UNIVERSITY OF SALENTO (Lecce, Italy)

Challenge: Towards distributed RFID sensing with Software-Defined Radio

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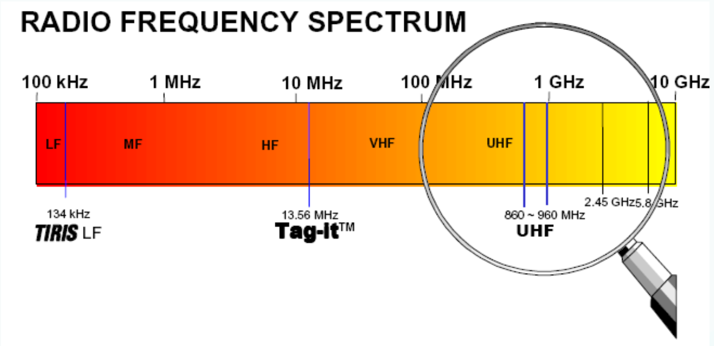
OUTLINE

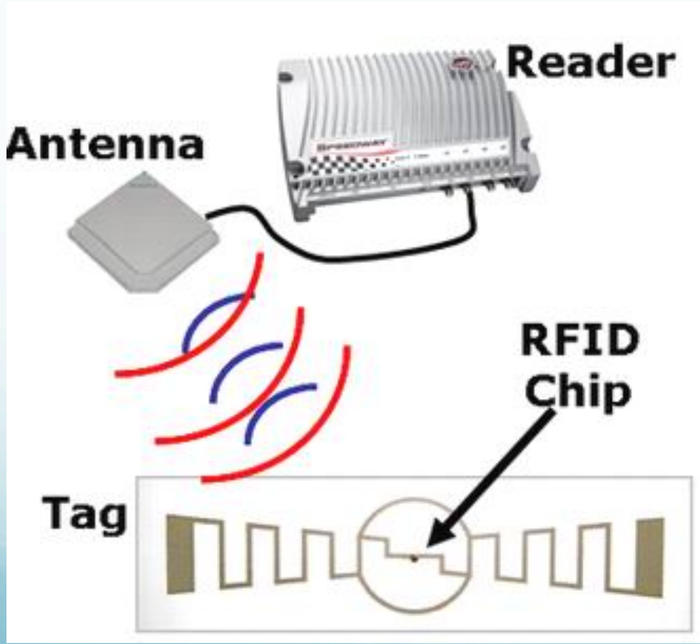
- Introduction
- Distributed RFID sensing
- Implementation of a RFID Listener in Software-defined Radio
- Validation (measurement results)
- Wrap-up and ongoing work

Introduction

- **RFID** = "**R**adio **F**requency **ID**entification"
  (of objects, animals, people...)

- The current technology of RFID systems involves two kinds of devices:
  1. the "**Reader**"
  2. the "**Tag**"

