $\text{W}/\text{cm}^3$ (human motion - Hz) 800 $\text{W}/\text{cm}^3$ (machines - kHz)	(Mitcheson, Green, Yeatman, & Holmes, 2004)
Vibrations (Piezoelectric)	200 $\mu\text{W}/\text{cm}^3$	(Roundy, Wright, & Pister, 2002)
Airflow	1 $\mu\text{W}/\text{cm}^2$	(Holmes, 2004)
Push Buttons	50 $\text{J}/\text{N}$	(Paradiso & Feldmeier, 2001)
Shoe Inserts	330 $\mu\text{W}/\text{cm}^2$	(Shenck & Paradiso, 2001)
Hand Generators	30 $\text{W}/\text{kg}$	(Starnier & Paradiso, 2004)
Heel Strike	7 $\text{W}/\text{cm}^2$	(Yaglioglu, 2002) (Shenck & Paradiso, 2001)





# The Solution



**LoRa** – 60 mW to 400 mW

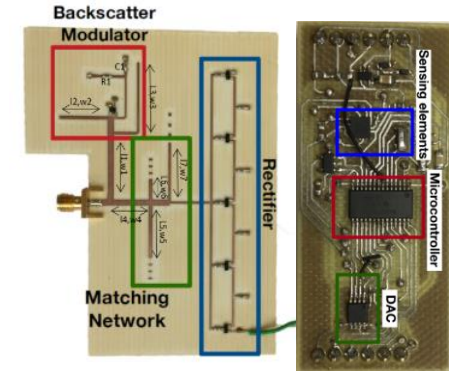


**Bluetooth** – 5 mW to 90 mW

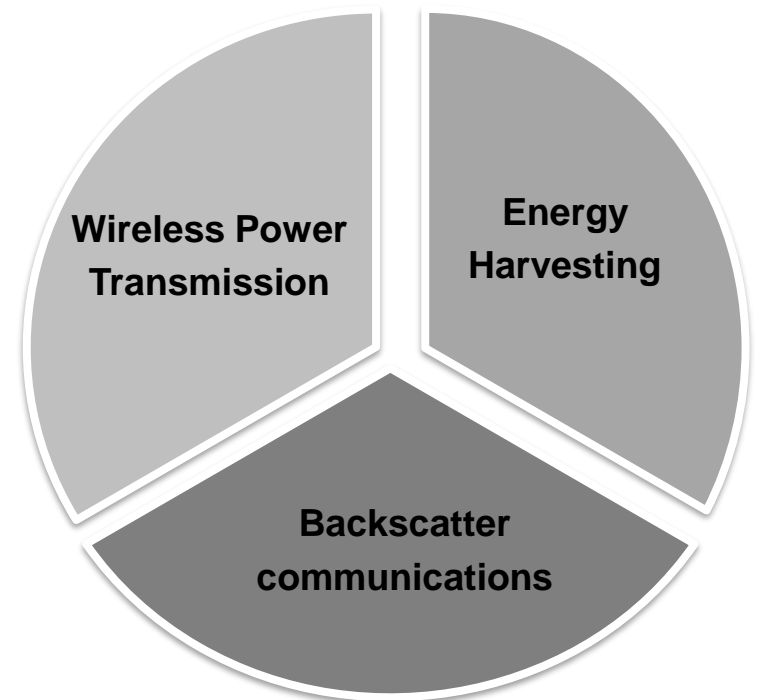


**WiFi** – 50 mW to 1 W

- Remove the need of power for transmit / receive!
- Eliminate batteries!

