ECE 1175
Embedded System Design

Embedded Communication

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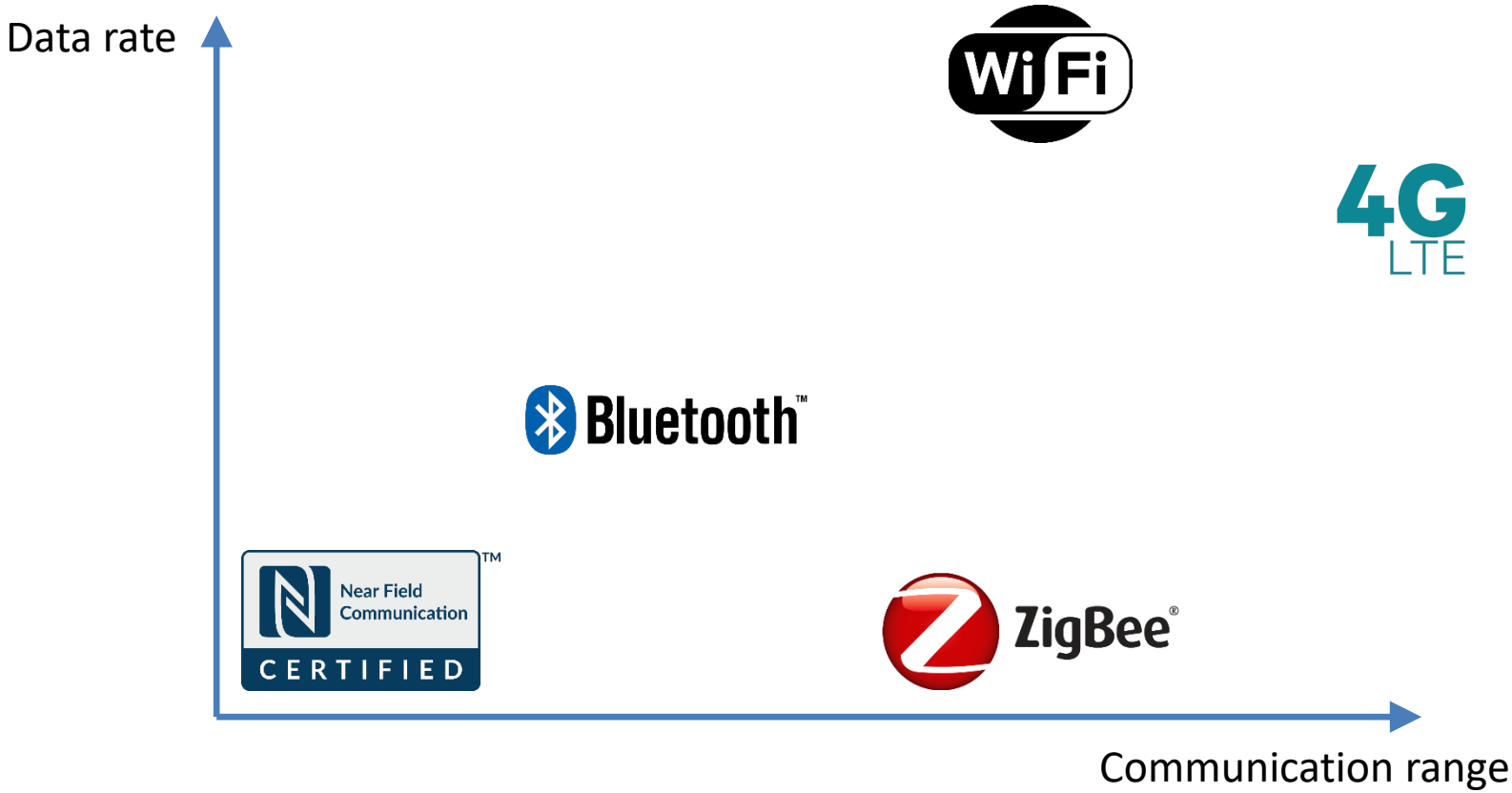
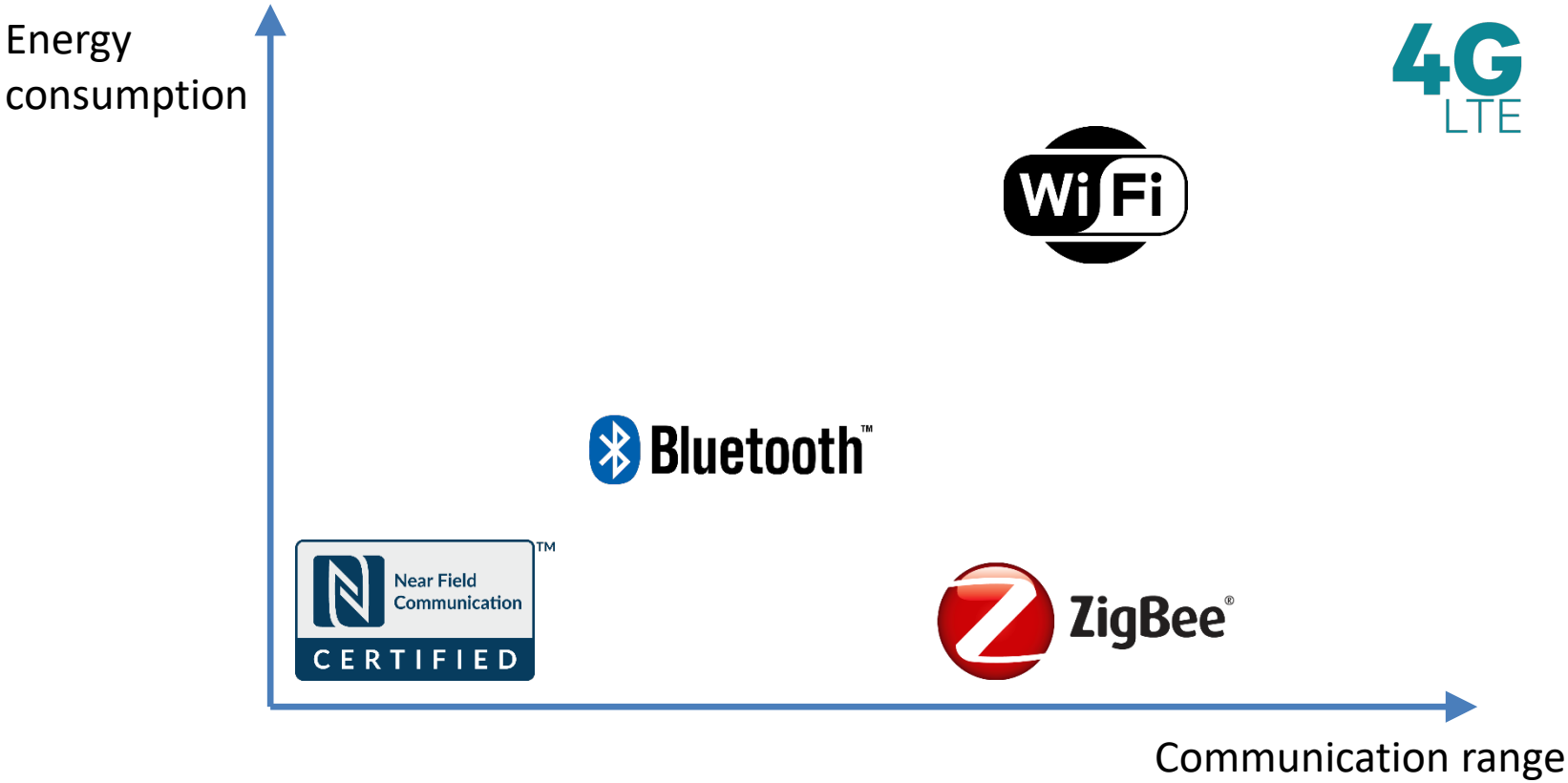
Communication Technologies

