

# 18-759: Wireless Networks

## Lecture 13: RFID and GPS

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<http://www.cs.cmu.edu/~prs/wirelessS10/>

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## Outline

- Some more technologies:
  - » RFID
  - » GPS
- Survey on software defined radios
  - » Cognitive networking motivation (very brief)
- Review

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## What is RFID ?

- Radio Frequency IDentification (RFID) is a method of remotely storing and retrieving data using devices called RFID tags and RFID Readers
- An enabling technology with many applications
  - » Tags can be read in bulk
  - » Tags can be read without line of sight restrictions
  - » Data can be stored and retrieved from the tag automatically with a Reader
  - » Tags can be write once read many (WORM) or rewritable
  - » Tags can require Reader authentication before exchanging data (Generation 2, Class1)
  - » Other sensors can be combined with RFID
- Technology has been around for a long time
- Also has critics, e.g. privacy concerns

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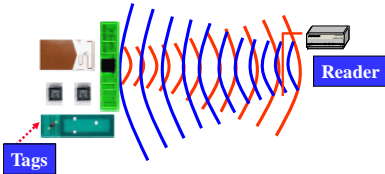
## Applications

- Operational Efficiencies
  - » Shipping and Receiving
  - » Warehouse management
  - » Distribution
  - » Asset management
- Total Supply Chain Visibility
  - » Inventory visibility in warehouses
  - » In-transit visibility, asset tracking
  - » Pallet, case level
  - » Item, instance level
- Shrinkage, counterfeit
  - » Reduce internal theft
  - » Reduce process errors
  - » Avoid defensive merchandizing
  - » Product verification
  - » Origin, transit verification
- Security, Regulations
  - » Total asset tracking
  - » Defense supplies
  - » Container tampering
  - » Animal Tracking

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## How Does It Work?



### What is RFID?

- A means of identifying a unique object or person using a radio frequency transmission
- Tags (or transponders) that store information, which can be transmitted wirelessly in an automated fashion
- Readers (or interrogators) both stationary and hand-held read/write information from/to tags

### How does it operate?

- RFID tags are affixed to objects and stored information may be written and rewritten to an embedded chip in the tag
- Tags can be read remotely when they detect a radio frequency signal from a reader over a range of distances
- Readers display tag information or send it over the network to back-end systems

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## Automated Identification Technology Suite

Linear Bar Code



2D Symbol



OMC  
Optical Memory Card



STS

Satellite-Tracking Systems



Smart Card/CAC



CMB  
Contact Memory Button



RFID - Active  
Radio Frequency ID



RFID - Passive  
Radio Frequency ID



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## RF ID Types

- **Passive Tags:** rely on an external energy source to transmit
  - » In the form of a reader that transmits energy
  - » Relative short range
  - » Very cheap
- **Active Tags:** have a battery to transmit
  - » Has longer transmission range
  - » Can initiate transmissions and transmit more information
  - » A bit more like a sensor
- **Battery Assisted Passive tags** are a hybrid
  - » Have a battery transmit
  - » But need to be woken up by an external source

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## A Bit of History

- **Early technology was developed in the 40s**
  - » Originally used as eaves dropping devices
  - » Used reflected power to transmit (transponder), e.g. the membrane of a microphone
- **First RF IDs were developed in the 70s**
  - » Combines transmission based on reflected energy with memory – can now distinguish devices
- **Dramatic growth in last decade as a result of mandates**
  - » Big organizations (DOD, Walmart) requiring the use of RFIDs from their vendors for inventory control
- **Now used in increasingly larger set of applications**