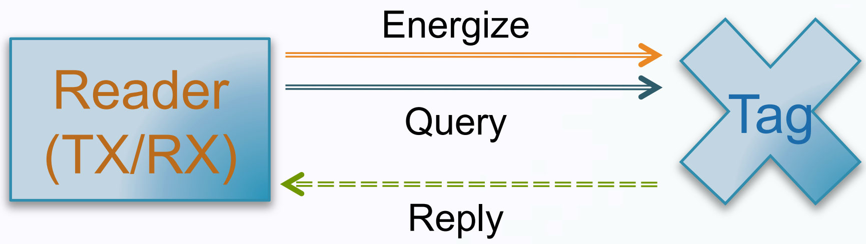




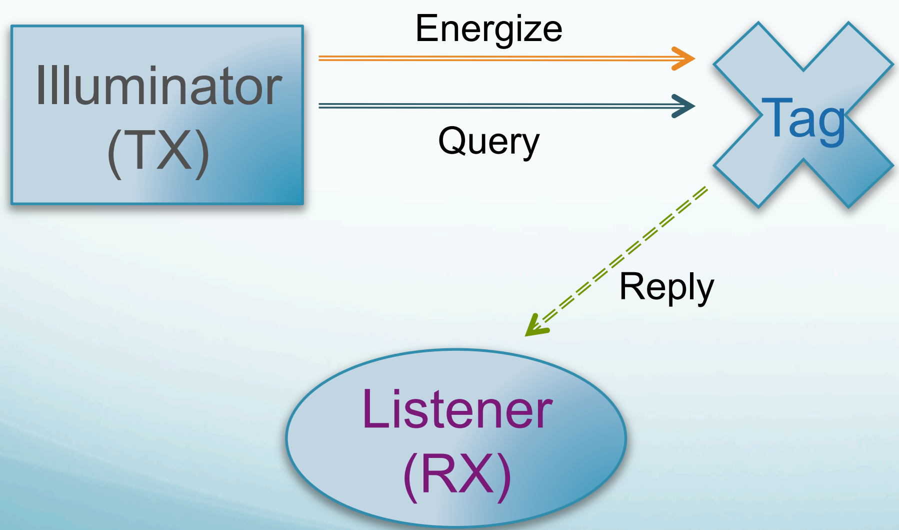
<u>The Reader energizes the (passive) Tags and then queries the ID</u>

Distributed sensing: overview

Current technology



We envision an alternative approach to RFID Tag reading
We separate the *"energization + query"* and the subsequent *"reply decoding"* phases by using two different dedicated devices



- **"Illuminator"** enegizes and queries the Tags (TX function)
- **"Listener"** decodes the Tag replies (RX function)

Distributed RFID sensing: benefits

<u>CAVEAT:</u>
<u>our aim is NOT to claim absolute superiority of the listener-based approach</u>

→ reader-based and listener-based approaches have different pros&cons, they suit different applications

- **Cost, size and power gains**

  RFID listeners are receiver-only UHF radios (save the whole TX chain, e.g. Power Amplifier and DAC)
  → lower fabrication cost, size and power consumption (battery lifetime)

- **Enabling Denser Deployment**

  Above savings concur to lower the cost of infrastructure deployment and maintenance

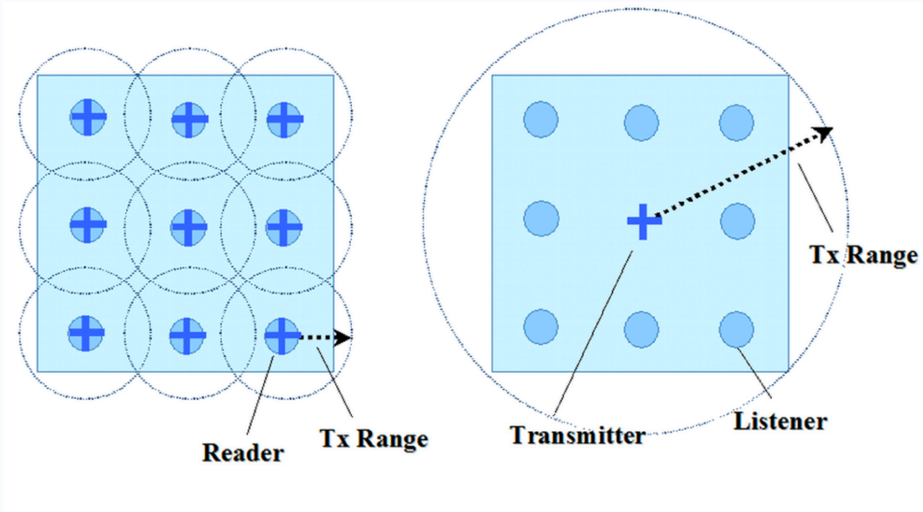
  → density of listeners can be increased!

  (benefits: gain of the cooperative reception schemes, better accuracy in the localization and/or tracking of tags, ...)