- Tradeoff between data rate and communication range



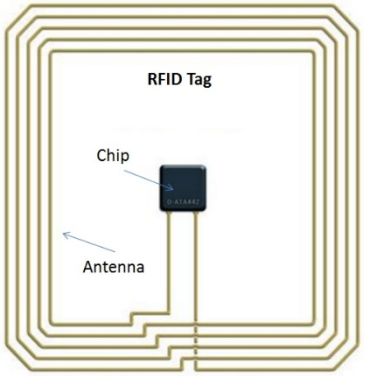
Communication Technologies

- Considering energy consumption



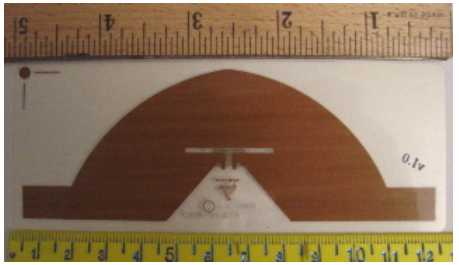
Radio-Frequency Identification (RFID)

- Small tags
  - Wirelessly send data when being triggered by a reader

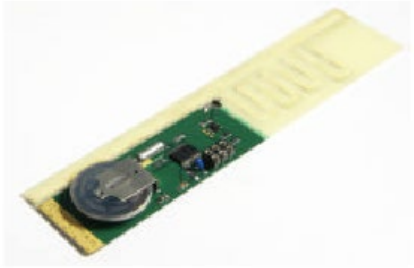


Radio-Frequency Identification (RFID)

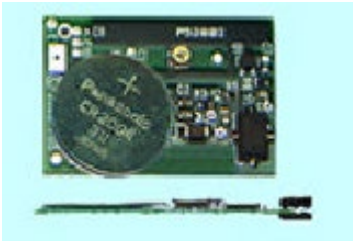
- Types of tags
  - **Passive**
    - Operational power scavenged from reader radiated power



  - **Semi-passive**
    - Operational power provided by battery



  - **Active**
    - Operational power provided by battery
    - Transmitter built into tag