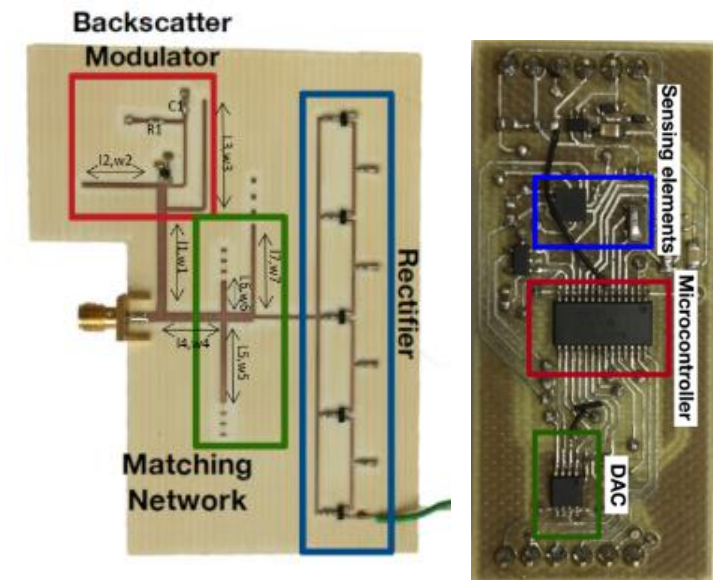
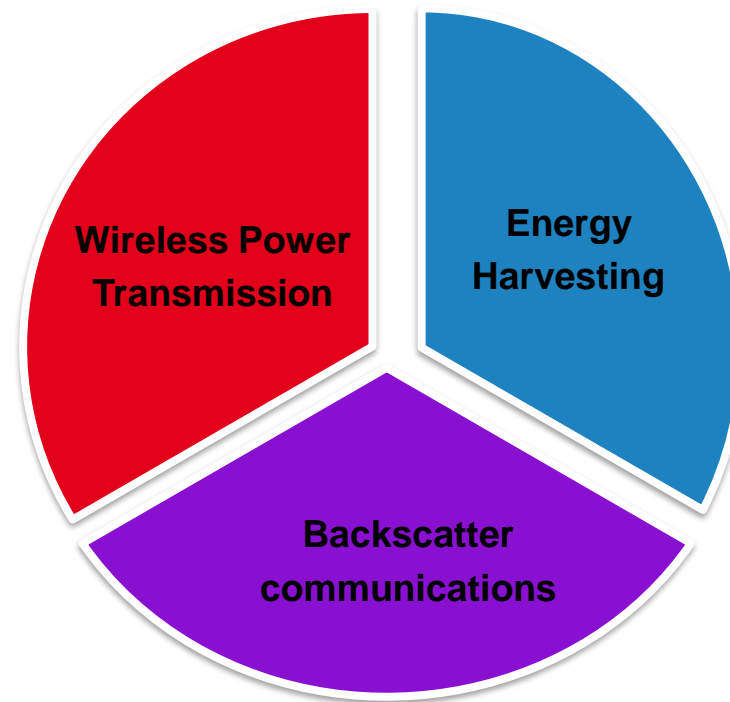