Distributed sensing: ease TX coordination

Traditional scheme
n TX/RX devices (readers)

Distributed 1:*n*
single TX device illuminates the area
n listeners receive Tags' replies



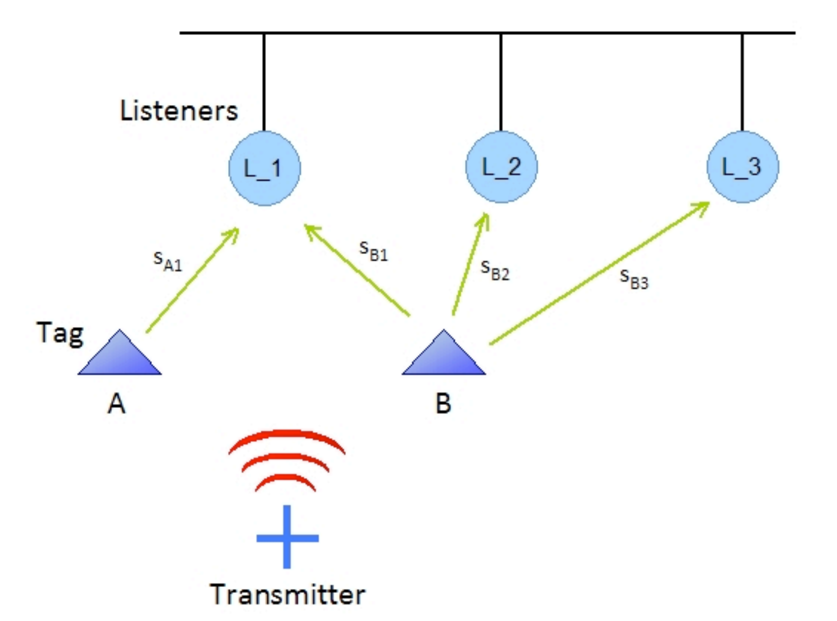
- **Reduced transmission coordination**

  Reader collisions (contemporary access to TAG by different readers → interference) are destructive events, must be avoided by Medium Access Control (MAC) mechanism

  Problem mitigated in distributed scheme

  → in 1:*n* scheme MAC not needed, huge saving in complexity (possible extension to *m*:*n* scheme: reduced TX cordination since *m*<<*n*)

Distributed sensing: efficiency and cooperation



❑ Temporal efficiency

- with traditional Readers, a K-slot (K=3) time-division scheme is needed to separate the transmissions from different Readers

→ reading of Tag-A can occur only 1/K of the time

- with 1:n listener-based scheme, each tag can be queried at every slot

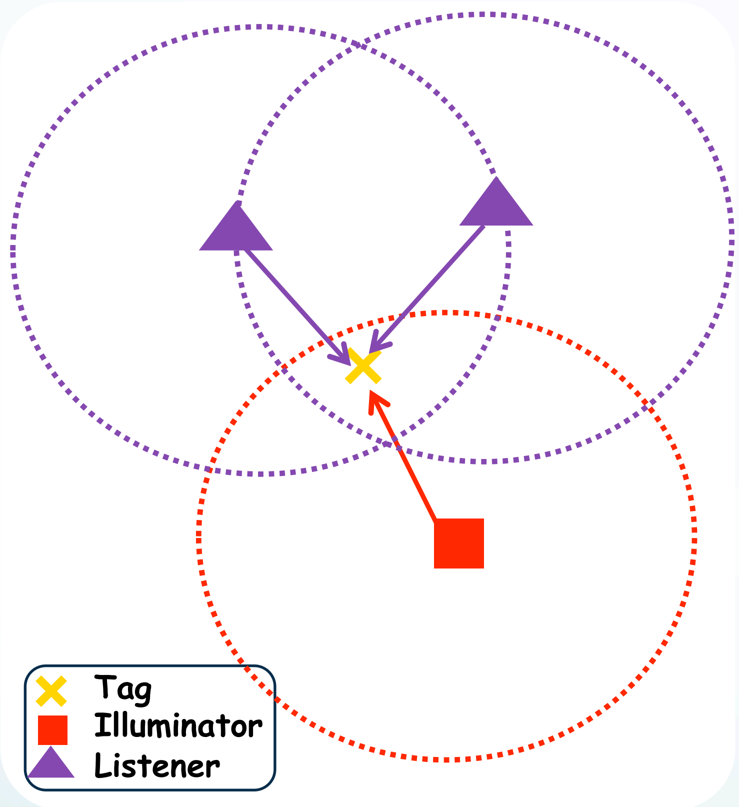
❑ Cooperative Reception

<u>Soft combining</u>: can be applied to $s_{B,2}$ and $s_{B,3}$ so that the combined SNR becomes sufficient to correctly decode Tag-B's frame.