RFID Market

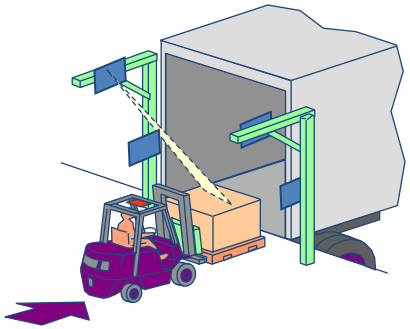
Auto Immobilizers

Automated Vehicle Id

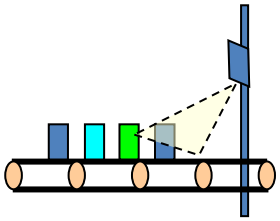
Access Control

Animal Tracking

RFID Market



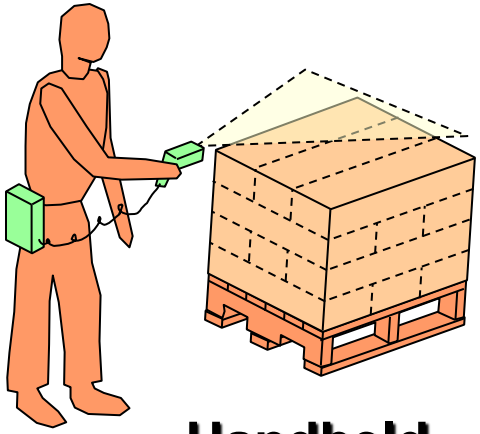
Dock Door



Conveyor Belt

Forklift

Printers



Handheld

Smart Shelves

Point of Sale

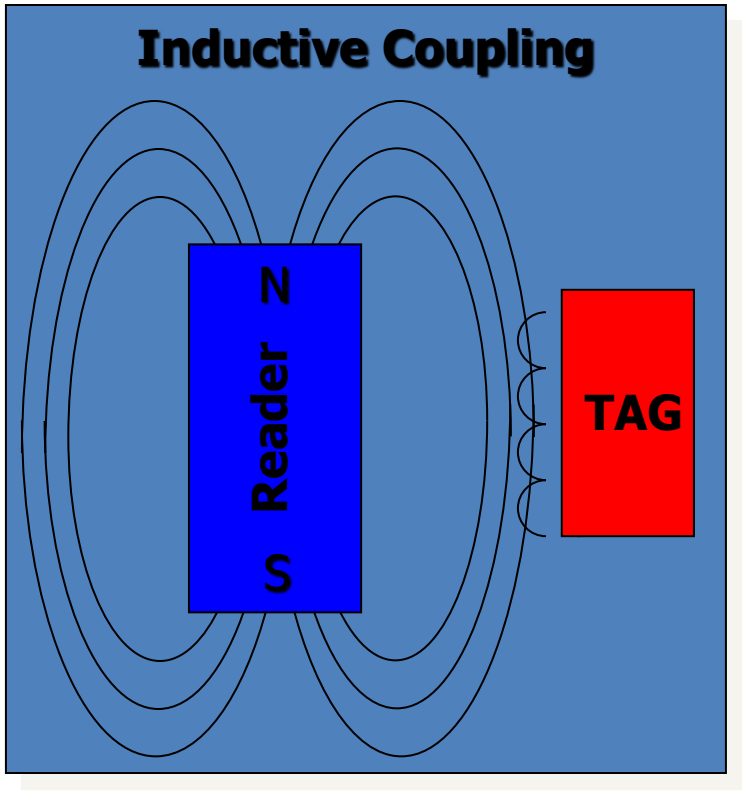
Radio-Frequency Identification (RFID)

- Tag details

	LF	HF	UHF	Microwave
Freq. Range	125 - 134KHz	13.56 MHz	866 - 915MHz	2.45 - 5.8 GHz
Read Range	10 cm	1M	2-7 M	1M
Market share	74%	17%	6%	3%
Coupling	Magnetic	Magnetic	Electro magnetic	Electro magnetic
Existing standards	11784/85, 14223	18000-3.1, 15693,14443 A, B, and C	EPC C0, C1, C1G2, 18000-6	18000-4
Application	Smart Card, Ticketing, animal tagging, Access, Laundry	Small item management, supply chain, Anti-theft, library, transportation	Transportation vehicle ID, Access/Security, large item management, supply chain	Transportation vehicle ID (road toll), Access/Security, large item management, supply chain

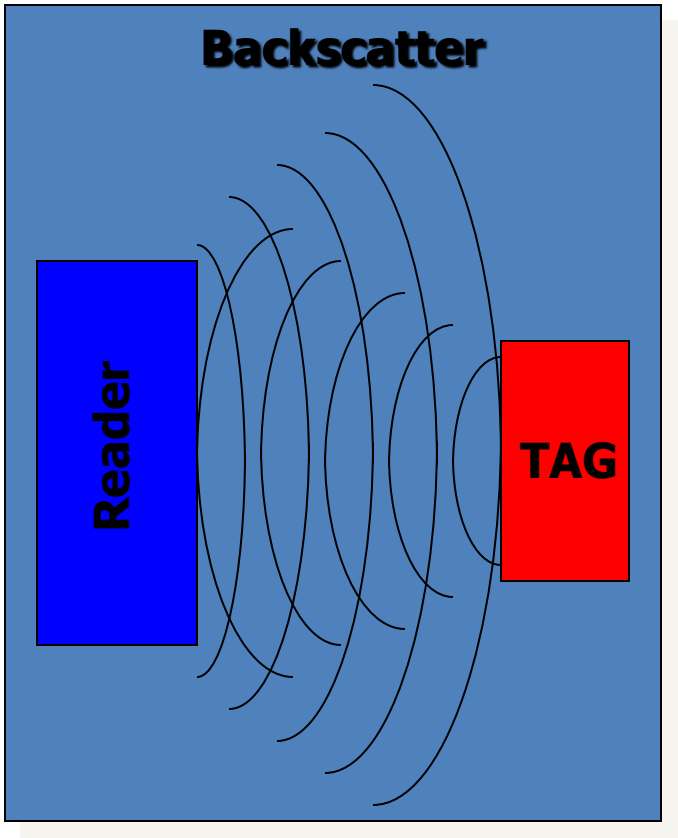
Communication Modes

- Near-field: inductive coupling
  - LF and HF frequency bands
  - Reader generates magnetic field
    - Mini transformer
  - Tag is powered by inducted current
  - Tag is modulated to communicate