**Passive**

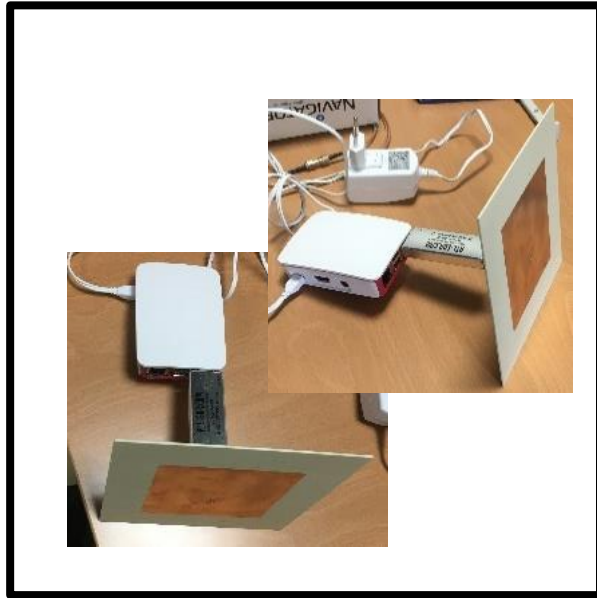


# SWIPT

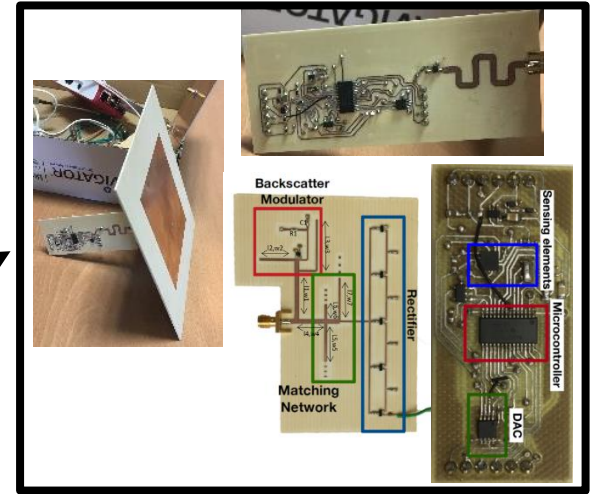
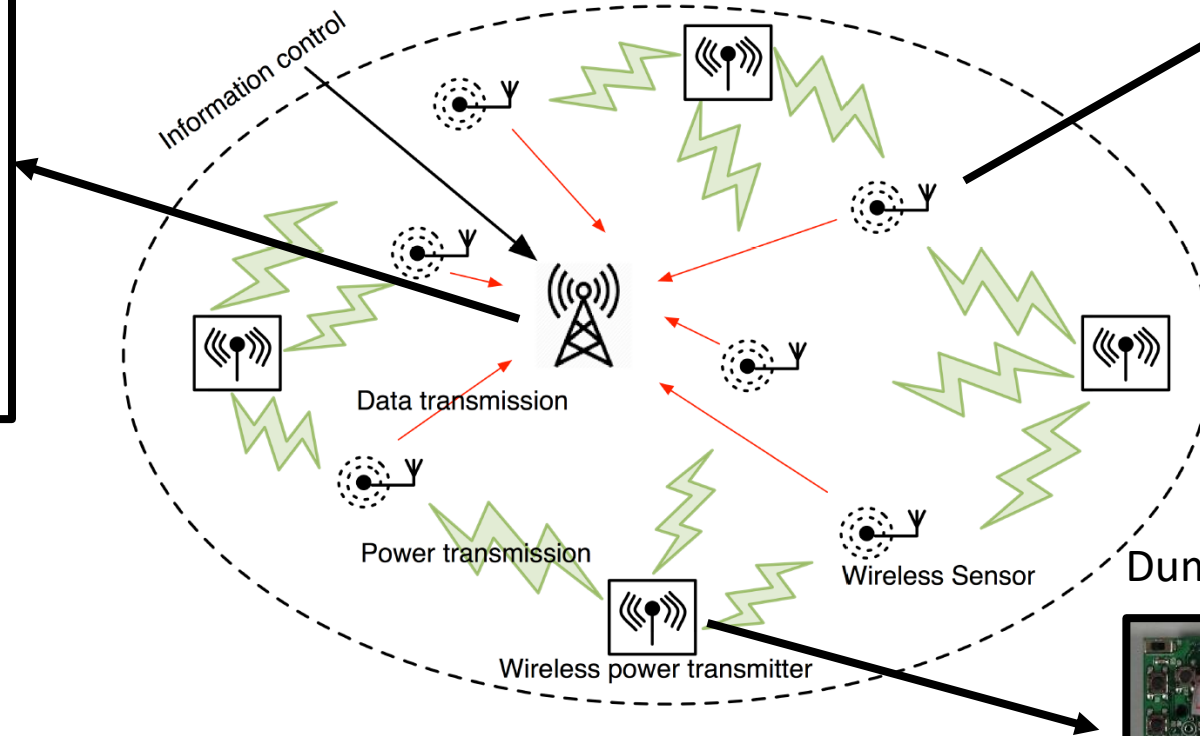
Simultaneous Wireless Information and Power Transfer