<u>Inferference Cancellation</u>: once recovered Tag-B's message, its re-modulated version can be subtracted from the signal $s_{A,1}+s_{B,1}$ received by L1 to finally obtain $s_{A,1}$

Room for Multi-User Single-Input Multiple-Output techniques (MU-SIMO)

Distributed RFID sensing: an application scenario



Better integration with WSN

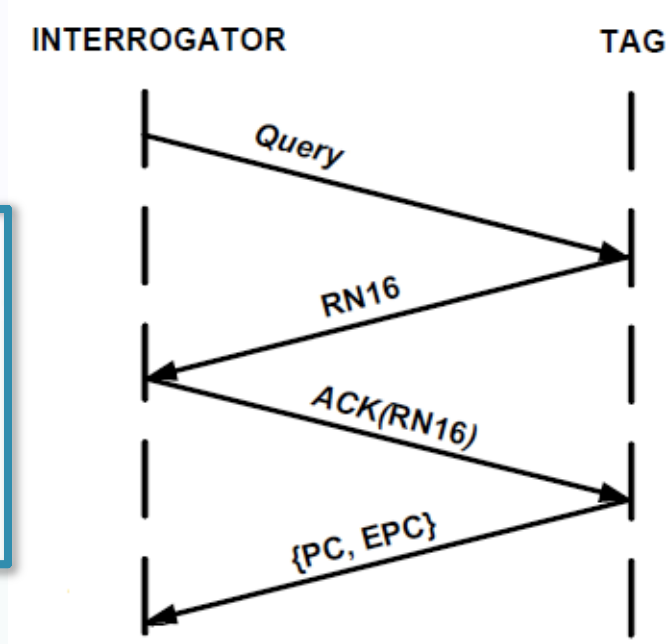
Cos/size/power gains ease integration with cheap wireless nodes (e.g. ZigBee)
→ RFID lilluminator as additional "sensing unit" onboard a sensor node to act as further sensor in a Wireless Sensor Network

Better localization

Denser deployments
→ more listeners hear the tag
→ better localization accuracy

Toward a Listener-based system: protocol issues

Current technology: *Gen2 protocol*



Illuminator

Gen2 “entangles” TX and RX functions!

handshaking impedes to implement a pure Illuminator device without RX function
→ we have to use a traditional Reader