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## Standards

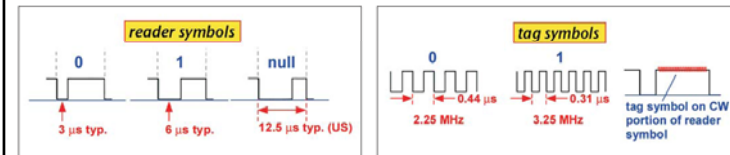
- Passive tags operate in the LF, HF, and UHF unlicensed spectrum
- Transmission consists of a bit stream and a CRC
- Many standards exist, mostly incompatible
  - » Early standards mostly defined by the ISO
- In 2003 EPCGlobal was formed to promote RFID standards
  - » Defined a standard for the Electronic Product Code (EPC)
  - » Also defined standards for coding and modulation

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## PHY Layer

- Depends on the frequency band used
- Different modulations used by reader and tag
  - » Different constraints, e.g. power and complexity
  - » E.g. cannot use amplitude modulation for tag (why?)
- Example of EPCGlobal symbols for UHF



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From: [http://www.highfrequencyelectronics.com/Archives/Aug05/HFE0805\\_RFIDTutorial.pdf](http://www.highfrequencyelectronics.com/Archives/Aug05/HFE0805_RFIDTutorial.pdf)

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## MAC Layer

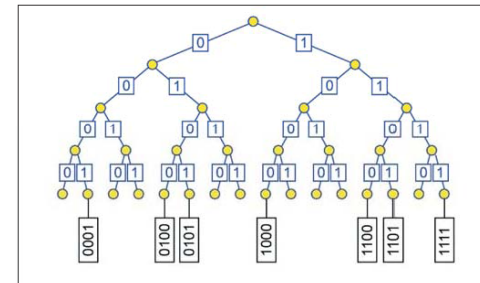
- Typically assumed that only one reader is present, i.e. no need for MAC on the reader
- MAC for tags is a challenge: in many contexts, very high concentrations of tags are present
  - » And tags are dumb, i.e. cannot have sophisticated protocols
- Two types of schemes used:
  - » Binary tree resolution: reader explores a tree of relevant tag values
  - » Aloha: tags transmit with a random backoff

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## Binary Tree Resolution

- Send requests to tags with ids that start with a certain string
- Narrow down search until one tag responds



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## What information does a RFID tag contain?



Gen 2 tags have four memory banks

Bank 0	Bank 1	Bank 2	Bank 3
<b>Reserved Memory</b> •32-bit Kill Password •32-bit Access Password (64 bits)	<b>EPC Memory</b> •16-bit CRC •16-bit Protocol Control •96-bit EPC (128 bits)	<b>Tag Identification Memory *</b> •8-bit Class Identifier •12-bit Tag Designer •12-bit Tag Model Number •52-bit Serial Number (optional) (0, 32, or 64 bits)	<b>User Memory *</b> •User-defined format (0 or more bits)

The CBP "GDTI-96" bit unique number

A 64-bit TID memory bank contains a tag serial number that uniquely identifies a tag.

\* TID and User Memory banks are not initialized on some Gen 2 tags

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## What information does RFID tag contain?

### Memory Bank 1 of the RFID Tag

*EPCglobal/GS1 allocated and managed.*

*An organization could define and filter up to 10,000 document types. Example: the number 1 = motorcycle, 2 = auto, etc.*

*Defined by Card/Tag Issuer*

Header	Filter Value	Partition Value	Company Prefix	Document Type	Serial Number
8 bits	3 bits	3 bits	27 bits	14 bits	41 bits
0010 1100 [Static, Binary value]	High-level filter option	Determines Company Prefix length	Equates to eight digits to uniquely identify an organization such as DHS/CBP, DoS, WA State, etc.	Equates to four digits, allowing up to 10,000 document types	Allows for over 2 trillion unique values

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## What does an RFID tag look like inside a card?



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## What is GPS?

- Radio-based navigation system developed by DoD
  - » Initial operation in 1993
  - » Fully operational in 1995
- System is called NAVSTAR
  - » NAVigation with Satellite Timing And Ranging
  - » Referred to as GPS
- Series of 24 satellites, in 6 orbital planes
- Works anywhere in the world, 24 hours a day, in all weather conditions and provides:
  - » Location or positional fix
  - » Velocity, direction of travel
  - » Accurate time

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## GPS involves 5 Basic Steps

- **Trilateration**
  - » Intersection of spheres
- **Satellite Ranging**
  - » Determining distance from satellite
- **Timing**
  - » Why consistent, accurate clocks are required
- **Positioning**
  - » Knowing where satellite is in space
- **Correction of errors**
  - » Correcting for ionospheric and tropospheric delays

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## How GPS works?