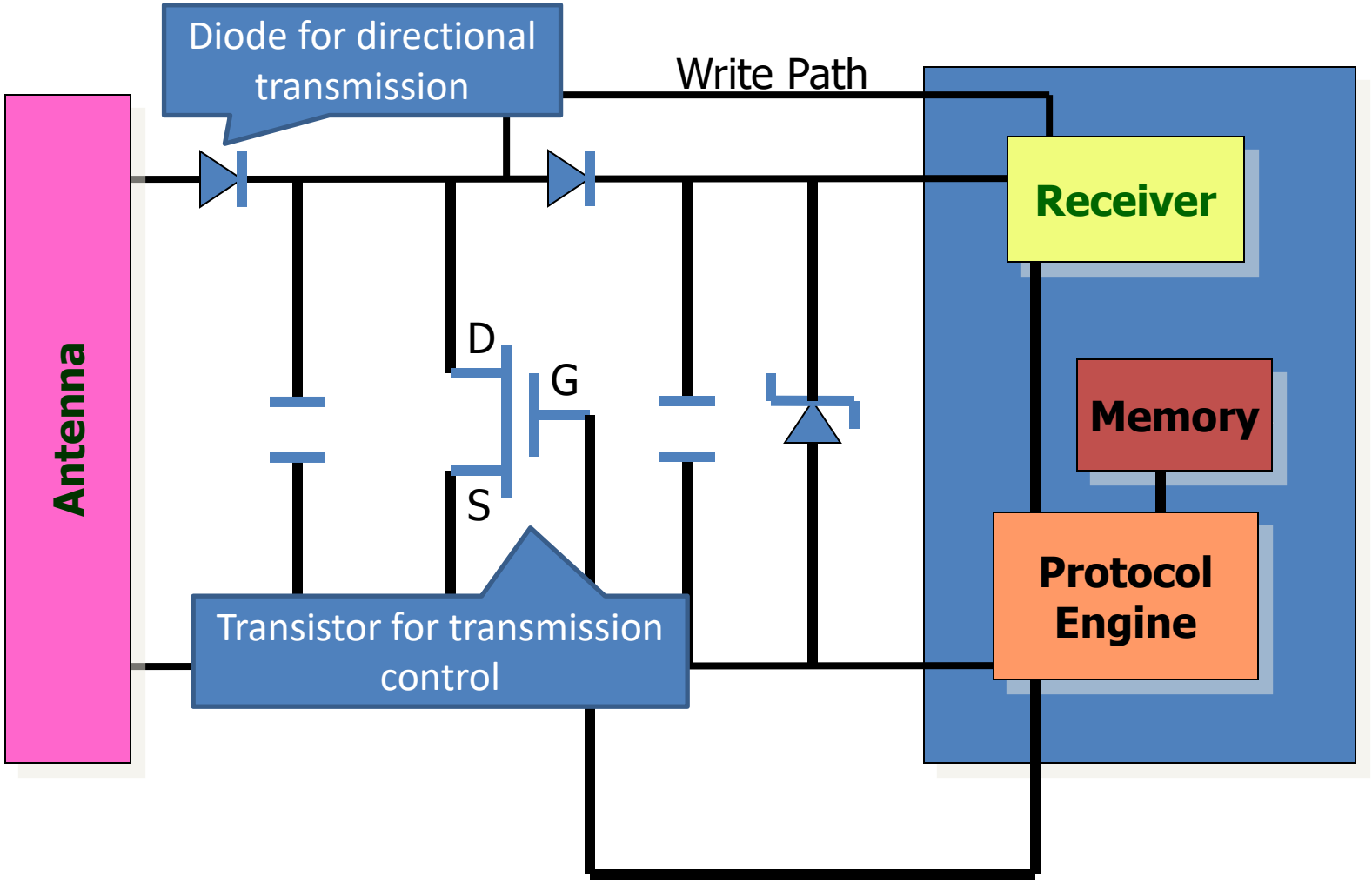


Communication Modes

- Far-field: backscatter
  - UHF and microwave bands
  - Tag is powered by resonance
  - Tag modulates backscatter by changing antenna impedance