a new protocol would be needed for a fully distributed approach

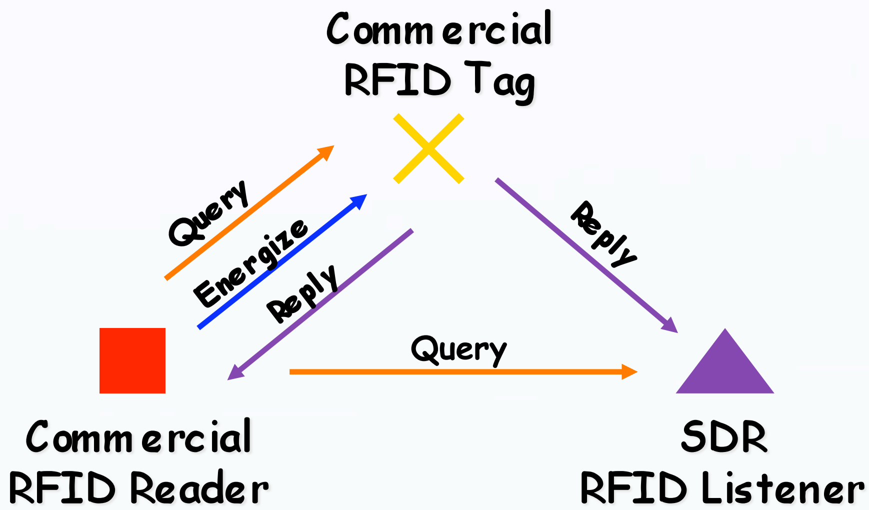
Listener

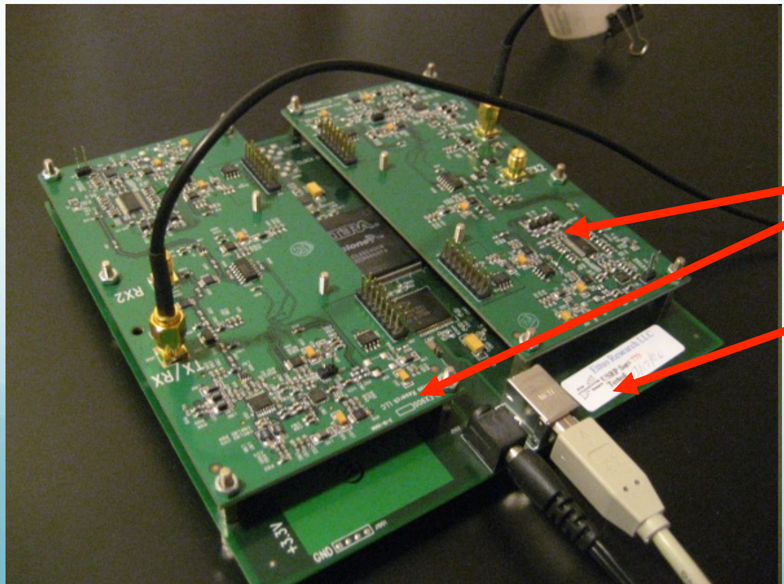
data-rate, UL freq. and modul. for Tag are set in the preamble of the Query
→ a Listener must implement two phases:

1. *Calibration*: decode Reader’s messages and up-link parameters
2. *Tag decoding*: decode messages between Tag and Reader (EPC)

Software-Defined Radio RFID Listener

We developed a SDR listener using USRP motherboard and GNU-Radio





Daughterboard: RFX900
(UHF tranceiver)