# Our Solution – SWIPT backscatter



Low Cost SDR Readers



Passive Sensors



Dummy Wireless Power Transmitters



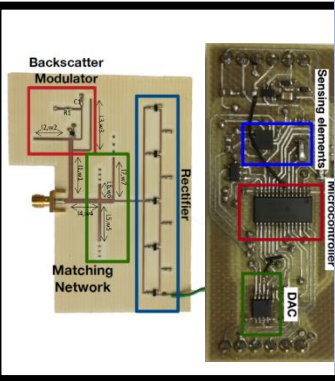
# Backscatter Battery-less Paradigm



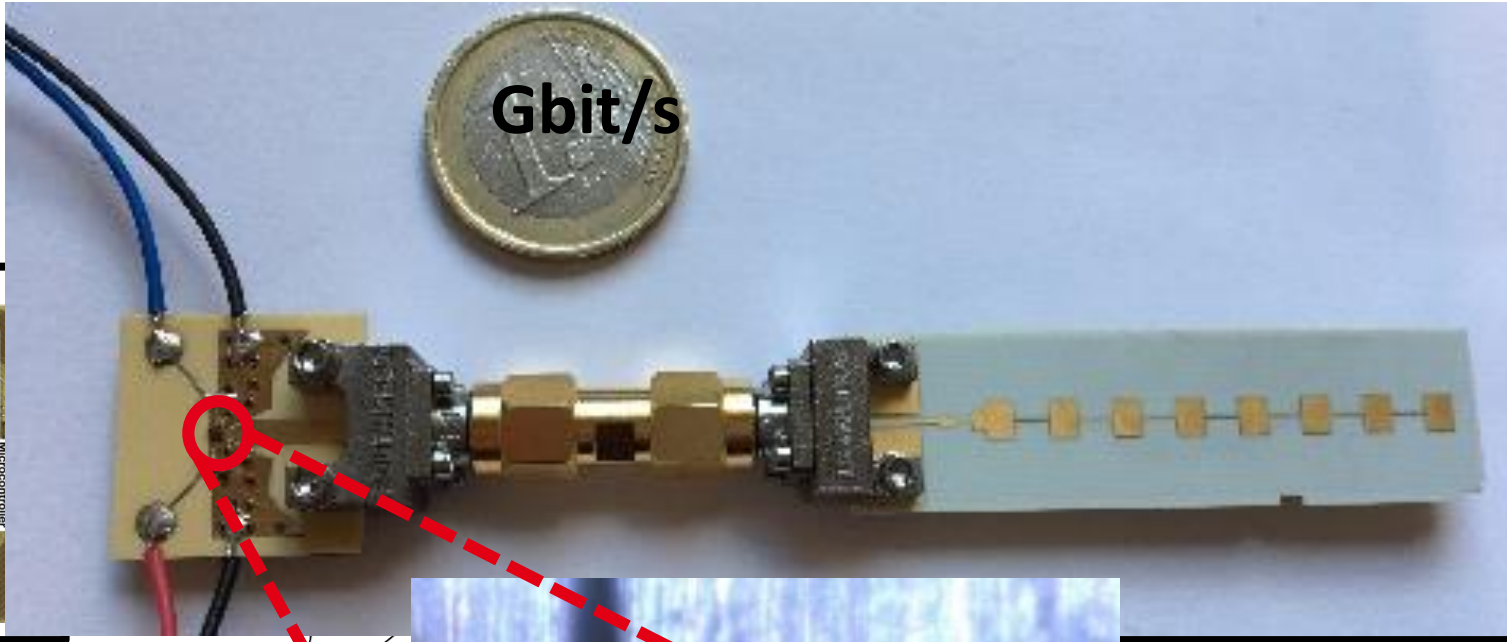
# Towards the FUTURE!!