Generic Tag Architecture

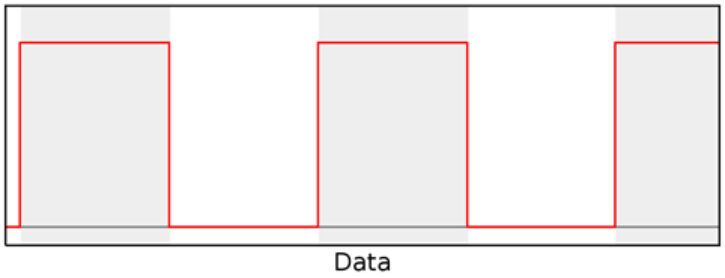


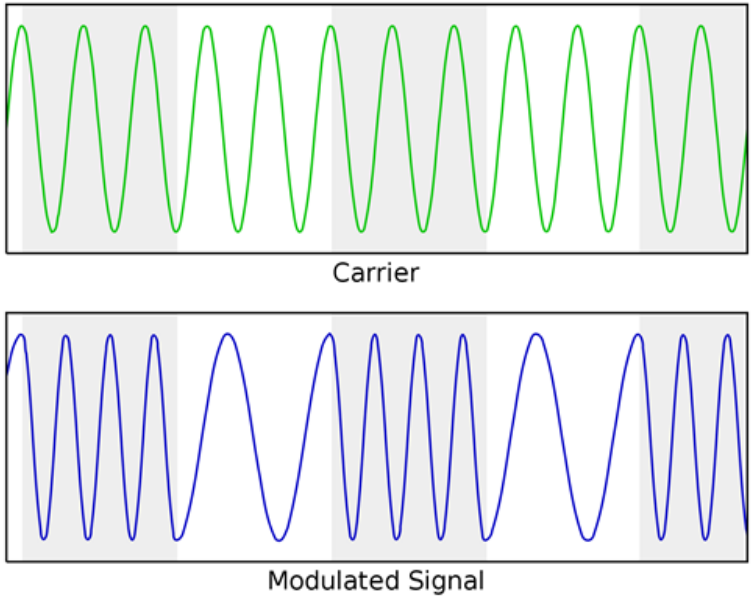
RFID Protocols

	Read Rate	Read or Read/Write	Tag Cost	Privacy	Security	Global Standard
Class 0	NA: 800 reads/sec EU: 200 reads/sec	Read Only	$$	24 bit password	Reader broadcasts OID or Anonymous modes with reduced throughput	No
Class 0+	NA:800 reads/sec EU:200 reads/sec	Read & Write	$$	See above	See above	No
Class 1	NA:200 reads/sec EU: 50 reads/sec	Read & Write	$	8 bit password	Reader broadcasts partial OID	No
Class 1 Gen 2* (UHF Gen2)	NA:1700 reads/sec EU: 600 reads/sec	Read & Write	?	32 bit password and concealed mode	Authentication and Encryption	Yes

Class 0 Protocol

- Operating frequency:
  - 3.3 MHz for data ‘1’, 2.2 MHz for data ‘0’
  - FSK modulation



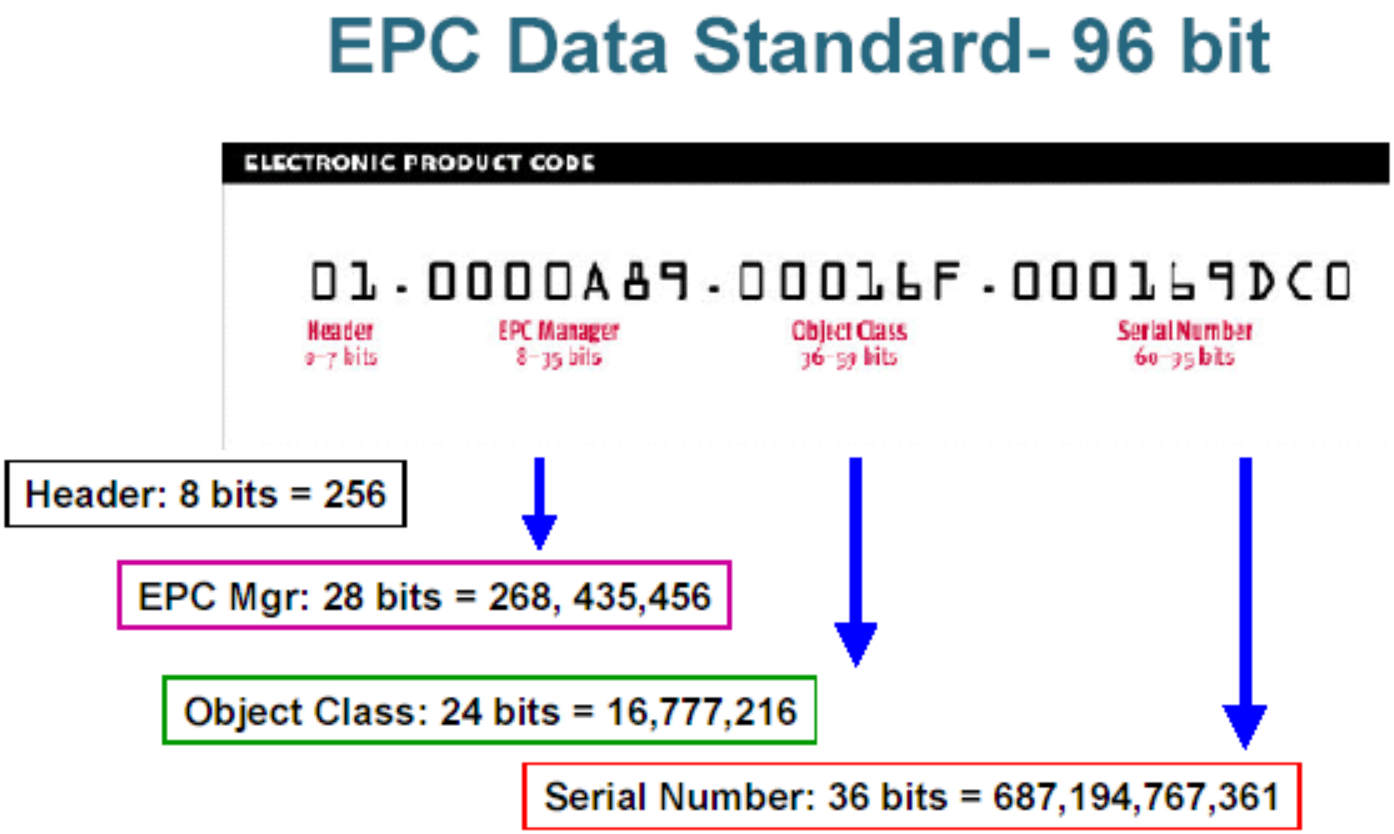


Class 0 Protocol

- Typical data stored in tag
- Globally unique identifier
  - 96 bit EPC code
  - 24 bit kill code
  - 16 bit Cyclic Redundancy Check (CRC)