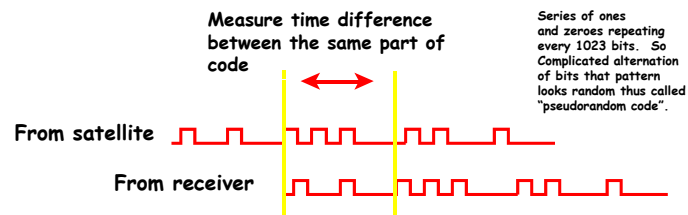
- **Range from each satellite calculated**
  - $range = time\ delay \times speed\ of\ light$
- **Technique called trilateration is used to determine you position or “fix”**
  - » Intersection of spheres
- **At least 3 satellites required for 2D fix**
- **However, 4 satellites should always be used**
  - » The 4<sup>th</sup> satellite used to compensate for inaccurate clock in GPS receivers
  - » Yields much better accuracy and provides 3D fix

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## Determining Range

- Receiver and satellite use same code
- Synchronized code generation
- Compare incoming code with receiver generated code



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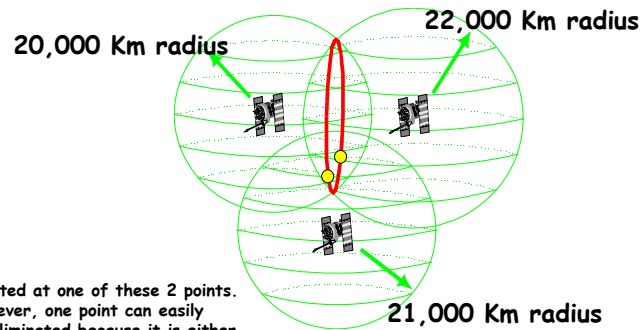
## Signal Structure

- Each satellite transmits its own unique code
- Two frequencies used
  - » L1 Carrier 1575.42 MHz
  - » L2 Carrier 1227.60 MHz
- **Codes**
  - » CA Code use L1 (civilian code)
  - » P (Y) Code use L1 & L2 (military code)

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## Three Satellite Ranges Known



Located at one of these 2 points.  
However, one point can easily be eliminated because it is either not on earth or moving at impossible rate of speed.

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## Accurate Timing is the Key

- Satellites have very accurate atomic clocks
- Receivers have less accurate clocks
- Measurements made using “nanoseconds”
  - » 1 nanosecond = 1 billionth of a second
- 1/100<sup>th</sup> of a second error could introduce error of 1,860 miles
- Discrepancy between satellite and receiver clocks must be resolved
- Fourth satellite is used to solve the 4 unknowns (X, Y, Z and receiver clock error)

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## Satellite Positioning

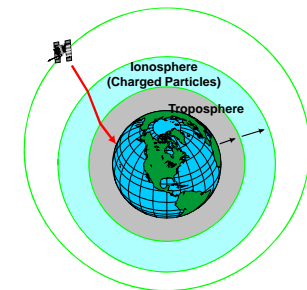
- Also required in the equation to solve the 4 unknowns is the actual location of the satellite.
- Satellites are in relatively stable orbits and constantly monitored on the ground
- Satellite’s position is broadcast in the “ephemeris” data streamed down to receiver

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## Sources of Errors

- Largest source is due to the atmosphere
  - » Atmospheric refraction
    - Charged particles
    - Water vapor
- Other sources:
  - » Geometry of satellite positions
  - » Multi-path errors
  - » Satellite clock errors
  - » SV position or “ephemeris” errors
  - » Quality of GPS receiver



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