Northwestern University

Wireless Sensor Networks and RFIDs

Instructor: Robert Dick

Slides from Randall Berry

So Far

1. Introduction
   - Characteristics/applications
2. Enabling trends
   - Moore's Law, MEMS, convergence
3. Mote components
   - Hardware/software
4. Design Trade-offs
   - Costs/size/energy efficiency

In this part

1. RFIDs
   a. Components
   b. Networking
      - Phy. Layer
      - MAC layer

RFID (Radio Frequency Identification)

- A close cousin to sensor network technology.
- Generally, RFID tags are cheaper, but less intelligent than sensor nodes.
- As things evolve the line between the two technologies is blurring.

RFID Systems

Main components:

- Tags (transponders).
  -microchip & antenna
- Tag reader
  - decoder & antenna (in some cases separate)

RFID Tags

Tags come in many different varieties (and costs).

Some key characteristics:

- Read-only/write-once/read-write.
- Packaging.
  - Ruggedness, size, mounting
- Active/passive.
- Operating frequency.
- Sensing capability.

Active vs. Passive

	Active RFID	Passive RFID
Tag Power Source	Internal to tag	Energy transferred using RF from reader
Tag Battery	Yes	No
Required signal strength	Very Low	Very High
Range	Up to 100m	Up to 3-5m, usually less
Multi-tag reading	1000's of tags recognized – up to 100mph	Few hundred within 3m of reader, about 3 sec per read => at most 3 mph.
Data Storage	Up to 128 Kb or read/ write & search	64 bits – 1KB of read/write

Also semi-active or battery assisted tags used for some apps.

Frequency Ranges

Price, range, EMI, reading speed

Low freq. 124kHz	High freq. 13.56 Mhz	UHF 860-960 Mhz

Ability to penetrate walls, water; directionality

Active tags generally operate at 433 MHz, 2.45 GHz and 5.8 GHz.

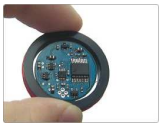
Frequency Ranges

FREQUENCY	125 kHz	5-7 MHz	13.56 MHz	303/433 MHz	860-960 MHz	2.45 GHz
TAG TYPE						
Passive	ISO11784/5, 14223 ISO18000-2	ISO10536 iPico DFIPX	MIFARE (ISO14443) Tag-IT (ISO15693) ISO18000-3		ISO18000-6 EPC class 0 EPC class 1 EPC GEN II Intellitag tolls (Title 21) rail (AAR S918)	ISO18000-4 Intellitag µ-chip
Semi-passive					rail (AAR S918) Title 21	ISO18000-4 Alien BAP
Active				Savi (ANSI 371.2) ISO18000-7 RFCode		ISO18000-4 WhereNet (ANSI 371.1)

Some RFID protocols and frequency ranges.

Tags + sensors

- Some RFID tags are combined with sensors.
  - e.g. high-end sake shipping.
- Both passive and active.
  - Trade-offs?



A passive RFID tag embedded with temp. and strain sensors.

Tag readers

- Much more expensive than tags
  - $500 to more than $3000.
- Readers also come in many varieties.
  - Form factor
  - Dumb vs. intelligent readers
  - Frequency/Protocol agile readers
  - Single vs. multi-antenna
  - Networking ports

Networking

- RFID tags only provide very simple "networking."
  - Only "master/slave" communication.
    - Tags do not talk to each other/only to reader.
  - No routing issues, etc.
  - Tag standards really specify only physical layer, link layer and MAC layer protocols.
    - Also includes addressing conventions.
      - e.g. 96 bit EPC code.

PHY layer

- Variety of different PHY layer standards:
  - Generally very simple/low spectral efficiency schemes used (<1bit/Hz)
  - Dependent on frequency band:
    - LF often use binary FSK.
    - HF/UHF use some type of AM.
  - For passive tags, reader-to-tag comm. constrained by powering tags.

Link layer

- Very simple packet formats
  - General structure:

Sync	Header	Command	Data	CRC

  - Usually reader-to-tag and tag-to-reader format somewhat different.
  - Usually around 15-45 bytes
  - Typically 2 byte CRC.

MAC layer

- When multiple tags receive a query from the reader, they will all respond.
  => Responses will "collide" at the reader
- Many readers feature "simultaneous read" capability.
  - Must resolve collisions.
- Basic MAC problem (e.g. Ethernet)
  - but here the algorithm must be very simple.

Collision Resolution

- In wireless no "collision detection".
- Also, for passive tags - no ability to "carrier sense"
- Two common approaches:
  - Slotted Aloha (with back-off).
    - Also "Framed Aloha."
  - Binary tree algorithm.

Binary Tree algorithm

Reader polls tags "bit by bit."
- Some variations possible to speed up search.
- E.g. combine with FSK