Class 0 Protocol

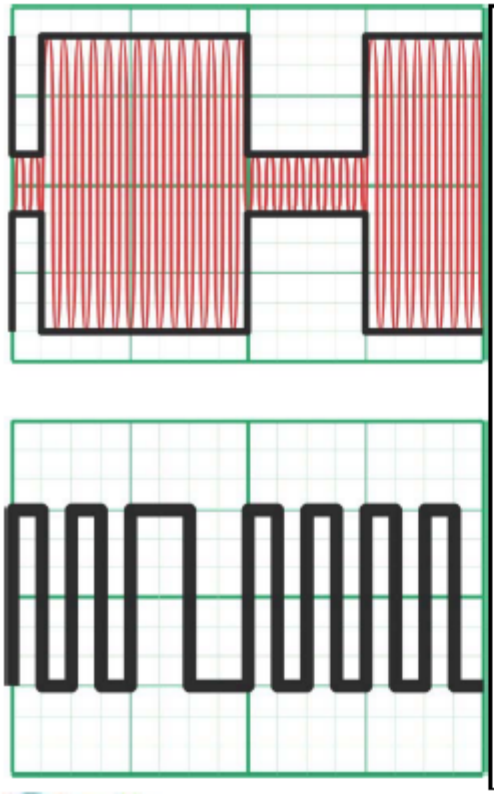
- Electronic Product Code (EPC) data standard



Class 0 Protocol

- Signaling

EPC : Reader-tag Communication

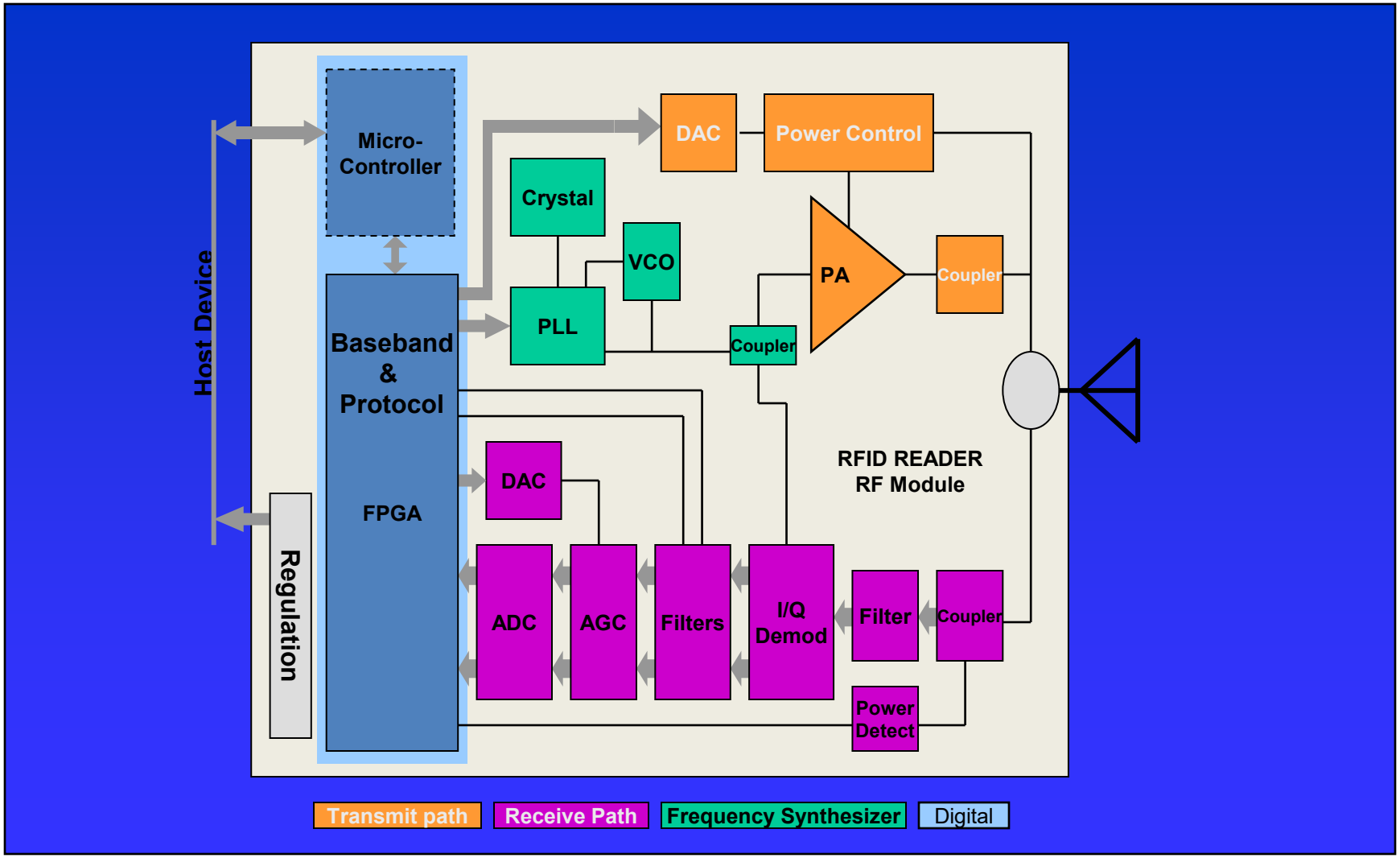


- Reader to tag communication (AM)
  - Output RF power is modulated between full and fractional power
  - 50% duty cycle is binary '1'
  - 88% duty cycle is binary '0'
    - Picture at left shows '01' Tag to reader communication
- Tag responds by FM
  - 2 cycles of modulation in one data bin is a binary '1'
  - 1 cycle of modulation is a binary '0'
    - Picture at left shows '1011'