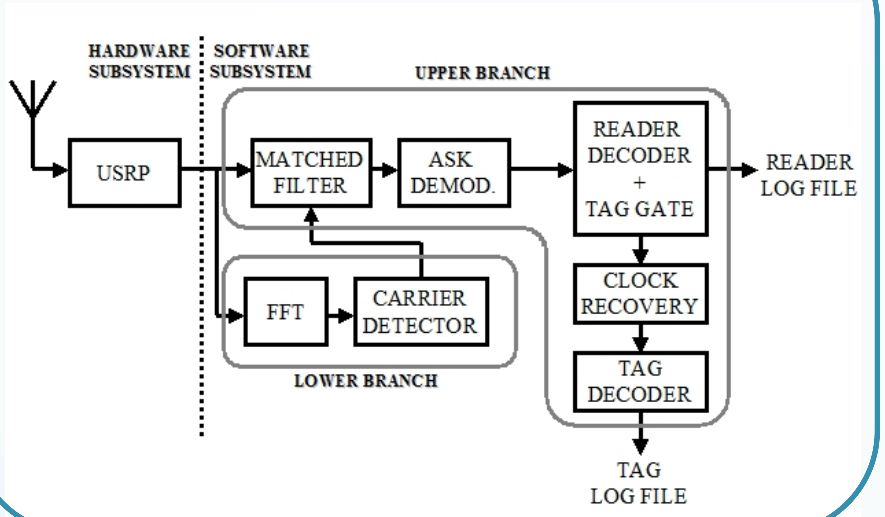
USRP motherboard

Alien ALR-9610 Circular
Antennas

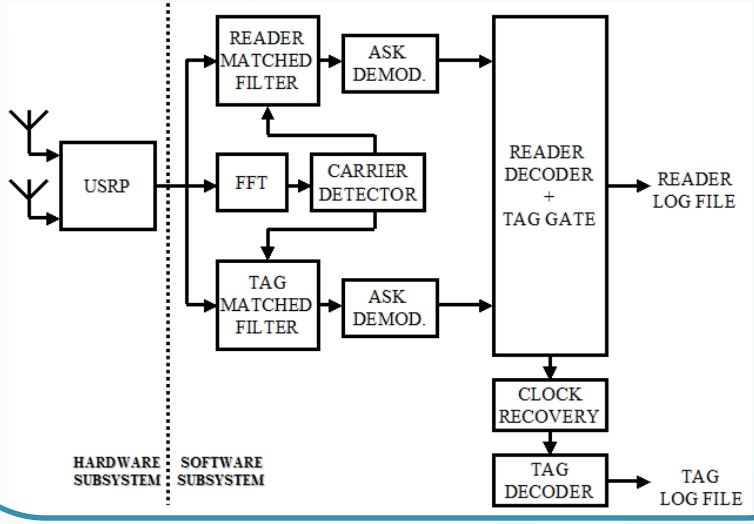
GNURadio RFID Listener: architecture

We developed two different implementations of the Listener

SINGLE-ANTENNA RFID LISTENER



DUAL-ANTENNA RFID LISTENER

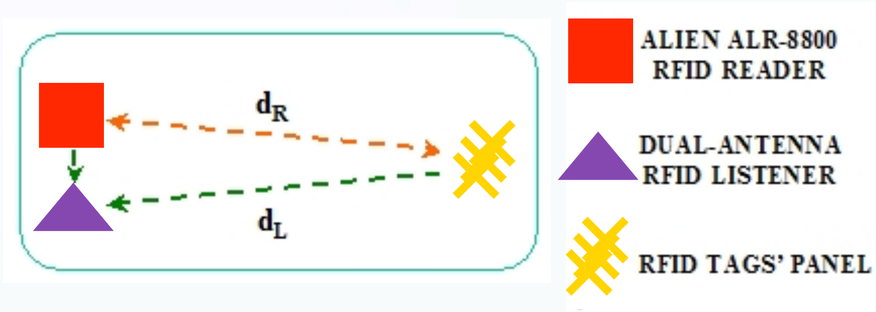


- The "dual-antenna" version achieves better performance thanks to the possibility of using directional antennas (differently oriented for the Reader and the Tag)

Experimental results (validation)

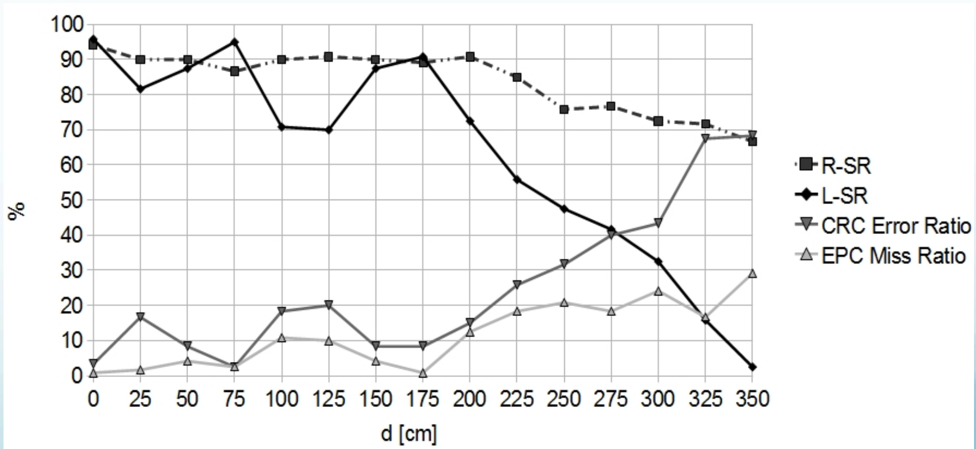
<u>Reading range</u>

Topology : commercial Reader and our Listener are close each other for a fair comparison



Up to 2 mt. the *Listener Success Ratio* (L-SR) is comparable with the *Reader Success Ratio* (R-SR)

→ <u>performance degradation due to limited dynamic range in the ADC of the USRP motherboard</u>



Wrap-up and ongoing work

- Presented a novel approach to RFID sensing decoupling Tx and Rx functions, discussing its benefits

- Implemented a prototype of "RFID Listener" on GNURadio/USRP compliant to Gen2 protocol
  (soon published in CGRAN)

- Our prototype can be used
  - protocol analyzer for Gen2
  - basis for experimenting with protocol variations, supporting research on distributed RFID schemes

- Ongoing work is to circumvent some hardware limitations of USRP in TAG reception (energization CW saturates ADC range)