kbit/s

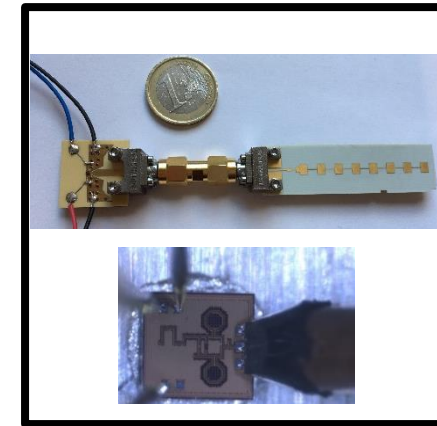
Passive Sensors



Gbit/s



Increase frequency and  
decrease size

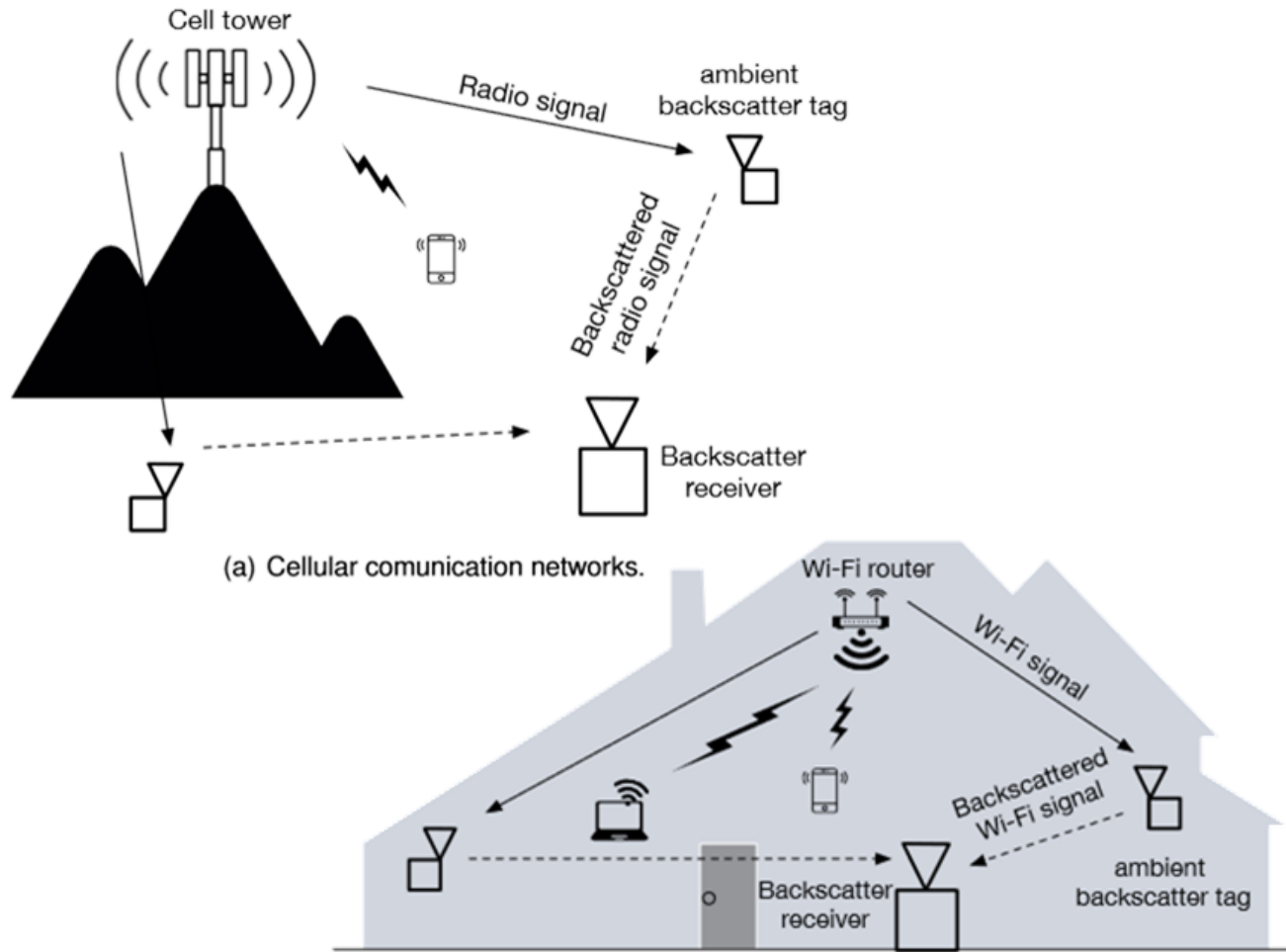


10 kbps  
1 kbps  
0.1 mW  
Average

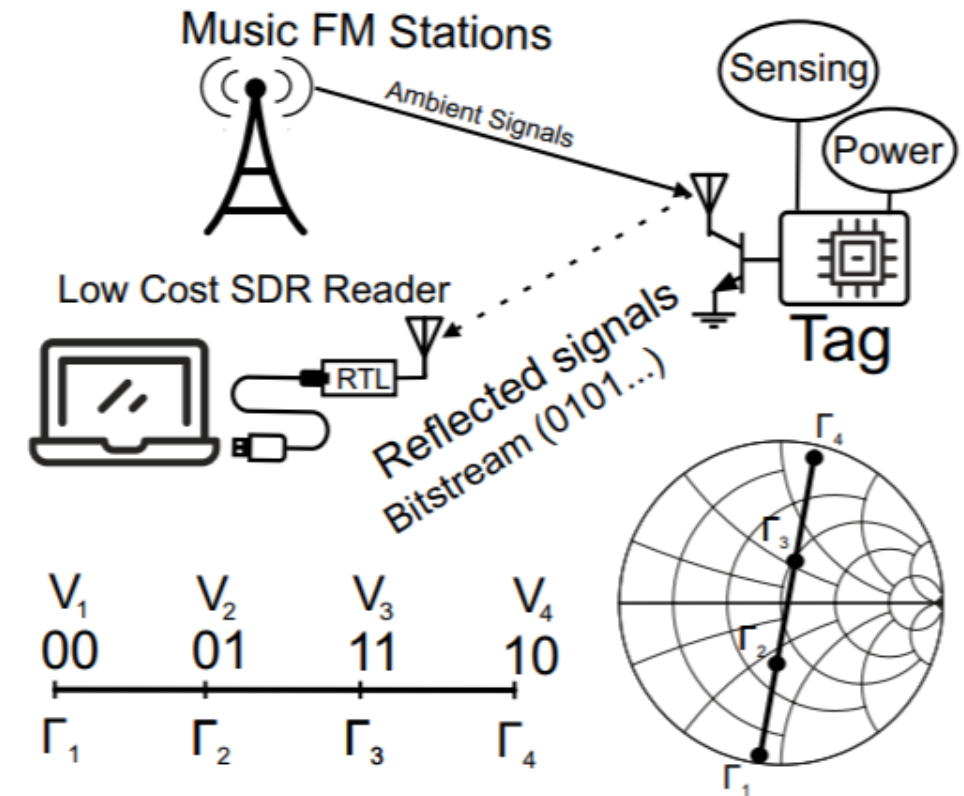


Total size = 0.92 mm<sup>2</sup>

# Backscatter ambient backscatter



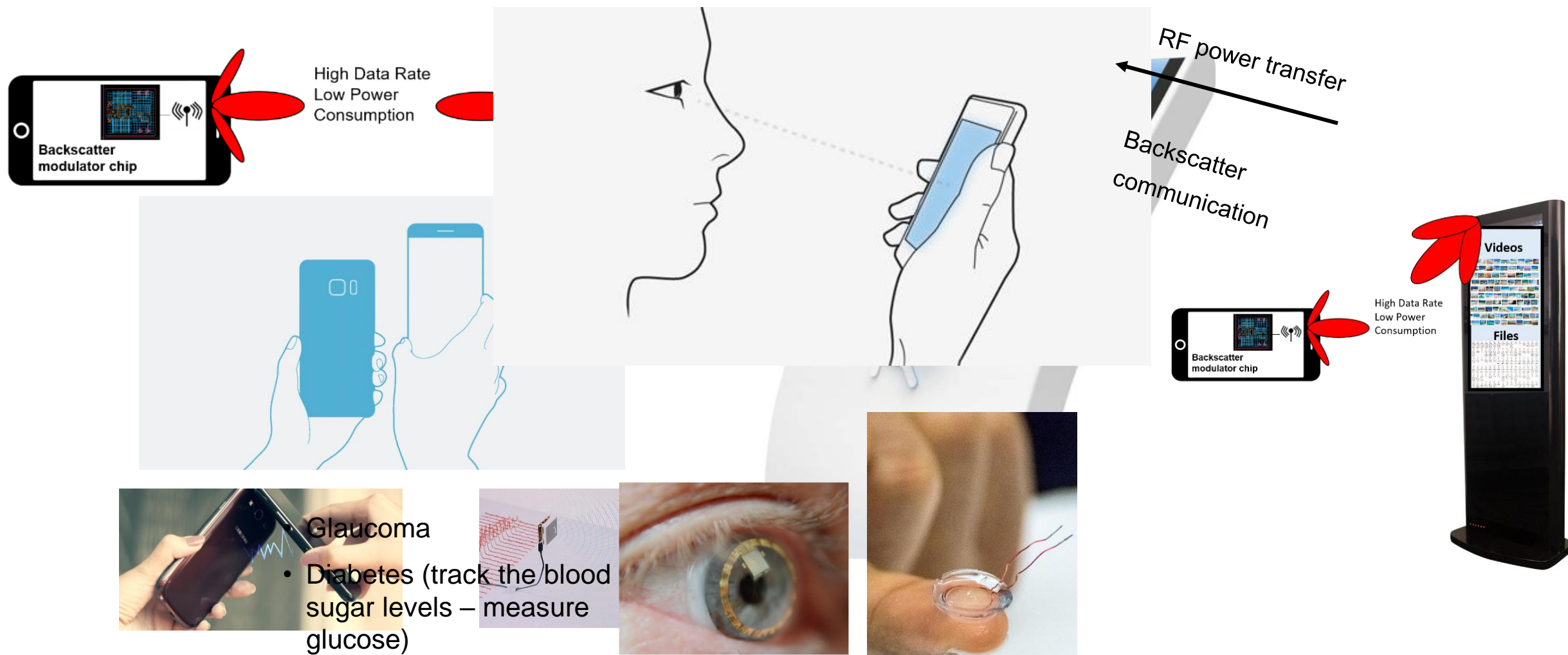
(b) Wi-Fi ambient signals.



Spyridon N Daskalakis et al, "Spectrally Efficient 4-PAM Ambient FM Backscattering for Wireless Sensing and RFID Applications", to be presents in the next IMS2018 in Philadelphia



# mmWave low power connectivity – Applications & Investors



Extremely *small, low power and cheap* connectivity solution which can be embedded in every object

# Thank you very much for your attention



[wpt.ieee.org](http://wpt.ieee.org)