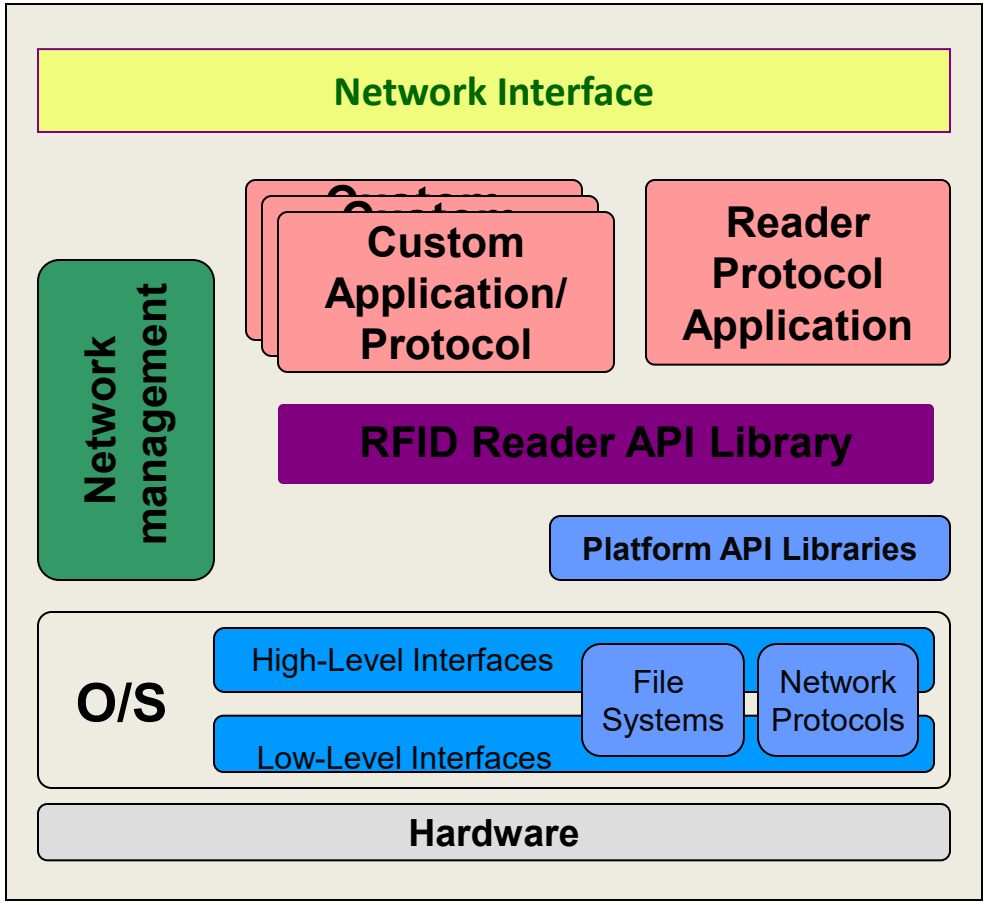
RFID Readers

- Implementation challenges
  - Must deliver enough power from RF field to power the tag
  - Must discriminate backscatter modulation in presence of carrier at same frequency
  - 70db magnitude difference between transmitted and received signals
  - Interference between readers
  - Hugh volume of tag data – readers need to filter data before releasing to enterprise network

RFID Reader Hardware Design

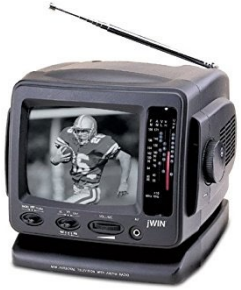


RFID Reader Software Stack



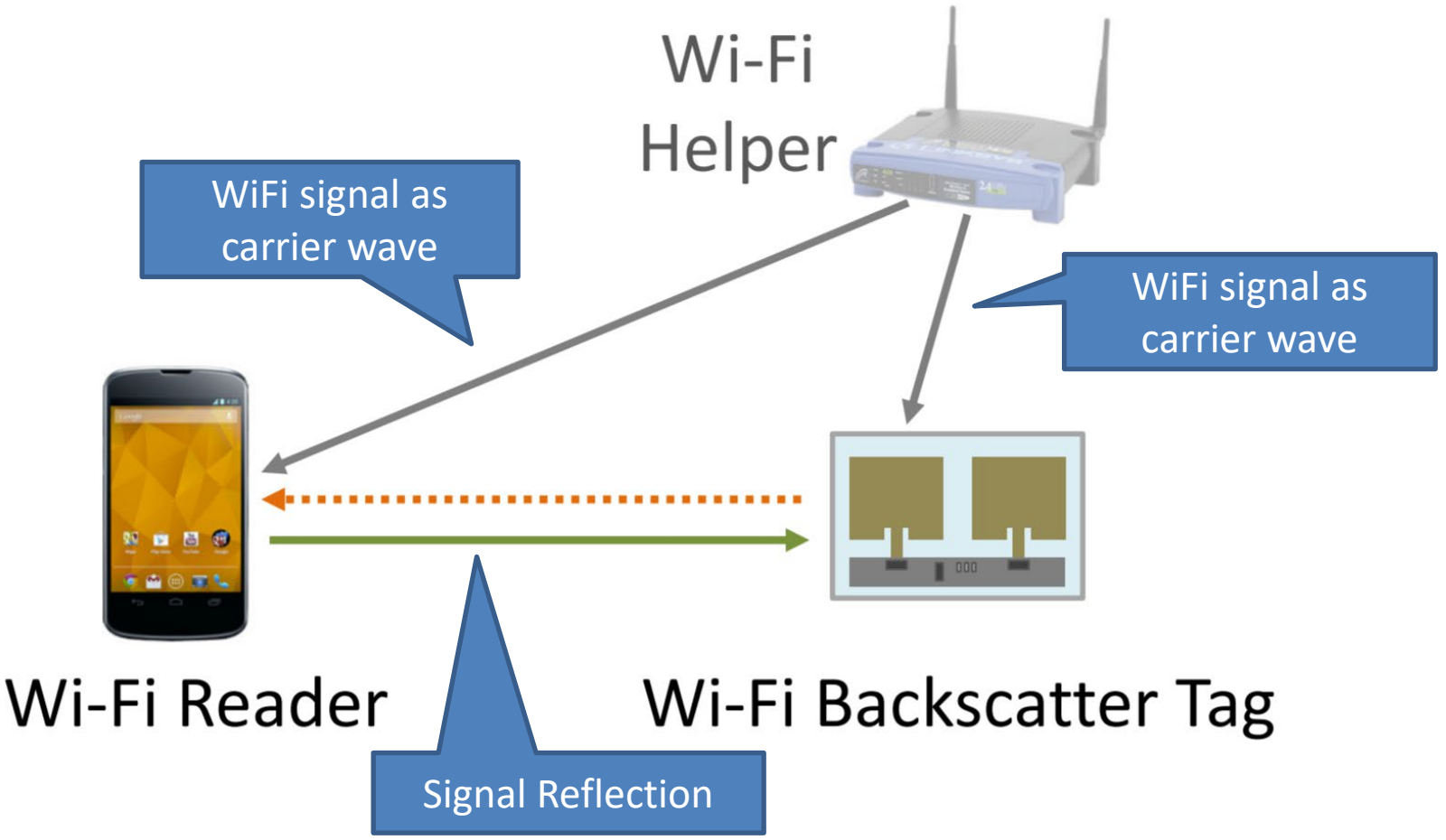
What's the Future

- Backscatter out of the reader
  - Using other wireless signals on the air as the "helper" to backscatter



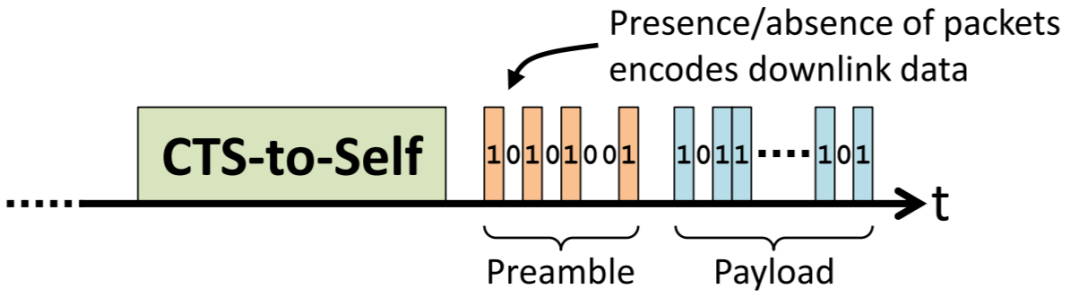
  - Any wireless device can potentially become a RFID reader!
    - Need redesign on both the wireless device and RFID tag

WiFi Backscatter



WiFi Backscatter

- Key challenges
  - At the tag: how to re-modulate the incoming signal?
    - Data is encoded as absorption/reflection of incoming packets



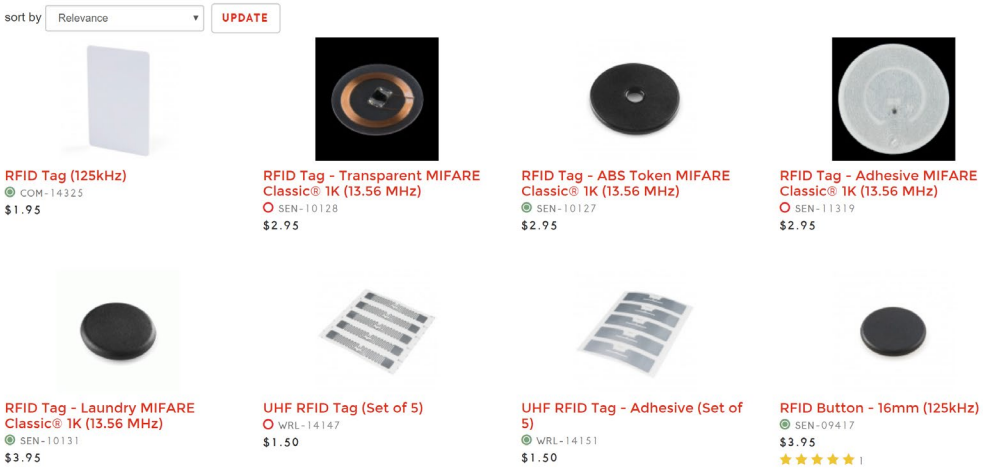
  - At the WiFi reader: how to decode the difference?
    - WiFi packet detection

WiFi Backscatter

- Limitations
  - Low data rate
    - One bit per WiFi packet
  - Short communication range
    - Helper must provide strong power

Available RFID devices

- RFID tags
  - With pre-loaded identifiers
  - Available at all frequency bands



- RFID readers
  - Can be used as I/O device via USB/SPI/I2C
  - Use the starter kit for easier access